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Performance Evaluation of Selected Cassava Roots Harvesters

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Abstract
The mechanization of cassava uprooting process on large expanse of cassava plantation is an important and urgent need to resolve the present plights of peasant farmers in tropics. These farmers employ the manual uprooting methods of the roots of this crop and it is quite an extremely difficult task most especially during the dry season when the soil crust is very hard. Most peasant farmers who employ this method and are at their old age are subjected to acute back pain due to accumulated stress on the back muscle over their productive years. The advanced methods of uprooting which are attachments to farm tractor are beyond the reach of this poor farmers. These low scale farmers are the major producers of the crop and they need a better, gender friendly uprooting device that would reduce the accumulation of a stressed life emanating in the uprooting process. A strategic approach of a three-year plan of developing a better method of uprooting the cassava roots were embarked upon sequentially by three different members of this research group to advance the development of the uprooting device. In the plan that was executed in this order machine design, refinements, modifications, evaluations and machine final design and adjustment were embarked upon over these periods. In the end a feasible design from faults of preceding year design were corrected and tested to obtain the best uprooting method. Out of the three investigated designs of hydraulic arm uprooting device, pillar arm uprooting device and lever hoist uprooting device, the later was found favorable and most effective for the uprooting of cassava roots. This assessment was based on the energy input of 24.03 kJ and output performance 19.19 kJ which was lower and of better performance than the other two methods. With a little further modification, this unit, the lever hoist uprooting device would be a handy tool for cassava harvest for peasant farmers all over the globe at a very affordable price not beyond the income of these farmers. This unit would also remove all forms of stress attributed to the uprooting process.

Keywords: *cassava roots, harvester, uprooting, energy expended, refinement, sequential development*

1.0 INTRODUCTION

The production level of cassava in Nigeria had reached 34 million metric tons yearly as reported in FAO (2004a) while Oriola and Raji (2013) as stated in Uthman (2011)) gave a figure that it had grown to 40 million metric tons per year. Out of these figures, a substantial quantities of these roots harvested were uprooted using machines and manual means of which machine to manual ratio is unknown. However the information obtained in literatures showed that out of all the eleven listed in the production processes enumerated in Ola (2014) a report obtained from Chan *et al.* (1983),the uprooting process had the highest level of percentage manual labor requirement of 61.7 %. A yield rate of 15 to 30 tons per hectare for 10,000 plants population as opined in IITA (2004) inferred that a plant weight is in the range of 1.5 to 3 Kg indicating a maximum force of 300 N per root handling. Sar (1979) gave a value of 1.0 kN as the required force for uprooting cassava stem beyond the level of force of 0.8 kN which a man could handle as reported in Crossley *et al.* (1983). Reports of various attempts in mechanizing the harvesting process are recounted in literatures like; Johnson *et al.*,1981; Odigboh and Ahmed 1982; Makanjuola and Moldenhawer,1984; Alejandro, 1989 and Agbetoye, 1999. Claims was made in one of these cited literatures that rates of harvesting attained with power drive requirement, blade width, depth of operation and field speed of the harvester developed was 0.29 ha/h, 105 kW, 0.95 m, 0.4m and 2-3 km/h respectively (Agbetoye, 1999). Other harvesters like API, CIAT, Mark III and CEEMAG ARM81 mentioned in Agbetoye, 1999 are beyond the reach of the common low income earnings of cassava farmers who are the major producers all over the globe. Most big time farmers still found the harvesting stage cumbersome, challenging and costly since some still employ the manual labor resulting in low rate of harvesting which result in loses of matured tubers to rot especially during the wet season.

Due to this inference the problem of getting good and timely machines is still a mirage in this area of crop production, for most farmers in this region. Developing progressively and continuously refining the design of the smaller unit of cassava uprooting over the years of previous designs might completely resolve this issue of non-availability of sustainable machines for famers in this aspect of cassava uprooting process. Similar efforts and drive in the area of obtaining sustainable machines for crop mechanization and machine development were reiterated in Adisa, (2012) and Adisa *et al., (2017)*.

Hence a progressive development of a smaller unit over a three year period of improvement and refinement of design was desired and researched to remove the limitations of non-availability of cassava uprooting machines which cut across the geographical cultivating zone around the globe.

