

Evaluation of Some Power Sources and Performance Parameters of a Continuous-Flow Rotary Cassava Chipper

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Abstract
This study investigated the differences in key performance parameters and total cost of using a Nigerian-built continuous flow rotary cassava chipper to chip fresh peeled and unpeeled cassava root tubers when powered by Diesel engine and when powered by an electric motor. The machine was found to be most efficient and cost effective when powered by an electric motor and used to chip fresh unpeeled cassava tubers. This was when it exhibited the highest chipping efficiency of 86.67% and the least total cost of (or US$ 4.35 per tonne as opposed to the lowest efficiency of 85.17% and highest total cost of US$ 9.65/tonne when powered by a Diesel engine and used to chip fresh peeled cassava tubers. With these results, chipping fresh unpeeled cassava tubers with the machine when powered by an electric motor costs almost only 50% of what it costs to chip peeled fresh cassava tubers when powered by a Diesel engine. The study has clearly shown that the campaign to ensure regular supply of electricity in Nigerian rural communities (where most of the Nation's resource poor cassava processors, who constitute majority of the Nation's cassava growers and processors, are based) must be intensified if Nigeria is to be an active participant in the highly competitive but profitable world cassava market .
KEY WORDS: Cassava Chipper, Chipping Chamber, Chipping Efficiency, Throughput capacity, Fossil fueled engine.

1. Introduction

Cassava is a starchy food crop that grows in almost all the tropical regions of the world (Adzimah and Gbadam, 2009). It is widely used in the production of human foods and animal feed (Fayose, 2011).

Cassava (Manihot Esculenta Cranz) is a dicotyledonous plant which belongs to the botanical family Euphorbiacea (Sriroth and Peterson,2000). Although it originated from Brazil in South America, it is presently one of the most popular food crops in the West African sub region (Jekayinfa and Olajide, 2007).

Asia which accounts for about 27% of the world's cassava production area produce 37% of the crop. Thailand, Indonesia and India are the major producers of cassava in Asia (Howeler, 2007). Presently, Nigeria is the largest producer of cassava in the world with an annual production of over 34 million tones of fresh root tubers per annum (FIIRO, 2006).

The tuber, because of its high moisture content (about 65%), cannot be stored for more than two or three days due to its natural accumulation of a toxic Hydrocyanic Acid(HCN) content which makes it unsuitable for consumption until it is removed (Nweke, 1992).

Several attempts have been made by various researchers in the past to solve the problem of fast deterioration of fresh cassava tubers, but unfortunately, all the efforts made (although generally appreciable) have not been effective in combating the various problems associated with fast post-harvest deterioration of fresh cassava tubers. In view of this, it is imperative that fresh cassava tubers be converted into some kind of intermediate product with relatively low moisture content before it could be stored(Fayose, 2011).

The simplest intermediate product into which fresh cassava tubers could be processed are dry cassava chips which could go through further processing for the production of virtually any other cassava product. The production process consists of five basic unit operations viz: Peeling, Washing, Chipping/slicing, drying and packaging out of which Peeling, chipping and drying contribute the most to the production cost apart from the cost of the fresh tubers. The dried cassava chips can be used in non-traditional food industries such as cassava starch manufacturing, food starch production, livestock feed production and exportation during the off-season periods (Taiwo,2012). Dried cassava chips have better keeping quality and require smaller transportation and storage space than fresh cassava tubers. The tubers are sometimes converted into chips just to facilitate drying (Ajibola et.al, 1991).

The export potential of cassava chips is enormous and has continued to attract the attention of policy makers in recent years. According to the Minister of State of Agriculture, one million tonnes of cassava dry chips was ordered by China in 2012 at an estimated net income value of $136 million (Jimoh, 2012). The aim of this study was to investigate the differences in key performance parameters and total cost of using a Nigerian-built continuous flow rotary cassava chipper to chip fresh peeled and unpeeled cassava root tubers when powered by Diesel engine and when powered by an electric motor. The specific objectives were to determine the chipping efficiency, fuel consumption, throughput capacity and chipping cost of the machine when powered by a Diesel engine and compared with those obtained in addition to electric energy consumption when powered by an electric motor.

