

# Design and Fabrication Details of An Improved Mechanized Palm Fruit Harvester

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**Abstract** The design and fabrication details of improved mechanized harvester was presented. The harvester was produced from locally sourced materials. The harvesting process is carried out by fast and continual rotary motion of a cutting mechanism; circular saw attached to a motor coil. The cutting mechanism is fixed to a long aluminum pole of about 15m. A 12V DC dry cell battery was connected to a 220V AC inverter which transmitted power to the cutting mechanism. To operate the harvester the operator handles both the inverter and battery in a backpack and extends the cutting mechanism to the crown of the palm tree. The cutter is placed at the base of the fresh bunch at an angle of 300 to 600. The cutting mechanism is agitated with the aid of switch button and causes the circular saw to rotate at 110 rpm. The machine was tested and performance efficiency of 159% was achieved.

**Keywords:** palm fruit harvester, locally sourced materials, cutting mechanism, inverter, switch button and performance efficiency

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## 1. Introduction

Palm oil is edible vegetable oil derived from palm fruits on African oil palm trees. Oil palm trees originate from West Africa, but can flourish wherever heat and rainfall are abundant. Palms for palm oil production can be found almost anywhere in Nigeria and is one of Nigeria's agricultural value chain currently experiencing dramatic changes and intervention in the daily lives of farmers. The height of most palm trees is 5 to 6 meters with thorny leaves fronds.

Fruit bunches are made up of thousands of oval-shaped fruits weighing between 15 to 25kg. Palm tree cultivation entails sowing the seeds, transplanting seedlings, harvesting and transporting fruit bunches. This research work is limited to the aspect of harvesting, hence the idea of design and construction of the harvester. Harvesting is a critical issue in palm oil production, overripe fruits give poor fruits and less oil during processing. A bunch is considered ripe when two or more loose fruits fall to the ground. The fresh fruit bunches are harvested every 10 to 15 days [1].

This research is geared towards alleviating the problem involved in manual method of harvesting. The manual methods constitute the use raffia rope, pole, Indian bamboo and machete; a procedure that is very strenuous. The mechanized palm fruit harvester will harvest a large number of bunches over a short period of time and offset the rigors of the manual methods of harvesting [2].

## 2. Literature Review

Oil palm *elaeis guineensis* originated from Guinea, Africa. In 1961 this specie was taken from Eastern Nigeria to Malaysia. The implication is that this specie originally grew in West African sub-region. From West Africa the seedlings were transported to Mauritius and Indonesia in 1948. In 1949 the seedlings were transferred to Singapore. The African oil palm has also been taken to Central and South America where it was cultivated in Brazil and later Columbia and other neighboring countries, courtesy of Raw Materials Research and Development Council (RMRDC, 2004).

To improve upon the yield of palm oil, extensive breeding and agronomic research had been carried out by industries such as the Nigerian Institute for oil palm research (NIFOR) and the Malaysian Palm Oil Board (MPOB); also Private Plantation Companies [3].

Primary products from oil palm are used for human feed, livestock feed and animal feed. In recent times, palm fruit is part of the famous agricultural product with multi-items produce from it. Harvesting came into existence from the time of ancient people having the need of palm oil in their foods. But as the world advances, the demand for palm oil for both industrial and commercial purposes increased. For this reason different methods of harvesting have evolved over the years to overcome the problem associated with bruising the fruits bunch. The traditional method of harvesting employing

the use of raffia rope and machete pose health problem and hazards. These include diseases such as catarrh, cough and asthma [4]. Another method of harvesting is the use of aluminum pole with cutter.

In order to meet up with high rate of demand for palm oil, Engineers invented palm fruit harvesters. This is to reduce problems associated with manual methods of harvesting. The use of bamboo pole and knife, aluminum pole and knife is for trees of height less than 5.5 meters. Above this height, tremendous amount of strength is required to harvest even a single bunch due to associated bending and twisting of the pole at such heights. Even the use of Malaysian pole and knife requires force in the neighborhood of 750N [5].

