Design and Fabrication of a Mechanical Cassava Harvester for Small and Medium Scale Farmers

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Abstract

In Nigeria, cassava is consumed as major staple food in different forms, namely: starch, Garri, Fufu, Tapioca. Though harvesting is known to be one of the most difficult and cost-intensive field operations, use of technology for cassava harvesting is still very low in most cassava farming concerns and communities in Nigeria. This is mostly due to inadequate machines for process application. This product prototype address basic design and construction of a simple, effective, cheap, and easy to maintain Cassava harvester for local Cassava farmers in Nigeria. The principle of a simple lever was used as a basis for the design. The first effort applied by the operator will engage the fork while the second effort applied on the lever handle will overcome the uprooting load (load of the soil and Cassava). From the analysis, a little effort of 200N can overcome about 2000N of force and this gives a mechanical advantage of about 5. The total cost of design and fabrication at the time of production was One Hundred and Ninety Thousand Nigerian Naira (₦190,000, which is approximately $522 USD, as at the time of project execution in 2018).

Keywords: **Sustainable design,Cassava, Mechanical Harvester, Ease of Maintenance**

1. Introduction

Cassava (ManihotesculantaCrantz) is the world's third most important crop and essential source of food and income throughout the tropics (IFAD et al., 2003). Worldwide, cassava provides the livelihood for more than 500 million farmers and countless processors and traders (IFAO and IFAD, 2011). It is the basic staple food of millions of people in the tropical and subtropical regions, as well as being a major source of raw materials such as flour and starch for numerous industrial applications and animal food with worldwide acreage of more than 18 million ha and annual root yield of more than 233Mt (Anderson et al., 2008; FAOSTAT, 2011). Cassava provides food security, not only because it can be grown on less productive land, but also because it is a source of income for producers and generally a low-cost source of food (Plucknett et al. 2000). According to FAOSTAT (2011), out of a total world cassava production of 233,796,000 t,

Africa accounts for 51% followed by Asia with a production of 35%, and the remaining production of 14% going to the America. Nigeria is among the highest producers of cassava in sub-Sahara Africa. Due to increase yield by use of improve cassava hybrids and the application of fertilizer, it is envisaged that labour constraints will be shifted from land preparation to harvesting. Cassava is ready for harvest as soon as there are storage roots large enough to meet the requirements of the consumer, starting from six –seven months after planting, especially for most of the new cassava hybrids (Ekanayake et al, 1995; USDA and NRCS, 2004).

Cassava is mostly harvested by hand, lifting the lower part of stem, and pulling the roots out of the ground, then detaching them from the base of the plant by hand after the upper parts of the stem with the leaves are removed.Manual harvesting may also employ harvesting tools such as hoe, cutlass, mattock, and chisel. However, due to the relatively higher level of drudgery and stress in manual harvesting, farmers' physical bodies are adversely affected causing rapid aging.

According to Nweke et al (2002), manual harvesting requires about 22-62 man per hectare. Mechanical harvesting of cassava involves the use of a harvesting implement integrally hitched to a tractor to uproot the cassava roots. Manual effort is however required after the uprooting has been completed to collect and detach the cassava root tubers. However, research on mechanical cassava harvesting in Nigeria is yet coming into the limelight.Agbetoye (2003) confirmed that the most difficult operation in cassava production is harvesting. Research conducted by Addy et al. (2004) also revealed that cassava harvesting constituted the highest production cost.Odigboh and Ahmed (1982), did research and developed