2.The Research Methodology

The rotary cassava chipper whose performance was evaluated in this study is a Tropical Engineering-built and IITA -designed rotary cassava chipper. It was powered in sequence with a 4.5 kW Daedong Diesel engine and a 2.6 kW General Electric single phase electric motor. An electronic stop watch was used to time the operations while a PHCN installed Kilowatt-hour meter was used to measure the electric energy consumption. Diesel fuel volumes were measured with the use of a plastic measuring cylinder. Two thousand four hundred kilograms of unpeeled fresh cassava root tubers were washed and weighed on a platform scale. Thereafter, they were divided into two equal samples of 1,200 kilograms each by weighing and labeled A and B respectively. Sample A was further divided into six samples of 200kg each by weighing and labeled A1, A2, A3, A4, A5 and A6 respectively. Samples A4, A5 and A6 were peeled while samples A1, A2 and A3 remain unpeeled. Similarly, sample B was divided into six samples of 200 kg each and labeled B1, B2, B3, B4, B5 and B6 respectively. While samples B4, B5 and B6 were peeled, samples B1, B2 and B3 were left unpeeled . The Diesel engine was connected to the continuous-flow rotary cassava chipper. The fuel tank was filled with Diesel fuel and put into operation. Sample A1 was continuously loaded into the chipping unit feed tray of the machine at a rate that got the machine fully loaded whilst the electronic stop watch was switched on simultaneously. The machine was kept running until the chipping of the sample was completed. At this time, the machine was stopped simultaneously with the electronic stop. The fuel tank was filled back to full level with the plastic measuring cylinder. The amount of fuel required to return the fuel tank to full capacity was recorded as the fuel consumed while the time that elapsed on the electronic stop watch was recorded as the time taken to chip the sample. This process was repeated for samples A2 and A3. The meter reading was taken before the electric motor was switched on. The electronic stop watch was switched on simultaneously with the electric motor. At the same time the chipper was continuously loaded with sample B1 until chipping was completed. At this time, both the electric motor and the electronic stop watch were simultaneously switched off . Elapsed time was read from the stop watch and recorded as the time taken to chip the sample. The initial reading taken from the kilowatt-hour meter was subtracted from the final reading and recorded as the electric energy consumed by the chipper during the chipping of the sample.

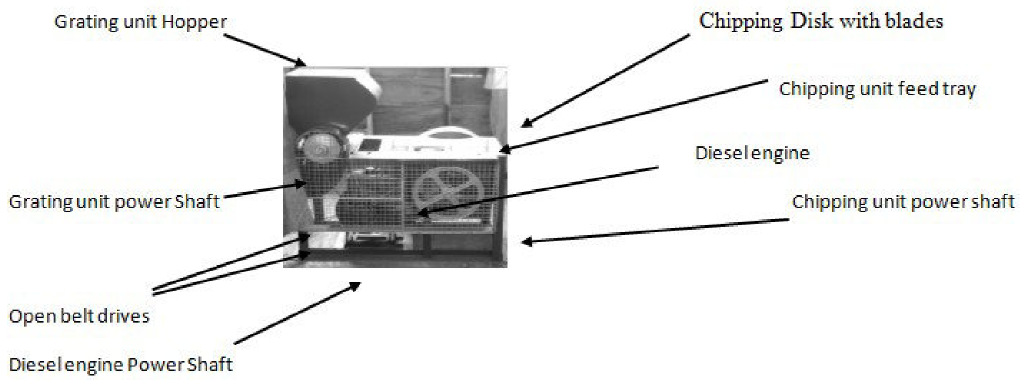

Figure 1: Tropical Engineering-built Continuous-Flow Rotary Cassava Chipper(Courtesy Tropical Engineering, Nig. Ltd.)

The material balance of the rotary cassava chipper is described with Equation (1) as:

$$W_1 = W_2 + W_3 + W_4 \qquad \text{.......(1)}$$

where:

W_1= mass of freshly-harvested (peeled or unpeeled) cassava tubers, kg.; W_2 = mass of completely-chipped Cassava tuber, kg. ; W_3 = mass of partially-chipped cassava tuber, kg. ; W_4 = mass of cassava chips that got stuck to the surfaces of the chipping disc and chamber, kg.