In the modern times, there are various types of mechanized palm fruit harvesters classified by their usage be it domestic or industrial and the type of power system be it mechanically or electrically driven by battery. The most essential part of the harvester is the cutting mechanism and the cutter blade design. The common types of cutting mechanisms include reciprocating saw, horizontal endless band saw, universal tilt frame, band saw, abrasive saw and cold saw.

In this research, the rotary saw cutting method which is versatile and more attractive has been chosen.

### 3. Materials and Methods

#### A. Design Considerations and Calculations

The design considerations for palm fruits harvester involves the following technical steps: material sourcing, marking out the components, cutting operations, electrical fittings and finishing operation.

#### B. Material Specification

Dry cell battery: 12V×6.5 AH/hour  
Cable (wire): 2.5mm diameter × 10m  
Inverter: 220V / 300W  
Aluminum pole: 14" × 1,  
Aluminum socket: 1.5"

#### C. Design Equation and Computational Analysis

Adetan. D. A. et al quantify the numerical value of the average force,  $F$  that could be applied by human exertion as 750N, see Figure 1. This force is resolved into horizontal and vertical components  $F_2$  and  $F_1$  respectively as shown in Figure 1. The maximum value of angle of cut  $\theta$ , is  $30^\circ$ .

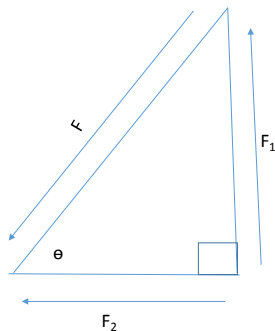


Figure 1. Force components During Cting Action

The required maximum horizontal force for cutting action is given as:

$$\cos(\theta) = \frac{F_1}{F} \quad (1)$$

$$F_1 = F \cos \theta = 750 \cos 60 = 375N$$

The required maximum horizontal force for cutting action is given as:

$$\cos(\theta) = \frac{F_2}{F} \quad (2)$$

$$F_2 = F \cos \theta = 750 \cos 30 = 649.5N$$

The required torque,  $T$ , for cutting action is expressed as in Equation (3):

$$T = \frac{60P}{2\pi N} \quad (3)$$

$P$ —rated power of the electric motor (Watts)

$N$ —cutter speed (rpm)

$$T = \frac{60P}{2\pi N} = \frac{60 \times 680}{2\pi \times 110} = 59.03Nm$$

Power for cutting action is given as:

$$P = \frac{T \times 2\pi N}{60} \quad (4)$$

$$P = \frac{T \times 2\pi N}{60} = \frac{59.03 \times 2\pi \times 110}{60} = 679.63W$$

To determine the mechanical efficiency of the harvester, :

Mechanical advantage of the system is given as:

$$\text{Mechanical advantage}(M.A) = \frac{\text{Load}}{\text{Effort}} = \frac{L}{F} \quad (5)$$

$$\text{Velocity ratio} = \frac{2\pi r}{n_p} \quad (6)$$

Where,

$r$ —radius of the cutting disc

$n_p$ —pitch of the cutting disc

To calculate the force applied by the man

The radius,  $r$ , of the cutting disc is given as:

$$r = \frac{D}{2} = \frac{230}{2} = 115mm = 0.115m$$

The torque for cutting action is given as:

$$\text{Torque} = \text{Force} \times \text{radius} = Fr$$

$$T = Fr$$

$$F = \frac{T}{r} = \frac{59.06}{0.115} = 513.04N$$

Thus, the mechanical advantage is expressed as:

$$\begin{aligned} \text{Mechanical advantage}(M.A) \\ = \frac{\text{Load}(T)}{\text{Effort}(F)} = \frac{59.03}{513.04} = 0.1151 \end{aligned}$$

The velocity ratio is determined as follows:

$$\text{Velocity ratio} = \frac{2\pi r}{n_p} = \frac{2\pi \times 0.115}{10} = 0.07226$$

Cutting efficiency is given as:

$$\eta = \frac{\text{Mechanical advantage}}{\text{Velocity ratio}} = \frac{MA}{VR} \times 100\% = \frac{0.1151}{0.07225} \times 100\% = 159\%$$

#### D. Cost Estimation

The imperative of producing the improved mechanized palm harvester can be classified into indirect and direct costs.