a cassava digger, which collects the cassava rhizomes in a tray at the back of the digger, dropped them down and piled them up at the same distance of 10-15 meters along the length of every row. However, it has not yet been found that this prototype is being used by agricultural lists. Odigboh and Moreira (2002a) further developed the cassava digger and the conveyor units by using a bucket that is directly attached to the back of the digger. The cassava rhizomes are then transported to a trailer at the back in order to increase the distance of the bulk. There is no need to pile them up so closely, but several problems have been found (1) The movement caused by the cassava rhizomes being taken from the soil surface always causes the bucket and the cassava rhizomes to be knocked to the ground. This makes it hard to get the cassava rhizomes. (2) The weight of the bucket together with the weight of the cassava rhizomes and the weight of the soil causes the chain to become twisted or broken. (3) The chain vent is always blocked with the soil and causes the chain not to be driven continuously. Because of these obstacles, this method has been abandoned.Thereafter, Odigboh and Moreira (2002b) proposed an equipment to push the cassava rhizomes into the bucket so that the bucket will not touch the soil while gaining access to the cassava by using the bar device to sweep the cassava rhizomes from the ground and then passing them up to the inclined plane. When the cassava rhizomes had gotten to the end of the inclined plane, they will fall into the bucket that comes right on time. Onfurther interrogation of thisresearch output of the trialsusing the cassava rhizome sweeping device are yet to be found. It is expected that such concept is still being developed.To construct this simple cassava harvester, the type of materials used were properly selected, considering safety, design for agricultural engineering application. The following factors were considered: Availability of the material, Suitability of the material for the required component, Cost of

the materials which were locally sourced. The cassava harvester is basically made of mild steel, the reason for the selection are: Mild steel are readily available in the market. It is economical to use and it is available in standard size. It has good mechanical properties. It has moderate factor of safety, because factor of safety result in unnecessary waste of materials and selection. Low factor of safety result in unnecessary risk of failure, it has high tensile, low coefficient thermal expansion.

2. Detailed Design Description
2.1 Design Principle/ Calculations
The design for the simple harvester is based on a simple machine device for converting a small input force to overcome a much larger load by causing the input force to move through a much longer distance. This is just like the levers used in lifting heavy weight when the force available is much smaller than the weight.

Figure 1 shows the mechanical design for the manual cassava harvester with dimensions.
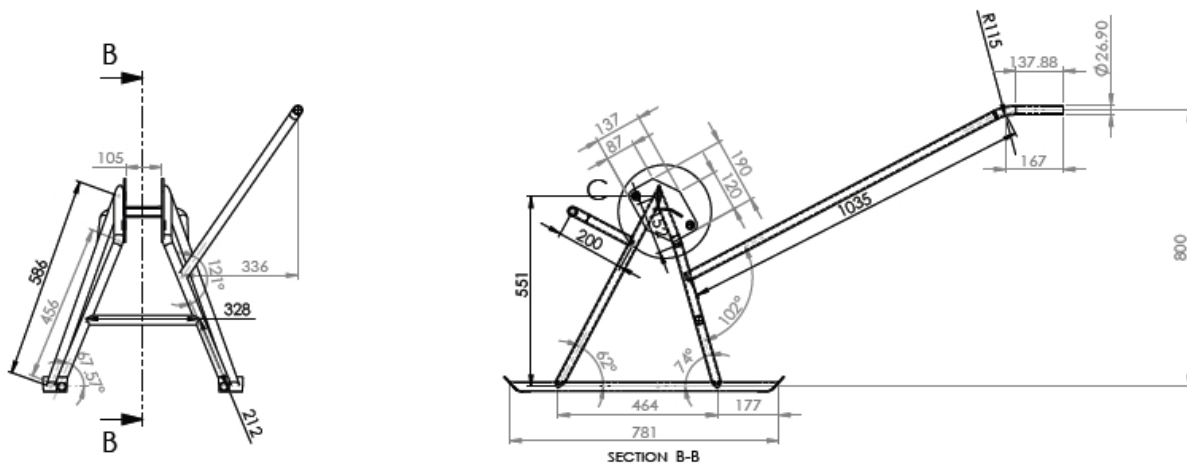

Figure 1: Mechanical design for the manual cassava harvester

The mechanical advantage (MA) of a simple harvester machine is defined as the ratio of the output force to the input force.

$$MA = \frac{Force\ Out}{Force\ In}$$

The lever is pivoted through a bearing, so that the lever arm of the applied or input force is larger than that of the output force.