In Nigeria, peasant farmers, who cultivates small hectares of cassava, found the uprooting process of cassava root tubers an extremely difficult task that must be done in order to meet up expected livelihood and survival, there is need to develop a low scale, gender friendly and a handy cassava uprooting device which was the main thrust of embarking on this research. This device will also resolve the issue of farmers at old age who complained of severe and acute waists pain bedeviled by years of stressful handling of manual loads; of different manual tasks ranging from heaping, weeding with manual hoes and cutlasses and with uprooting of cassava root tubers an inclusive task done in their life time of farming. Therefore developing a very low cost and handy device would reduce this stress affecting poor farmers in this area of harvesting of cassava roots all over the globe.

The development of a small, simple low cost and handy cassava uprooting device would reduce the problems these farmers are facing. This targeted end user would found a low cost unit affordable and quite useful in eliminating farm stress involved in the process of uprooting the roots of the crop.

Out of the numerous machines developed for harvesting cassava roots by being attached to the farm tractor, none were readily available to most small to medium scale producers of cassava in Nigeria. Developing a less costly unit would help peasant farmers who could easily generate a small amount of money from their yearly productions of cassava cultivation. Improving on the ease of harvesting cassava is a positive drive to mechanization, greater productions and a better livelihood for farmers and indeed this would proffer a gender friendly device that could easily be operated by anyone regardless the gender or age of the operator. This handy and relatively light weight device would not be beyond the income of farmers who desire better less stressful method being developed. Literature survey showed that the manual labor requires 50 man days to finish uprooting a hectare of land as sighted in Chan *et al.* (1983). A cassava uprooting device operating at a faster working rate more than the manual were the main thrust of this work and was rigorously pursued in this work.

2.0 MATERIALS AND METHODS

2.1 Conceptual Design of the Three Uprooting Device

The conceptualized design of the root harvester were developed over three years plan of rigorous design, fabrication, modifications and adjustment to obtain a handy simple technology for accomplishing the given task easily without compromising the rate of uprooting as compared with the manual method.

The three conceptual concept investigated were;

1. Hydraulic Arm Cassava Uprooting Device.
2. Pillar Frame Hydraulic Uprooting Device.
3. Flexible Lever Hoist Uprooting Device.

The three concepts were design and fabricated were conceived consecutively as the first, second and third design in three sequential years. In evolving the design and development of the devices spanning over the period of three years of study to obtain an effective uprooting device at shortest time of operation while delivering an appropriate uprooting force of 2 KN were the main basis of evaluating each of the design and subsequently improvements were made on the design to impact the desired features over the years of modification, redesigning and fabrication. These three methods conceived over the space of three years by three different independent researchers exploring three different design approaches were developed and evaluated for effectiveness and functionality of the uprooting operation. The three designs were done based on the knowledge of the required uprooting force of 2kN as stated in literatures (Agbetoye, 1999). Theory of machine mechanics under stability control was adapted and applied in designing the uprooting systems; while maintaining a light weight material without compromising its overall stability was an important factor considered during the design modification.
The lapses observed in the preceding design were improved upon in the subsequent years. Within these years the device evolved from the first, to second and over to the third design.

2.1.1 Design of Hydraulic Arm Cassava Uprooting Device

This design was the initial conceived design initiated and fabricated by the first researcher in the first year on this work. The Device was made of essentially of seven components parts illustrated in Figure 1.The design made use of a 2 metric tons bottled hydraulic jack to develop the required uprooting force. The orthographic projection of the machine is given in Figure 2. The design specification of the unit is given Table 1. The device made use of the hydraulic principle coupled to a lever arm mechanisms shown Figure 1 to actuate the cassava root uprooting process of the stem attached to the gripping arm through the lever hydraulic arm. This unit was design to uproot cassava roots with minima efforts inputted by the operator. The devices were all tested in the laboratory before taken to the field for final assessment.

2.1.2 Design Pillar Frame Hydraulic Uprooting Device

This second design by the second researcher was orchestrated by the lapses observed in the second year of study of the first design; of the Hydraulic Arm Cassava Uprooting Device. This second design shown Figure 3 was conceived and fabricated by the second researcher as a refinement over the first method. The Device also makes use of the hydraulic principle like the first method but with a different approach as shown in Figure 3. This is also made of seven major components as indicated in the drawing. The frame of the whole machine was now modified and designed such that it is in the form of a pillar. The orthographic drawing of this unit is shown in Figure 4.
This modification of changing the frame of the machine into pillar form was to reduce the overall weight of the device and energy expended in maneuvering the unit on the field. A 2 metric tons bottled hydraulic jack was also used to develop the required uprooting force. The design specification of the unit is given Table 2. This device was also tested both in the laboratory and in the field.