##### i. Indirect Cost

Indirect cost is made up of components such as transportation, feasibility study, communication among others. The different cost items is as in Table 1.

**Table 1. Indirect cost components for the harvester**

|                   |           |
|-------------------|-----------|
| Feasibility study | N1,000.00 |
| Transportation    | N1,000.00 |
| Communication     | N2,000.00 |
| Total             | N4,000.00 |

##### ii. Direct Cost

This entails the cost of the materials used in producing the harvester.

The detailed cost analysis is as in Table 2.

**Table 2. Direct cost components for harvester production**

| S/No | Parts/Items             | Unit Cost (N) | Quantity | Amount (N) |
|------|-------------------------|---------------|----------|------------|
| 1    | 12 V Dry Cell Battery   | 2,000.00      | 1 Pcs    | 2,000.00   |
| 2    | Cable                   | 100.00        | 2 Yards  | 200.00     |
| 3    | Cable Terminals         | 100.00        | 2 Pcs    | 200.00     |
| 4    | Inverter                | 500.00        | 1 Pcs    | 500.00     |
| 5    | 1 ½ Aluminum Pipe       | 600.00        | 1 Length | 600.00     |
| 6    | Switch                  | 100.00        | 2 Pcs    | 200.00     |
| 7    | Cutting Disc            | 250.00        | 1 Pcs    | 250.00     |
| 8    | Electric Motor          | 5,000.00      | 1 Pcs    | 5,000.00   |
| 9    | Aluminum Socket         | 50.00         | 3 Pcs    | 150.00     |
| 10   | Bolt and Washer         | 20.00         | 3 Pcs    | 60.00      |
| 11   | Socket/Plug             | 100.00        | 3 Pcs    | 300.00     |
| 12   | Oil Paint               | 150.00        | 1 Tin    | 150.00     |
| 13   | Carriage or Housing Bag | 500.00        | 1 Pcs    | 500.00     |
| 14   | Total for Direct Cost   |               |          | 10,010.00  |

$$\begin{aligned} \text{Grand total} &= \text{Indirect cost} + \text{Direct cost} \\ &= \text{N4,000.00} + \text{N10,010.00} = \text{N14,010.00} \end{aligned}$$

## 4. Results and Discussions

### 4.1. Results

a. Time taken to Harvest a Bunch in The Morning is as in Table 3 below:

**Table 3. Time taken to Harvest a Bunch in the Morning**

| S/No | Maximum Size (cm) Bunch Neck | Time to Cut (s) |
|------|------------------------------|-----------------|
| 1    | 12                           | 15.0            |
| 2    | 12.2                         | 15.3            |
| 3    | 12.3                         | 15.4            |
| 4    | 12.4                         | 16.0            |
| 5    | 12.5                         | 16.0            |
| 6    | 12.6                         | 16.0            |
| 7    | 12.7                         | 16.09           |

b. Time Taken to Harvest a Bunch in The Afternoon is as in Table 4 below:

**Table 4. Time Taken to Harvest a Bunch in the Afternoon**

| S/No | Maximum Size (cm) Bunch Neck | Time to Cut (s) |
|------|------------------------------|-----------------|
| 1    | 12                           | 30.00           |
| 2    | 12.2                         | 30.10           |
| 3    | 12.3                         | 30.40           |
| 4    | 12.4                         | 31.00           |
| 5    | 12.5                         | 31.00           |
| 6    | 12.6                         | 31.00           |
| 7    | 12.7                         | 32.06           |

### 4.2. Discussions

Harvesting is achieved when the cutting disc in rotary form passes through the neck of fresh palm fruit bunch. Movement of the cutting disc imposes pressure on the palm fruit neck and causes the fresh fruit bunch to be cut off. In sickle type of harvester fresh fruit bunch are harvested by linear motion of the sickle. The mechanized palm fruit harvester has advantage over the existing harvesters in the sense that it can be easily carried about the palm plantation. The improved palm fruit harvester can cut and be used to clear the path way in the palm plantation by changing only the cutter disc to a knife-edge blade. This is rarely common with other harvester.