Let L_{in} and L_{out} be the lever arms. If we wish to lift a weight without acceleration, the input torque must equal the output torque as shown in Figure 2.
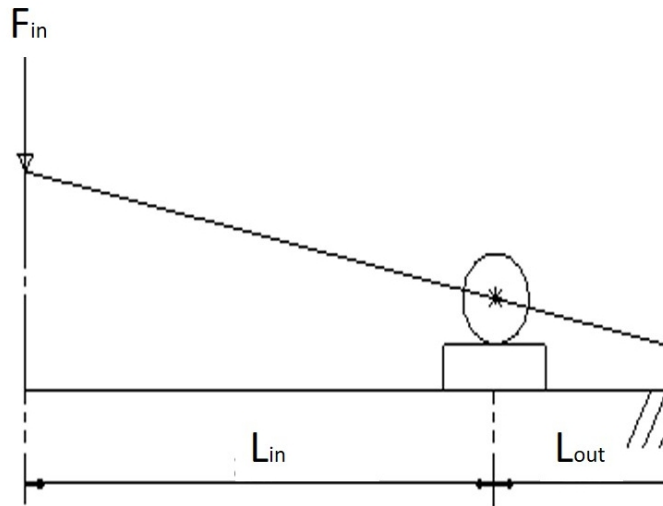
$$F_{in}L_{in} = F_{out}L_{out}$$

Figure 2: Model diagram of the forces acting on the manual cassava harvester.

W = Weight of cassava + Soil

The ideal mechanical advantage.

$$M.A._{ideal} = \frac{Force\ Out}{Force\ In} = \frac{Lin}{Lout} \quad (1)$$

2.2 Design for the Rod (Lever)

The maximum bending stress of the steel rod should be lesser or equal to the tensile stress of the steel rod in order to prevent the steel rod from buckling.

Given that the material of the rod is mild steel (A36),

Therefore, its ultimate tensile strength = 210MPa

Recall that

$$Factor\ of\ safety = \frac{Ultimate\ strength}{Permissible\ strength} \quad (2)$$

Using a factor of safety of 2, we have,

$$2 = \frac{210}{\sigma}$$

$$\sigma = 105MPa$$

Also, recall that

$$Maximum\ bending\ stress = \frac{Maximum\ bending\ moment}{Sectional\ modulus}$$

$$(3)$$

i.e. $\sigma = \frac{M}{Z}$

Where $Z = \frac{Moment\ of\ inertia}{Centroid\ Height}$

A cross section of the lever is as shown in Figure 3.

Figure 3: Cross section of the lever.
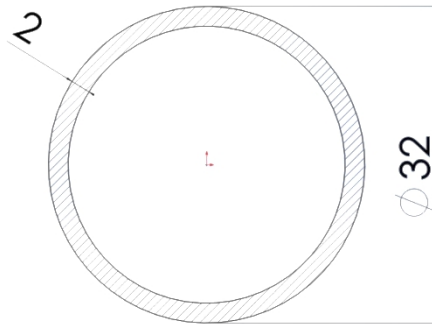
$$Moment\ of\ inertia = \frac{\pi(D^4 - d^4)}{64}$$

$$= \frac{\pi(32^4 - 28^4)}{64}$$

$$= 21299.99819\ mm^4$$

$$= 21300\ mm^4$$

Also, $Centroid\ height = \frac{D}{2}$

$$= \frac{32}{2}$$

$$= 16\ mm$$

Therefore, $Sectional\ modulus, Z = \frac{21300}{16}$

$$Z = 1331.25\ mm^3$$

From equation 1, we have,

$$105 * 10^6 = \frac{M}{1331.25 * 10^{-9}}$$

$$M = 139.78\ Nm$$

This implies that the maximum bending moment of the lever is $139.78\ Nm$.

Given

- Average weight of cassava designed for $= 10\ kg$
- Soil Holding Capacity $= 20\ kg$
  (Estimated value with the understanding that at rainy season the soil will be softer and at dry season it would be harder)
- Total load to overcome $= 30\ kg$ i.e., $300\ N$
- Average effort of a man$= 10\ kg$ i.e., $100N$.
- Assume that the maximum force exerted by a man is $14\ kg$ i.e., $140N$.