Equation (2) was obtained from Itodo,(2009) and used to determine the percentage of freshly-harvested cassava tubers fed into the machine that got completely chipped.

$$PTC = \frac{\text{mass of completely chipped cassava}}{\text{mass of tuber fed into the machine}} \times 100 \qquad \text{............(2)}$$

To determine the percentage of cassava tubers fed into the machine that were partially-chipped, equation (3) was used as :

$$PUC = \frac{\text{mas of partially chipped cassava}}{\text{mass of cassava tuber fed into the machine}} \times 100 \qquad \text{.........(3)}$$

From Equation (2), Mass of completely -chipped cassava tubers = PTC x $W_1 = W_2$ ....(4)
Chipping efficiency,

$$L = \frac{W_2}{W_1} \times 100 \qquad \text{........(5)}$$

Percent chips stuck to chipping disk and chamber surfaces =

$$\frac{W_4}{W_1} \times 100 \qquad \text{.........(6)}$$

The cost of using the machine for chipping using the two types of power sources were computed from the fixed and operating costs of the machine. The fixed cost was computed from. The fixed cost was computed from the first cost of the machine, estimated annual depreciation of 10%, and estimated machine life of 5 years, annual interest rate of 9% on capital and estimated housing and insurance pegged at 3% per annum.

3. Findings

3.1 Chipping Peeled Cassava Roots with the Machine when Powered by a Diesel Engine

The average chipping efficiency of the machine when powered by Diesel engine and used to chip peeled fresh cassava root tubers was 85.17%.The average machine throughput capacity was 418.28 kg/hr. The average fuel consumption rate measured in, L/tonne was 6.75 (Table 1).The average cost of chipping fresh peeled cassava root tubers with the use of the machine was ₦1,214.70 (or US$ 8.13) per tonne (Table 1).

3.2 Chipping Peeled Fresh Cassava Root Tubers with the Machine when Powered by an Electric Motor

The generated performance parameters of the machine when powered by an electric motor were better than those obtained when it was powered by a Diesel engine. The average chipping efficiency of the machine when powered by electric motor was 87.50%.The average machine throughput capacity was 432.20 kg/hr. The average electric energy consumption rate measured in kW.hr/tonne was 2.11 .

When expressed in terms of Nigerian Naira (or US dollar) per tonne, the average chipping cost was 649.93 (or 4.35) respectively when the machine was powered by an electric motor. This was over 40 % lower than it cost to chip with the machine when powered by a Diesel engine (Table 1).

Table 1: Machine performance when powered by Diesel Engine and used for chipping peeled fresh cassava root tubers

SN	Mass of Fresh Tubers, (kg)	Time Taken, (min)	Performance (or Chipping) Efficiency, %	Fuel Consumption, L/tonne	Machine Throughput Capacity, kg/hr	Chipping Cost, ₦/tonne US$ tonne (US$/tonne)
1	200.00	30.30	85.50	7.09	396.04	
2	200.00	28.30	85.00	6.66	424.03	
3	200.00	27.60	85.00	6.49	434.78	
	Mean	28.73	85.17	6.75	418.28	1,214.70 (8. 13)

Note: The prices in these tables were computed with the 2009 value of the Nigerian Naira to the US Dollar.

3.3Chipping Unpeeled Fresh Cassava Root Tubers with the Machine when Powered by a Diesel Engine

Chipping unpeeled fresh cassava tubers with the machine generally resulted in higher chipping efficiency, as well as machine throughput capacity because the chips did not stick to the surfaces of the chipping chamber of the machine appreciably .The average performance (or chipping) efficiency and machine throughput capacity were 87.67% and 351.78kg/hr respectively when the machine was powered by Diesel engine and used to chip unpeeled fresh cassava tubers; the fuel consumption rate, expressed in L/hr was about the same for fresh peeled and unpeeled tubers . The cost of chipping operation was ₦/tonne 1,441.81 (or US$9.65) per tonne.

3.4Chipping Unpeeled Cassava Roots with the Machine when Powered by an Electric motor

The average performance (or chipping) efficiency and machine throughput capacity were 86.67% and 427.09kg/hr when the machine was powered by an electric motor and used to chip unpeeled fresh cassava tubers. Not only were these figures higher than those obtained when the machine was used to chip unpeeled cassava tubers when powered by a Diesel engine, they were also higher than those obtained when used to chip peeled cassava tubers when powered by an electric motor. All these figures simply corroborated the statement earlier made in the previous section that chipping unpeeled fresh cassava tubers with the machine generally resulted in higher chipping efficiency, as well as machine throughput capacity.