It can also be seen that the size of the palm fruit neck will have a little effect on the cutting efficiency of the newly developed machine as a result of low battery voltage. The speed of moving the blade through the fruit bunch was slow enough to carry out an accurate and successful cutting.

The evaluation results for cutting efficiency in the morning and the time taken are presented in Tables 3 and 4. From the results obtained in this study, it vividly clear that moisture content has significant effect on palm fruit harvesting. The cost of producing the machine is estimated at fourteen thousand and ten naira only (N14,010.00). Hence the machine is very cheap and affordable.

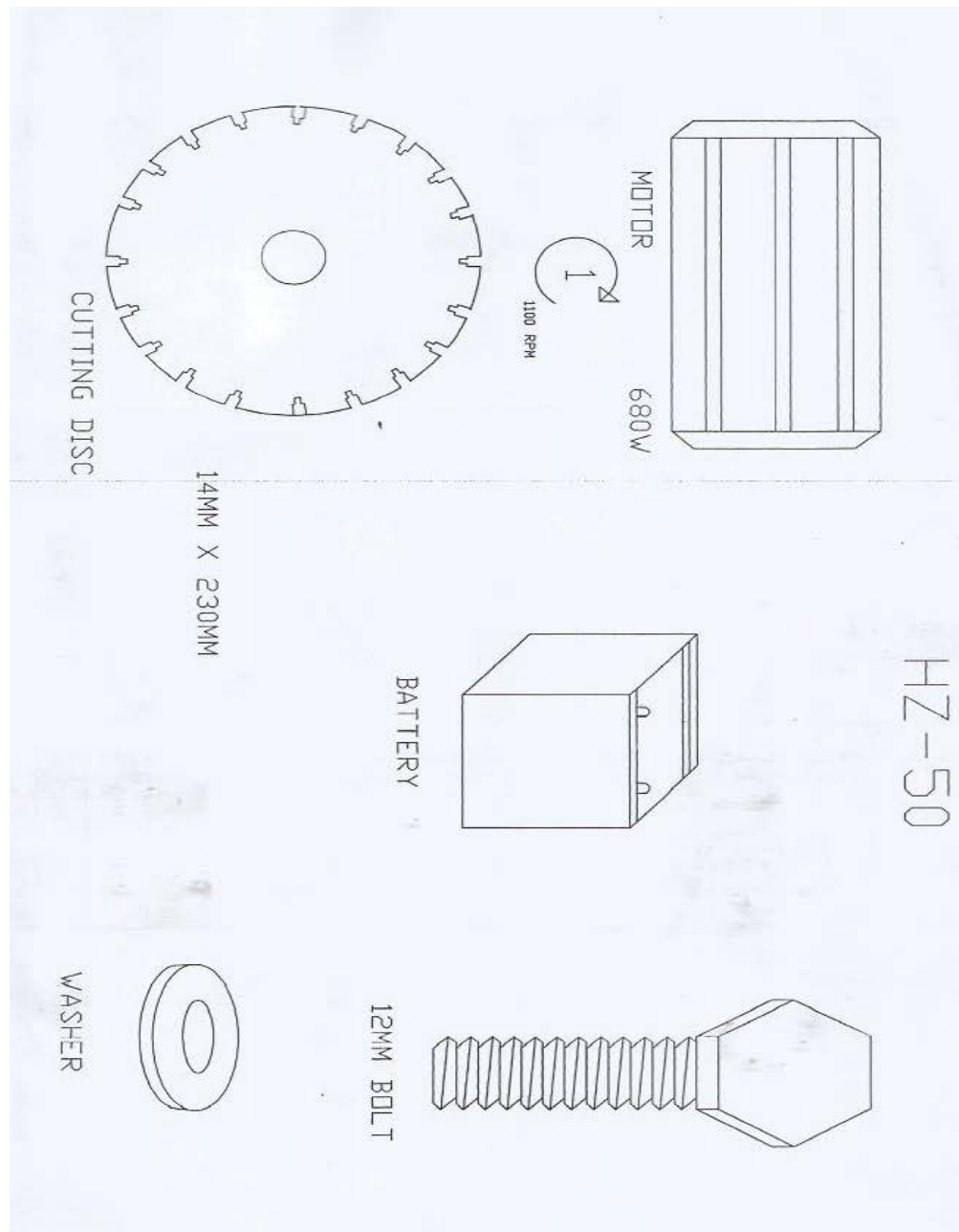
## 5. Conclusion

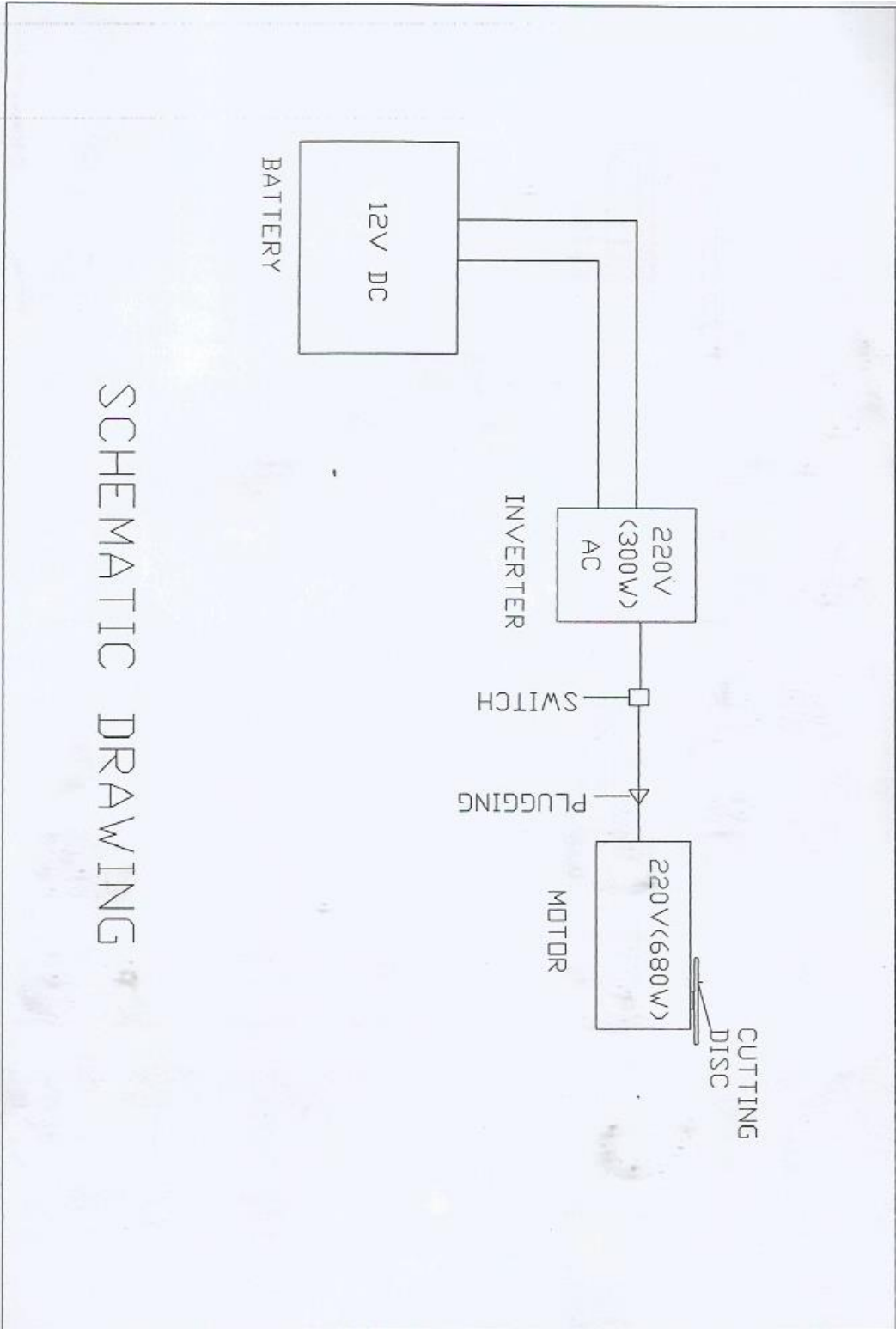
Palm oil has been accepted as useful material in soap and tin plating industries especially in America and Europe. It is also gradually gaining ground in Africa. The improved palm fruit harvester uses one motor coil to serve