The schematics of the machine as shown below in Figure 4, has the bending moment about the pivot (which is the bearing fixed about the lever).
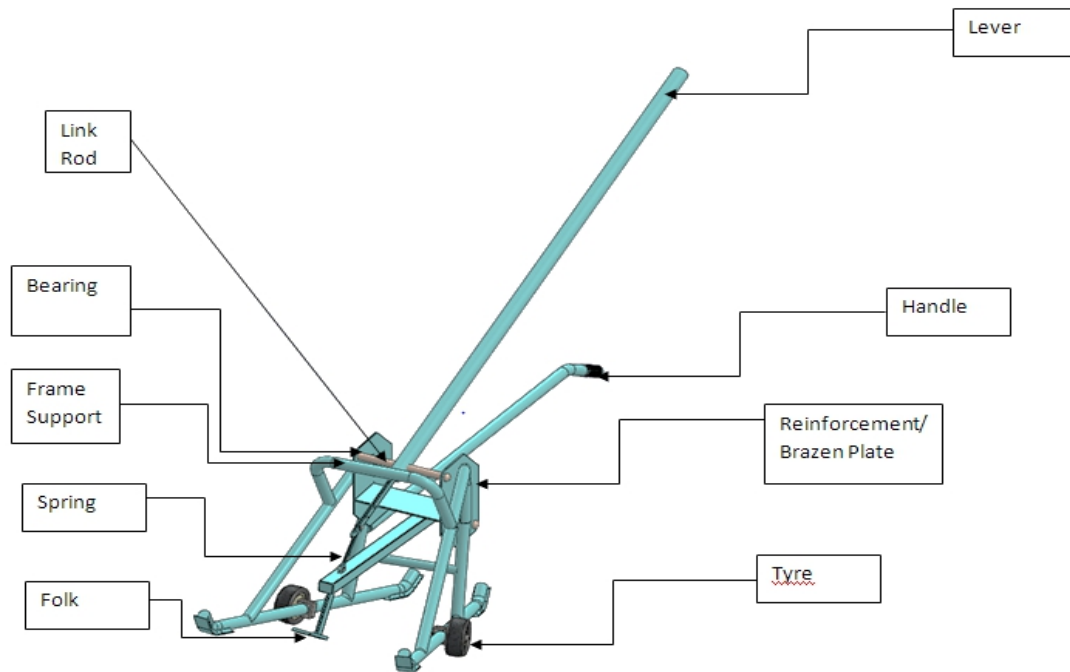
Figure 4: Model diagram of the bending moment about the pivot.

3. Results and Discussion

The field test on uprooting using the designed cassava harvester displayed that it was very fast, less energy expended, no risk of health hazards of developing blisters in the palms, callus palms, arched spinal cord and waste pains. The cassava harvester is simple operate, and easy to maintenance.

The table 1 below shows the performance of the lever on load, mechanical advantage and efficiency.

Table1. Performance table of the lever

S/N	Load (W)	Minimum Effort Required (F)$+20N$	Mechanical Advantage	Efficiency
1	200.00	86.67	2.3076	76.92
2	220.00	93.33	2.3572	78.57
3	240.00	100.00	2.4000	80.00
4	260.00	106.67	2.4374	81.25
5	280.00	113.33	2.4707	82.36
6	300.00	120.00	2.5000	83.33
7	320.00	126.67	2.5262	84.21
8	340.00	133.33	2.5501	85.00
7	360.00	140.00	2.5714	85.71
10	380.00	146.67	2.5909	86.36
11	400.00	153.33	2.6088	86.96
12	420.00	160.00	2.6250	87.50
13	440.00	166.67	2.6399	88.00
14	460.00	173.33	2.6539	88.46

From Table 1, the higher the mechanical advantage for a given velocity ratio, the higher the efficiency of the machine.