2.1.3 Flexible Lever Hoist Uprooting Device

In the third year of the continuation of this study a new method was adopted by the third researcher using of a lever hoist mechanism which was a refinement over the other two methods. This made it lighter in weight to reduce the overall energy inputted in operating the unit. The design of the component members of this device is given in Table 3. This is made of five component parts as shown in Figure 5 and the orthographic projections in Figure 6.

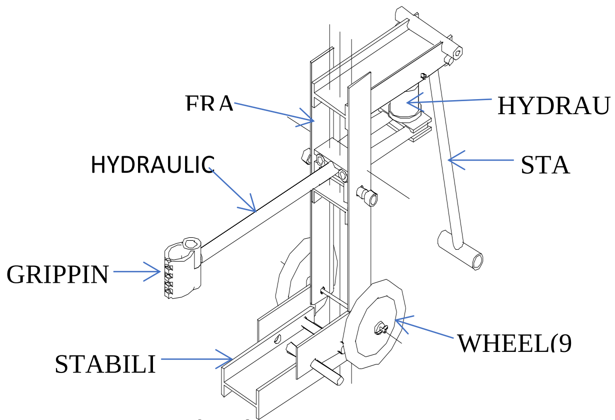


Figure 1: Hydraulic arm cassava root uprooting device (37.92 kg)

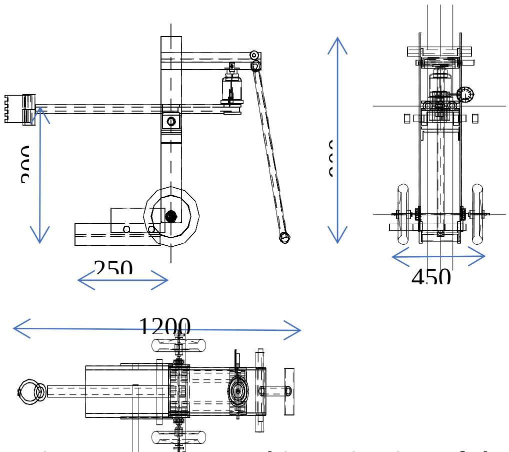


Figure 2: Orthographic projection of the hydraulic cassava stems uprooter

Table 1: Design specification of the Hydraulic arm cassava uprooting device

PARTS	DESIGN FORMULA	PART SPECIFICATION	MAYERIAL TYPE
HYDAULIC ARM	$\sigma = \frac{4}{\pi d^3}[(8M + Fd)^2$ $I = \frac{\pi}{32}(D_o{}^4 - D_L{}^4)$	L=68.9 cm D_o=25 mm D_L =20 mm	MILD STEEL PIPE
FRAME	$\delta = \frac{wl^3}{3EI}$	I=61.06cm^4 minimal size=89 mm× 89 mm	I-BEAM MILD STEEL
GRIPPING ARM	$\sigma = \frac{F}{A}$	4 mm x 50 mm x 100 mm	FLAT BAR MILD STEEL
STABILITY ARM	$\delta = \frac{wl^3}{3EI}$	I=61.06cm^4 minimal size=89 mm× 89 mm	I-BEAM MILD STEEL
WHEEL	-	9.66 Kg	RUBBER
STAND	$I = \frac{\pi}{32}(D_o{}^4 - D_L{}^4)$	25 mm diameter	MILD STEEL PIPE
HYDRAULIC JACK	-	2 TONS	