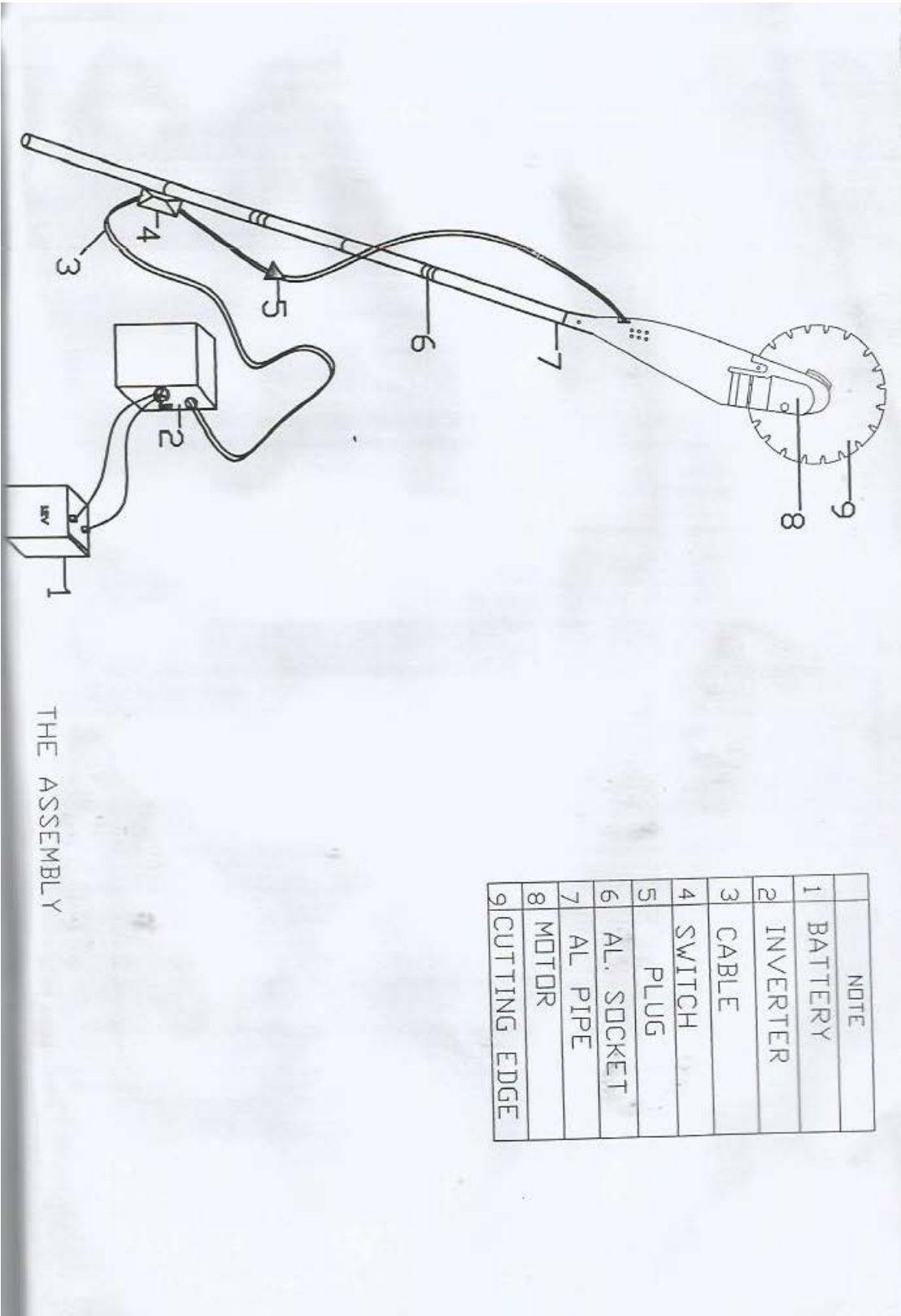
dual purses, saving cost, energy, reduces hazards and increases productivity more than the existing palm fruit harvesters. The machine is easy to operate, efficient and affordable for most Nigerians because of the materials used and cost of production which is on the low side. The