Therefore, the efficiency of the machine for the intended load of *300 N w*ith an applied effort of $120\ N$ is 83%.Figure 5 demonstrates the direct relationship between Load and Effort.
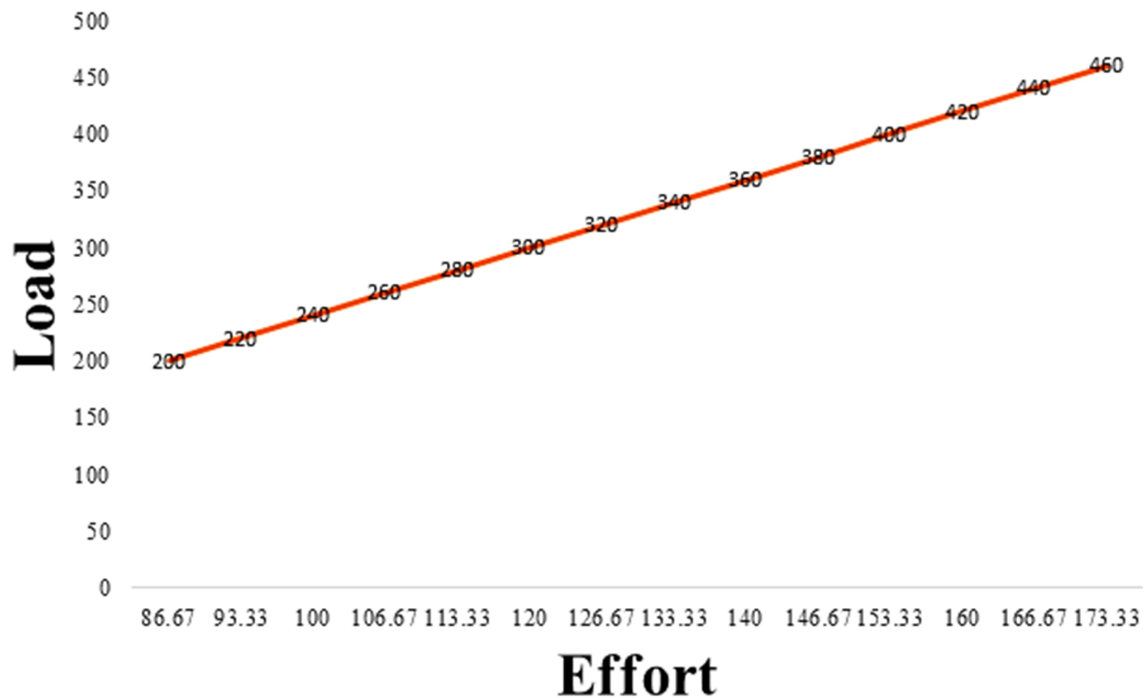

Figure 5: Performance curve plotted Load versus effort.

The figure 5 above shows the performance graph of Load plotted against Effort, maximum effort of 173N overcame a load of 460N

3.1 Harvesting Time

Time for harvesting using the mechanical cassava harvester recorded with a timer

▶ It took 30 seconds to harvest a cassava plant with the mechanical harvester.

▶ 10meters square area coverage with 50 cassava plant = 50 X 30 = 1500Seconds = 25minutes

3.2 Sequence of operation of the mechanical cassava harvester

Figure 6 shows the sequence of operation of the mechanical cassava Harvester, while Figure 7

Time for harvesting using manual method

▶ It took 90 seconds to harvest a cassava plant by the manual method

▶ A 10m^{2}area covered with about 50 cassava plantswas harvested within 75minutes