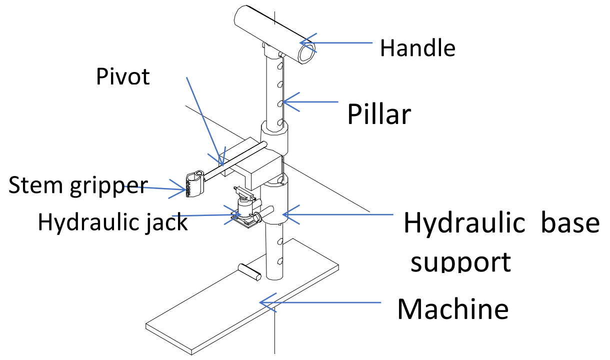


Figure 3: Pillar Frame Hydraulic

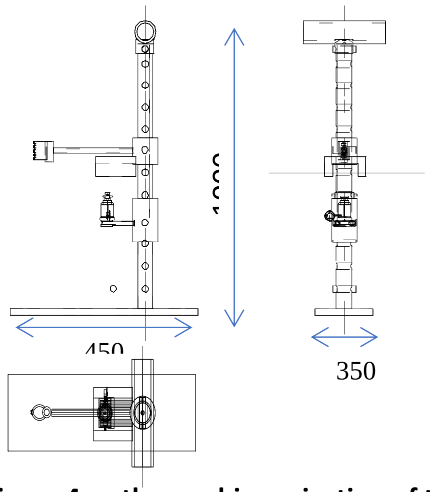


Figure 4: orthographic projection of the pillar uprooting device

Table 2: Design specification of the Pillar Frame Hydraulic uprooter

PARTS	DESIGN FORMULA	PART SPECIFICATION	MAYERIAL TYPE
PIVOT ARM	$\delta = \frac{wl^3}{3EI}$ $I = \frac{\pi}{32}({D_o}^4 - {D_L}^4)$	L=77 cm D_o=25 mm D_L =20 mm	MILD STEEL PIPE
PILLAR	$I = \frac{\pi}{32}({D_o}^4 - {D_L}^4)$ $Z = \frac{I}{y}$ $\sigma_b = \frac{M}{Z}$	I=67274 mm^4 D_o= 100 mm D_L = 95 mm L = 1000 mm	MILD STEEL PIPE
STEM GRIPPER	$\sigma = \frac{F}{A}$	4 mm x 50 mm x 100 mm	FLAT BAR MILD STEEL
MACHINE BASE	$\sigma = \frac{F}{A}$	I=61.06cm^4 minimal size=89 mm× 89 mm	I-BEAM MILD STEEL
HYDRAULIC BASE STAND	- $I = \frac{\pi}{32}({D_o}^4 - {D_L}^4)$	9.66 Kg D_L = 25 mm D_L = 23 mm	RUBBER MILD STEEL PIPE
HYDRAULIC JACK	-	2 TONS	

Table 3: Design specifications of the Flexible Lever Hoist Uprooting Device

PARTS	DESIGN FORMULA	PART SPECIFICATION	MAYERIAL TYPE
LEVER HOIST	$\sigma = \frac{4}{\pi d^3}[(8M + Fd)^2$	15 tons	MILD STEEL PIPE
FRAME	$\delta = \frac{wl^3}{3EI}$ $I = \frac{\pi}{32}({D_o}^4 - {D_L}^4)$	I=61.06cm^4 minimal size=89 mm× 89 mm	I-BEAM MILD STEEL
GRIPPER	$\sigma = \frac{F}{A}$	4 mm x 50 mm x 100 mm	FLAT BAR MILD STEEL
FLEXIBLE CORD	$\delta = \frac{wl^3}{3EI}$	I=61.06cm^4 minimal size=89 mm× 89 mm	Fibre