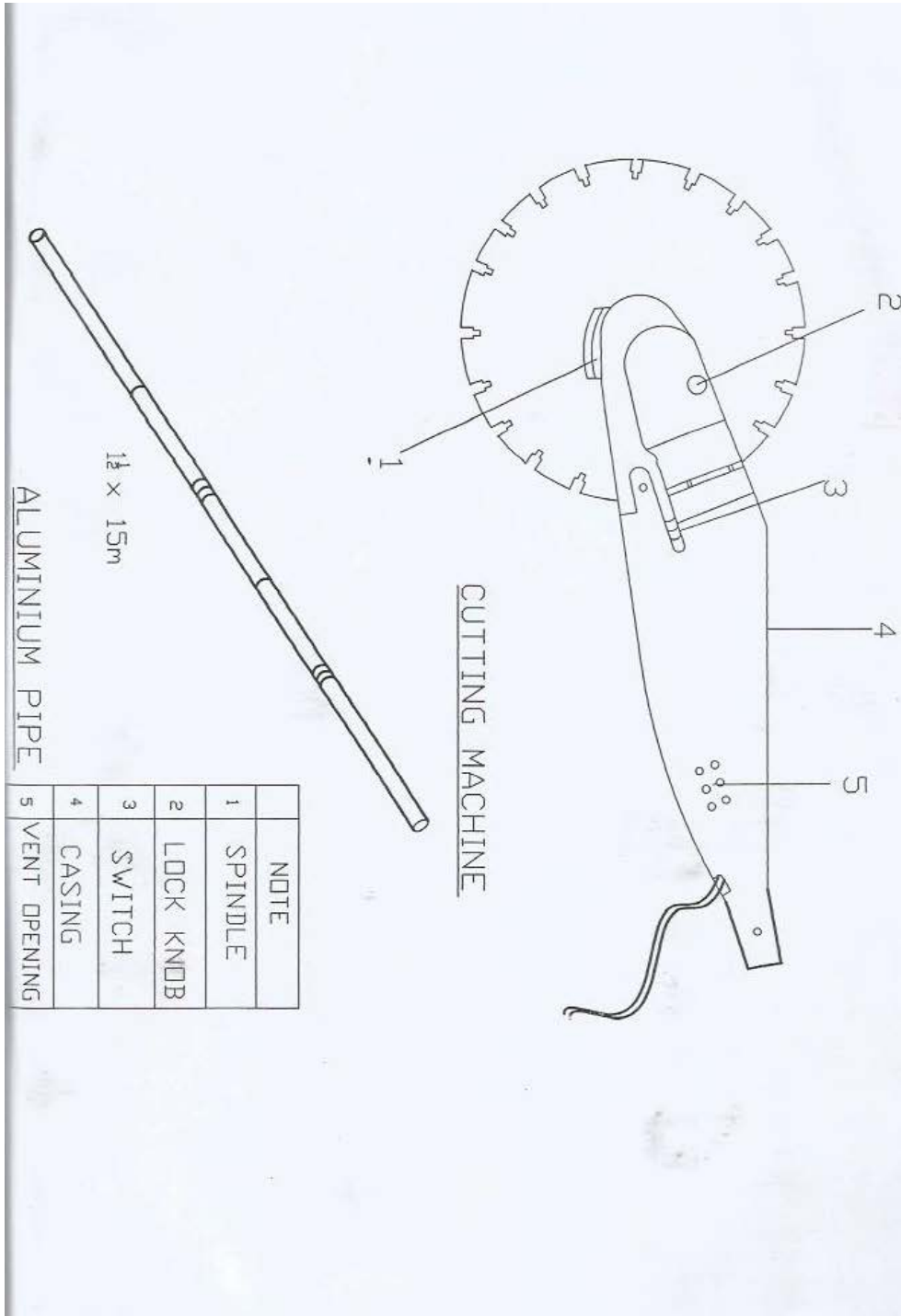
mechanical efficiency of the harvester is on high side, as much as 159%.

## Appendices









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