represents the general features of the manual cassava machine

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┌─────────────────────────────────────────┐
│   Rolling of Cassava Harvester to the    │
│              cassava Farm                │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Locating & positioning of the cassava   │
│     harvester on the particular stem     │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Lowering of folk to key the stem at     │
│  2mm from ground level via the control   │
│             of the lever.                │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Vibration of the cassava tubers via     │
│        the control of the lever          │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Further pressing down of the lever      │
│   movement to lift the cassava tubers    │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Hand picking of the cassava tuber to    │
│   isolate it from the harvester folk     │
└─────────────────────────────────────────┘
                    │
                    ▼
┌─────────────────────────────────────────┐
│  Cutting off of the cassava tubers       │
│             with cutlass                 │
└─────────────────────────────────────────┘
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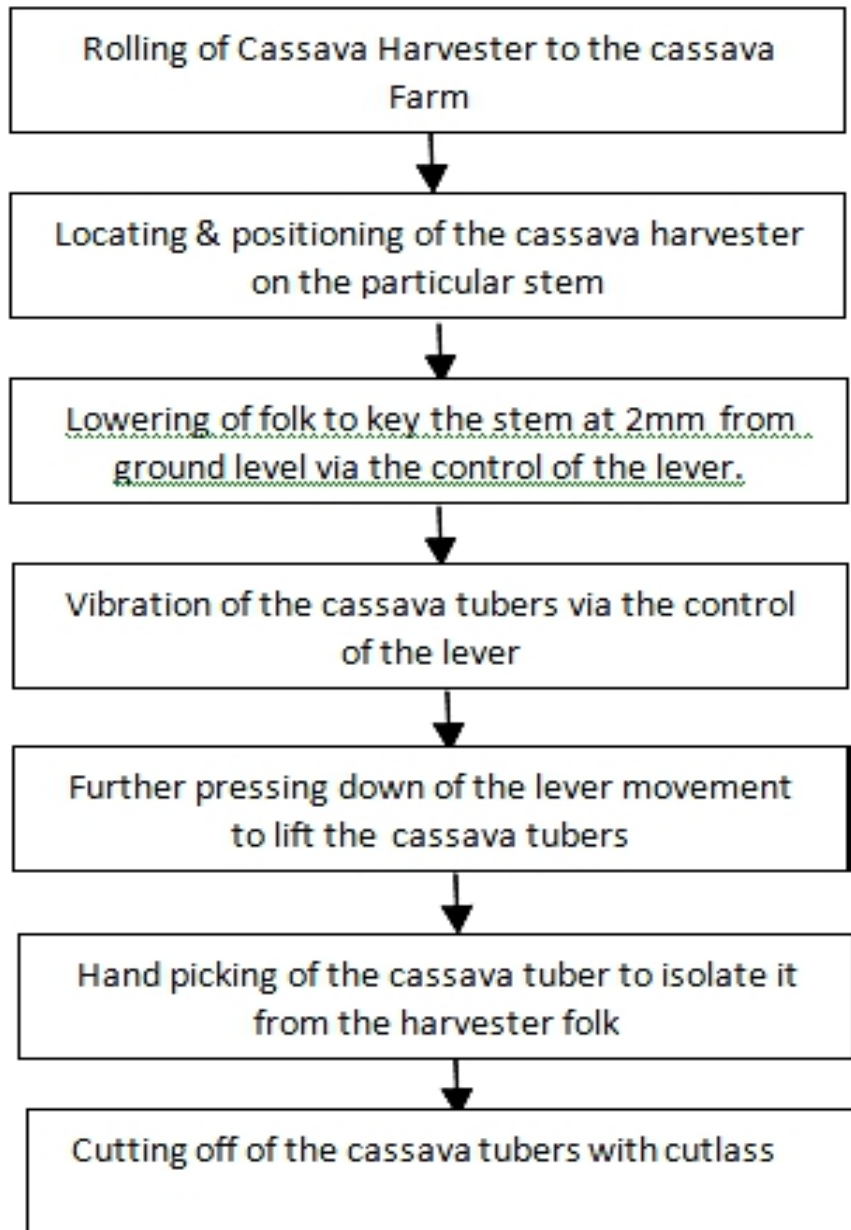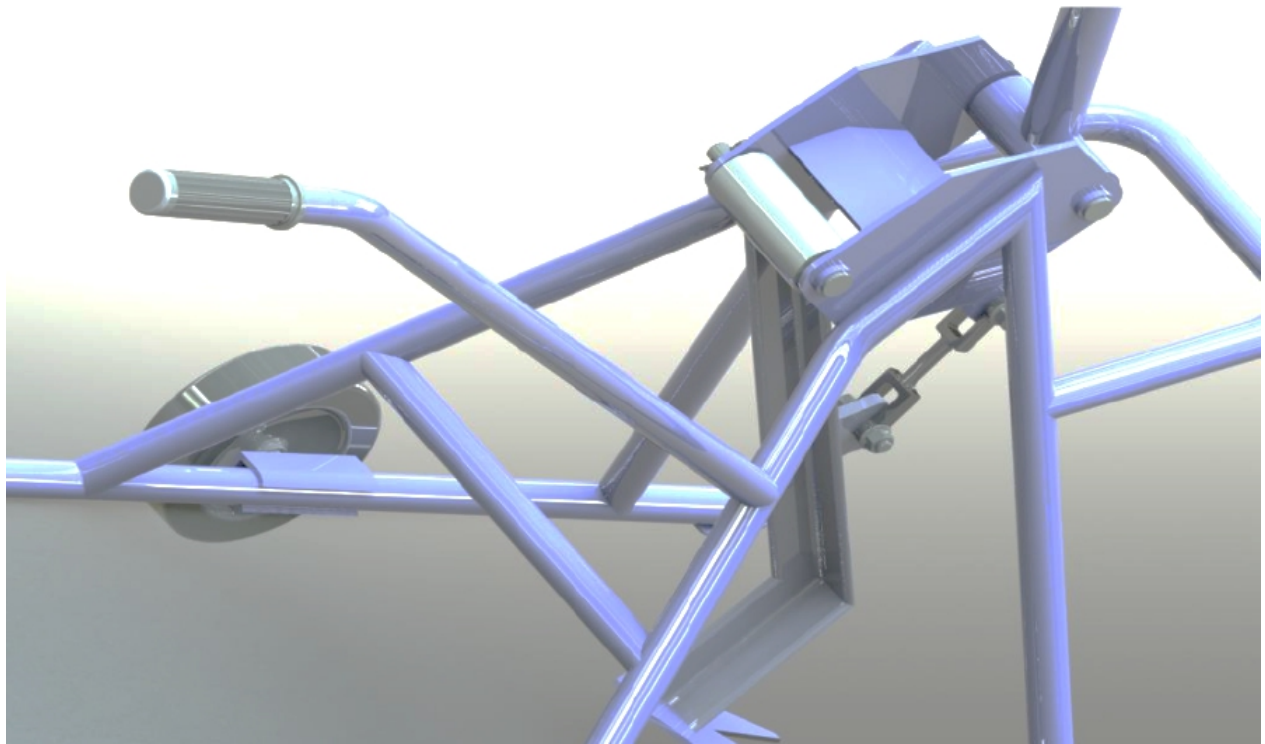
Figure 6: Sequence of operation.