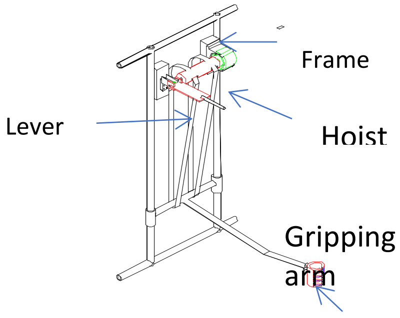


Figure 5: Lever hoist cassava root uprooting device

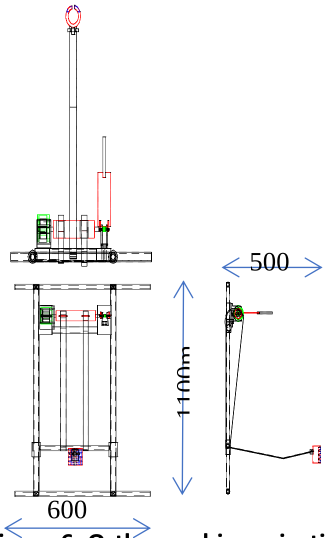


Figure 6: Orthographic projection of lever hoist uprooting device

2.2 Energy Evaluation of the Cassava uprooting Devices

The three mechanisms developed were tested on the same farm site over the period of study separately. The time of the field test was done during the dry season, precisely the month of January of each year of study. In the field analysis of the uprooting devices, critical assessments of the time to maneuver and operate each unit as compared to the manual method were studied. The manual field rating estimated from consulted literatures; Ola (2014), Chan *et al.* (1983) and Agbetoye, (1999). showed that work rate of uprooting the stem must be lesser than 1 stand per 2.4 minutes. Although, this value might be higher in cases where the ground was hard, stony and root stumps in soil strata which would definitely increase the uprooting time and force required. The conceptual designs of all the three methods presented earlier were evaluated to obtain the merits and demerits of each method and the findings were presented in the results and discussion. The basic equations of mechanics of evaluating energy and power within a given machine were adopted here to assess the performance as the basic relevant parameters of evaluating each device. The parameters measured were the time, weights of members and distance (machine motion and farm land distance) using a stop watch, sensitive weighing balance, a meter rule and GPS. These parameters were used in the following equations of mechanics to determine the energy input and output thereby evaluating the performance of the three devices;

$$F = (M_e \times g) + F_v \tag{1}$$

Where F = force for uprooting the cassava stems

F_v = resistance force due to root vine and stumps on top of the cassava roots hindering the uprooting process.

M_e = mass of cassava root uprooted and the soil clods on top of the roots

g = acceleration due to gravity

$$E = F \times d \tag{2}$$

Where, E= Energy expended in uprooting the stems

d= distance moved by the uprooting arm

and to determine the power utilized P is given as;

$$P = F \times V \tag{3}$$

where V = the velocity of the uprooting mechanism which is also given as;

$$V = \frac{d}{t} \quad (4)$$

where t= time taken to uproot a given stem.

The actual force of uprooting the cassava roots, was a bit complex in that the force of probable roots stumps resting over the cassava roots resisting the uprooting force were unknown and indeterminate, so also was the soil weight on top of the cassava roots being uprooted were unknown.

However, to resolve all these issues, the following rational assumptions were made to determine the force during the process of uprooting of the cassava roots; An hypothetical approach termed "fragment theory of mechanics" were assumed and adopted here as;

1. The mass of cassava roots uprooted stem multiplied by the acceleration due to gravity gives the equivalent force that overcomes soil resistance for situations where the cassava stem were not broken up into fragment; that is, no roots was retained in the soil. For this instance F_v is the force of soil weight and restriction from roots stumps resisting the uprooting process which was negligible and is taken as zero as given in Equation 1. Hence the force of uprooting the roots for this occurrence is equal to the weight of roots being uprooted.
2. For situations where the stem roots were broken into fragments and there were remnants roots retained in the soil; the component force F_v , in Equation 1, was assumed not to be negligible. This situation do occur generally in most uprooting processes of cassava roots when the soil moisture content is low due to dryness and hard soil crust and also when there are roots of other plants lying directly on top of the cassava roots being harvested. To resolve this complex problem in soil mechanics of determining the uprooting force, a fragment theory was proposed and assumed to solve for "F". Hence the opined hypothesis states that; for a broken stem roots being uprooted from a ground with great soil restraints forces due to hard soil crust and other plant roots, resisting the uprooting process by exerting equal and opposite force or bit greater than the total weight of the cassava stem being uprooted thereby generating the inherent shear force that results in the fracture of the stem. The force causing this fracture of a given stem roots was assumed to be equal to the weights of both uprooted fraction and that which was not uprooted and retained in the soil.

   This implies that;

$$F \geq (M_T \times g) + F_S \quad (5)$$

Where, M_T = the total mass of the stems uprooted and the root remnants in the soil.

F_S= is the shear force required to shear off a given diameter of a cassava stem

The total mass of the whole stem was determined by adding the mass of the stems removed from the soil manually to the mass uprooted by the machine. The shear force that would fracture a given stem diameter was determined using measurement of weights obtained from roots uprooted by the machine and the weights of stems retained in the soil being uprooted manually.

This implies that;

$$F = F_u + F_r \quad (6)$$

Where, F_u = the force computed from the weights of roots uprooted by the machine.

F_r= the force computed from the weights of roots retained in the soil uprooted manually.

This Equation 6 eliminates the need to determine the shear force F_S which was also the F_v in Equation 1.