The electric energy consumption rate for chipping unpeeled fresh cassava tubers, when expressed in kW.h/hr were slightly lower (0.77kW.h/hr) than that obtained for peeled tubers .

Table 2: Machine performance when powered by an Electric motor and use for chipping unpeeled fresh cassava root tubers

S/N	Mass of Fresh Tubers, (kg)	Time Taken, (min)	Performance (or Chipping) Efficiency,%	Electric Energy Consumption kW.hr	Machine Throughput capacity,(kg/hr)	Chipping Cost, ₦/tonne (US$/tonne)
1	200.00	28.50	85.00	0.37	421.05	
2	200.00	28.00	87.50	0.36	428.57	
3	200.00	27.80	87.50	0.36	431.66	
	Mean	28.10	86.67	0.36	427.09	657.40 (4. 40)

Ordinarily, the fact that the average chipping cost of chipping unpeeled fresh cassava tubers with the machine when powered by electric motor was lower than the value observed for chipping peeled fresh cassava tubers may lead an individual to erroneously conclude that it is always better to avoid peeling fresh cassava tubers before peeling. The reason why this kind of assertion will be erroneous is that Taiwo, (2012) did report that it is only the chips intended for use in the animal feed industry that does not need to be chipped. Those who buy cassava chips for use in pharmaceutical and confectionery industries usually specify that cassava tubers be peeled before chipping. Since they are prepared to pay premium price for it, it is to the advantage of both parties that the tubers be peeled before chipping despite the added cost. This because in effect, cost of the added value to the peeled chipped cassava has been absolved by the buyer . This point is note worthy when negotiating orders for the supply of dry cassava chips to either domestic or export market.

4. Conclusions and recommendations

4.1Conclusions

The rotary cassava chipper in this study was most efficient and exhibited the highest throughput capacity when powered by an electric motor and used to chip unpeeled fresh cassava tubers. The highest chipping efficiency of the machine was 86.67% and the highest throughput capacity was 427.09kg/hr.

The highest percentage of completely-chipped fresh cassava tubers (87.5%) was obtained when the machine was powered by an electric motor and used to chip unpeeled fresh cassava tubers. Conversely, the machine was least efficient when powered by a Diesel engine and used to chip peeled fresh cassava tubers. Using the rotary cassava chipper to chip fresh cassava tubers when powered by an electric motor costs only 55.45% what it costs when powered by a Diesel engine. It costs least when powered by an electric motor and used to chip fresh unpeeled cassava tubers. This corroborates the findings of Taiwo, (2012) as well as Bamigboye and Adebayo, (2009) in cassava peeling, which is another key unit operation in cassava processing, that unit operations of cassava processing is cheapest with electric powered equipment. This implies that irregular supply of electricity to farmers and cassava processors may make their product prices uncompetive in the huge profitable world market. Unless the Federal Government of Nigeria speeds up her plan to make irregular supply of electricity a thing of the past, the dream of making Nigeria one of the major suppliers of cassava chips and other cassava products into the International market may be a mirage despite the fact that she is still currently the world's largest producer.

4.2Recommendations

It is highly recommended that this machine be powered by an electric motor and used to chip peeled fresh cassava tubers because these are the conditions of use that will generate the highest profit for the money invested by its procurement.

To mass produce dried cassava chips profitably for domestic and export markets, the rotary cassava chipper in this study should be used in tandem with the continuous-flow rotary cassava peeler only when necessary.

Government should, as a matter of urgency, speed up her on-going efforts being made in solving the problem of irregular electric power supply to all the nooks and crannies of Nigeria.

All the three tiers of governments in Nigeria should arrange a take-off grant for all identified serious minded cassava producers in the country(especially the resource poor peasant farmers and producers) to use in procuring the rotary chipper used in this study. This will assist a great deal in making the National dream of our economy becoming one of the largest 20 in the world by the year 2020 realizable because it will enable production by the masses rather mass production which is not participatory.

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