Figure 7: Drawing of the cassava Harvester

The field trials of the manual cassava machine are as captured below in Figure 8.

Figure 8: Field trial pictures to showcase the operation of the manual Cassava Harvester.

Conclusion

The mechanical cassava harvester is rugged, durable, and portable enough for daily operations with easy maintenance and repairs. The mechanical harvester was constructed at a cost of USD 522 with materials sourced in Nigeria. If Nigeria's economy is to progress more, there should be diversifications through revival of agricultural sector, bringing in indigenous technology as tool. With this Mechanical cassava harvester, it is clear that whatever Farm machine produced in oversea we could do better in Nigeria.Themechanicalcassavaharvester has no actuated parts, hence, itdoes not use anyform of fuel, and veryeasyto maintain. The level arm of

the harvester is effortlessly adjustable to accommodate variable heights of the operator, from 1m – 2m. These embedded featuresensure betterergonomics, thus eliminating adverse health issues such asmuscle damage to the hand and wrist, inflammation/irritation of tendons, and lower back Injuries, attendant to usage. Time for harvesting using the mechanical cassava harvester is 30 seconds. Hence, a 10m^2 coverage area with 50 cassava plants can be harvested in 25 minutes. This is far much better than harvesting by hand which took 90 seconds to harvest a cassava plant. The efficiency of the machine for the intended load of $300\ N$ with an applied effort of $120\ N$ is 83.33%.

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