3.0 RESULTS AND DISCUSSION

The Hydraulic arm cassava root uprooting device is shown in Plate 1. The design evolved from the Hydraulic arm cassava root uprooting device (37.92 kg) into the pillar uprooting device (17.7 kg) after initial evaluation of the hydraulic arm cassava root harvester which was not found favorable. Although the unit was able to handle weight range of 30.7 to 70.8 kg in the laboratory test, as shown Table 4, it was unable to completely uproot the roots on the field test. The maximum weight acting the arm gives a force of 0.705 kN, generating a turning moment of 211.5 N.m. at the base of the device. This moment that was transferred to the base point of the device required a counteracting moment to form a couple at the base of the device to stabilize the unit. This component that blocks this unwanted moment which could trip the whole system over is labeled the stability arm in Figure 1 and Plate 1. The addition of this unit arm increases the overall bulkiness of the machine. The problem encountered while evaluating the hydraulic arm was of two folds, namely;

I. More materials were inputted in the design and fabrication of this unit to attain the required device field stability and this compromised the desire to have a light weighted unit since it is bulky and it requires two wheels, weighing 9.86 kg each, to make it easy to maneuver while operating it.
II. The uprooting arm had a limited height of movement which was less than 0.3 m. This limitation affected the uprooting process, in that it was impossible for the unit to totally lift and remove the roots from the soil, although a maximum force of 705N were generated by the unit which was found sufficient to initiate the uprooting process. This limited uprooting height of 0.3 m aborts the uprooting process and grossly made this device not so adequate of uprooting the roots totally.

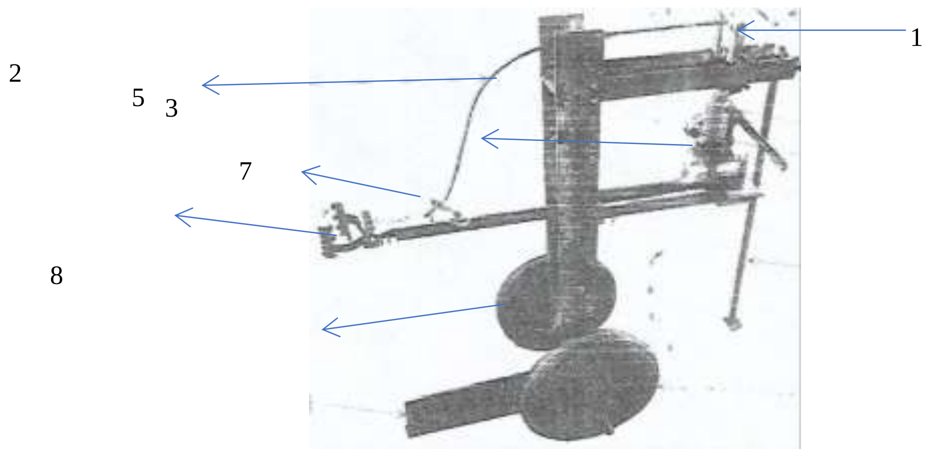
Table 4: Lifting performance of the hydraulic uprooting device

Weight lifted (Kg)	Pressure gauge reading (P)KN/m	Force (force x area) N
30.7	423.29	298.24
42.8	575.95	407.08
54.24	756.37	534.80
60.26	832.70	588.50
65.88	909.03	642.50
70.8	985.36	696.50

The anomalies discovered while testing the Hydraulic arm uprooting device resulted in the development of the second unit called the Pillar arm uprooting device which was an improvement over the former version. The pillar arm, shown in Plate 2, had a total weight of 17.7 kg. This makes it lighter in weight when compared with the former design.

In addition to this design advantage of lightness, this new technique was also made in such that the limited height movement of the uprooting arm occurring in the Hydraulic uprooting arm was completely eliminated by making the Pillar arm to have the features that facilitated the variability of heights. The ability to adjust the Uprooting arm with the hydraulic jack and its' base along the pillar column gave a better advantage over the Hydraulic uprooting device. The Pillar arm was evaluated in the laboratory using 20,30, 40 and 50 kg weights shown in Table 5. Plate 2 shows the laboratory evaluation of the unit before the field test.

The Pillar arm also makes use of a flat plate at the base of the pillar to block the unwanted moment created by the uprooting process. This flat plate serves as an equivalent component of the stability arm, a feature also designed for in the Hydraulic arm cassava stem uprooting machine.



S/N	COMPONENT
1.	LOCK ARM
2.	HANDLE
3.	HYDRAULIC JACK
4.	HYDRAULIC PUMP JACK
5.	PRESSURE GAUGE
6.	GROOVE
7.	STAND
8.	WHEEL
9.	LOCK CABLE
10.	GRIPPING ARM
11.	STABILITY ARM

Plate 1: Hydraulic arm cassava harvesting device

Table 5: Lifting performance of the pillar uprooting device

Lifted weight (kg)	Pressure gauge readout kN/m^2	Force (N)
20	277.57	196.18
30	416.35	294.28
40	555.13	392.37
50	693.92	490.46

Table 6: Lifting performance of the lever hoist uprooting device

Lifted weight (kg)	Pressure gauge readout kN/m^2	Force (N)
15.43	210.95	149.10
2023	276.04	195.11
31.42	431.75	305.16
43.40	598.16	422.78
55.43	764.69	540.49
62.32	860.46	608.17

This pillar arm cassava root uprooting device was able to uproot the stems successfully as shown in Plate 3. The stems diameters in the range 10 to 14 mm were gripped and the roots were uprooted by the machine as shown in Plate 3.

The evaluation of the pillar arm also generated salient observations that led to entire modification of the whole system and mechanism, changing from the hydraulic to the lever hoist system, a mechanism developed to impact the much-needed light weight and ease of operating the uprooting device.

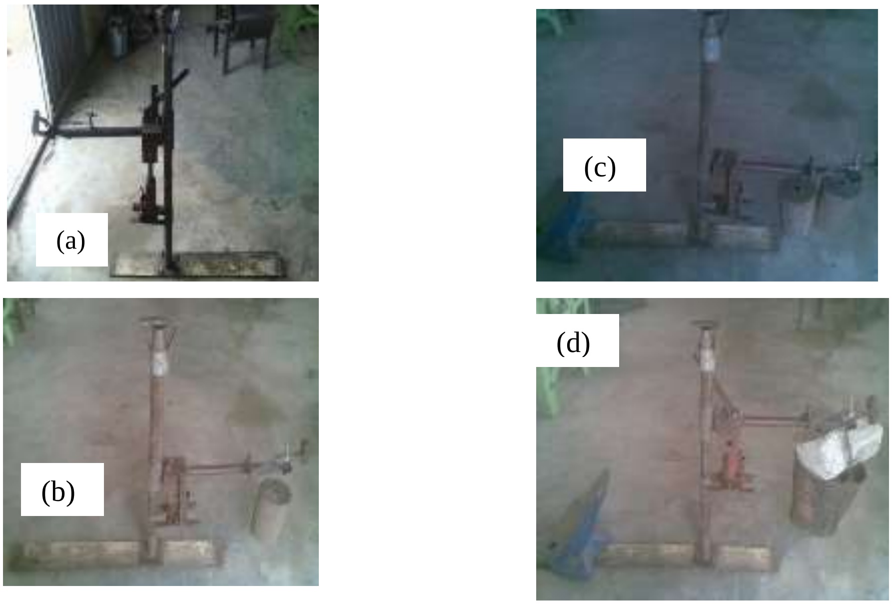


Plate 2: (a) Pillar arm cassava root harvesting device being evaluated in the laboratory with weights of; (b) 20 Kg, (c) 40 Kg and (d) 50kg respectively

Plate 3: Field evaluation of the Pillar Arm cassava harvester

These observations were:

I. There was need to continuously adjust the uprooting arm and the hydraulic jack base support as the uprooting process progresses while a pin was used to fix the height level of these two components intermittently. As the height increases gradually to attain the reasonable height, whereby the stems and roots were completely pulled out from the soil. This gradual process of increasing the uprooting height each time the maximum height attainable by the hydraulic jack was reached, fixing and removing the stopper pin which increases the uprooting time. This constitutes a major setback of this design since each time this adjustment of heights was made it affects the machine field capacity.

II. It was also observed that maneuverability of the whole unit was a little bit clumsy and not so effective due to discontinuation of uprooting process each time the extreme height of the mechanism was reached thereby breaking the uprooting process to cater for the change of height.

These two limitations observed in the evaluation of second design; the pillar arm hydraulic uprooting device generated the total modification of concept, completely by transforming the system from hydraulic to a lever hoist system which was the third new design namely; the Lever hoist uprooting device shown in Figure 6 and Plate 4.

Pate 4: (a-c) showing the field operation of the lever Hoist device in operation and (d) the uprooted root

The improvement attained in this third design was found to be far better than the other two preceding methods investigated sequentially in this work.
The total weight of the lever hoist is 16.32 kg. The lever hoist was tested in the laboratory using dead weights in the range of 15.43 to 62.32 kg before the field test. All weights; 15.43, 20.23, 31.42,43.49,55.43 and 62.32 kg were lifted successfully without failure of members. On the field test it was observed that all the limitations and restrictions observed in the evaluation of the other two methods were resolved successfully in the development of this later mechanism and was found to be better. Average weight of tuber harvested using the machine during the dry season of January 2017 March was 3.26 kg. and the tubers that remained in the soil was 4.76 kg given an harvesting efficiency of 0.43%. The rate of harvesting per stand was observed to be 63 seconds per stands. The uprooting speed from Equation 4 was found to be 9.52×10^{-3} m/s.
The weight of machine is 16.32 kg. the operator took a distance of 150.9 m to the farm at an average speed of 1.28 m/s this gives a total of energy and power expended by the operator to carry the machine to be 24.63 kJ and 208 W respectively. When compared to the other two methods, which gave energy and power expended in carrying the unit to the farm were; 56.13 kJ and 476.15 W and 26.2kJ and 222.25 W for the Hydraulic arm and pillar arm devices respectively. A summary of the energy analysis is given in Table 8, the parameters presented in the table were determined using Equations 1,2,3,4 and 5.

Out of the three methods evaluated, the energy and power expended was lowest for the lever hoist device which makes it the best over the other two methods. In terms machine energy capacity the lever hoist method is far better than the other two methods Table 7 shows the energy lifting capacities of the machine tested in the laboratory.

Table 7: Results of Weight and energy lifting capacity of machines

Item	Experiment1	Experiment1	Experiment1
Hydraulic Arm Uprooting Device	30.5kg 89.76J	50,5kg 148.62J	70.5kg 207.48J
Pillar Arm Uprooting Device	20kg 98.1J	40kg 196.2J	50kg 245.3J
Lever Hoist Cassava Uprooting Device	15.43kg 151.4J	31.42kg 308.2J	62.32kg 611.4J

The uprooting energy and power using this lever hoist is 19.188 J and 0.305 W. This energy and power level make the operation of uprooting process done with ease and of less stress thereby preventing situations where peasant farmers would stress the back muscle that could result into acute pain in the back in the nearest future as a result of years of continuous stress would be eliminated. The advantage of the lever hoist over the other two methods is shown in Table 8.
For effectiveness of operation, the lever hoist device must be held at an angle less than 50^o to the horizontal ground level. It was observed for angles more than this value the device becomes unstable. This instability was due to the couple generated, as a result of backlash reaction of the counteracting force opposing the positive uprooting force of the device. The effect of this couple was effectively eliminated to a zero value at angles lesser than 50^o because the leverage point was fixed at lower part of the device; with greater lever length above this pivot point gives the required torque for device stability and a good mechanical advantage for the uprooting process.

Table 8: Energy assessment of the three uprooting devices

Item	*Energy expended in lifting device to farm site (150.1m) (kJ)*	Energy lifting capacity Of device (j)	Energy accessible in uprooting cassava root (j) (work done)	Energy utilized in uprooting cassava stem	Mass of cassava root uprooted (kg)	Uprooting performance	**Percentage of machine energy utilization** (%)
Hydraulic arm uprooting device	55.84	5883.99	211.5	-	--	NIL	3.59
Pillar arm uprooting device	26.06	14,709.98	528.75	5.89	1	100% EFFECTIVE	3.59
Lever hoist cassava Uprooting device	24.03	125042.67	3525	19.19	3.26	100% EFFECTIVE	2.8

4. CONCLUSION

A new method of cassava uprooting device, a lever hoist device, had been developed which evolved from the hydraulic and pillar arm uprooting devices and it adequately handled the uprooting of cassava within shortest time of operation. The cost of making a unit in terms of material inputs for production when compared with the hydraulic and pillar arm uprooting devices, was of a low and affordable cost for peasant farmers who are the major stakeholders in cassava production in Nigeria. This unit still requires slight modifications of parts to eliminate, the minor need of recoiling the lever hoist rope mechanism that takes fraction of the time devoted to harvesting. This method is a better one which in the long run would be a vital tool in the mechanization aspect of harvesting cassava roots. Early adoption of this tool by farmers would remove farm stress and possible back pain ailment affecting peasant farmers at old age.

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