Instrumented rig for cassava harvesting data acquisition

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Abstract: In the design of a viable and appropriate cassava tuber harvester, the lifting coefficient of cassava tuber was determined to be a function of lifting force, lifting time, speed of lifting, weight of the tuber and soil surrounding the tuber. This paper described the design, construction and operation of an instrumented rig which allows the simulation of cassava tuber harvesting in the field. The rig consisted of the gantry, chain block, chains, hook/fisher, variable speed electric motor, 5 kN load cell and DI-1000U data logger. The developed rig was tested in a matured cassava field located at the experimental farm of the National Centre for Agricultural Mechanization, Ilorin, Nigeria in 2012. The rig effectively uprooted cassava tuber in the field in about 10 seconds and gave the maximum force of 678 N at soil moisture content of 11.96% db and uprooting speed of 8 mm/s. The developed rig should be utilized to generate force required to harvest cassava tubers at various soil moisture content and speed of uprooting at various soil types. The data generated could be utilized as base line data for the development of viable hand held and tractor drawn cassava harvester.

Keywords: instrumented rig, cassava harvesting, moisture at harvesting and speed of harvesting

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1 Introduction

Nigeria is the home of cassava but other countries like Thailand, Vietnam, Indonesia, Brazil and etc. reap abundant incomes from cassava because they have mechanized farms that produce quantum outputs to meet industrial and other demands. Any nation that aspires to achieve sustainable cassava business must have large mechanized cassava farms for reliable and continuous source of cassava tuber stock. Agbetoye et al., (2000) reported that harvesting is one of the major bottlenecks that made cassava business unattractive to the farmers. Once this is resolved, farmers would be ready to make cassava tuber production a business that could be relied upon. The cultivation of cassava is majorly by stem and followed by seed but as it grows, the root swells and store up food for the farmer. The fact that the root would stay minimum of nine to fifteen months in the ground, the soil around it would have hardened up after been beaten by rain and sun over some time. This condition is not good for the farmers when the swollen root (cassava root) is ready for harvesting, thus making cassava business unattractive to farmers. This explains why farmers are always willing to harvest the cassava root in the raining season because the soil around the cassava tuber would be easier to dig out than the dry season when the soil surrounding the cassava root would require extra effort to dig/excavate. Agbetoye (1999) reported that manual harvesting of cassava tuber cannot cope with the rapidly expanding cassava processing factories in Nigeria, leading to under-utilization of their capacities. It was further asserted that research on the mechanization of cassava harvesting had lagged behind the mechanization of its post-harvest processing and utilization.

A rig is simply defined as an apparatus used for assessing the performance of a piece of mechanical

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equipment. In coming up with a suitable cassava harvester, the need of studying the harvesting activity becomes imperative vis-à-vis as it relates to the soil moisture, speed of lifting, weight of tuber to be lifted and the time required to lift the tuber out of the soil. The volume of soil displaced while uprooting the cassava tuber was reported by Ogunjirin et al., (2014), however the estimation of the force required to lift the cassava tuber needs to be further researched, and in addition, taking cognizance of the rootlets which hitherto has been neglected by previous researchers.

A testing rig is one of the best ways to go about ensuring that you understudy a process of carrying out an activity mechanically before embarking on final prototype construction. This would guide the researcher in avoiding errors that could end up in wasting of material resources and time.

In the design of a suitable commercial harvester, there is the need to know the actual force required to pull the cassava tuber out of the soil. This would assist in coming up with an effective soil loosening and lifting tool. In order to numerically estimate the cassava lifting coefficient, k, for the toughest condition under which the cassava tuber is harvested, an experimental rig is required which would lift cassava tuber out of the soil at varying speed and moisture content combinations.

Markham (2016) reported that test rigs and testing facilities come in many forms and are used within a broad spectrum of industries. They perform a variety of key functions from product validation through to the training and development of operators. Test rigs have specific hardware and software requirements and before deploying a test rig for any research, it is important to understand the specific requirements of the research. The objective of the study is to develop an instrumented rig for cassava harvesting data acquisition.

2 Materials and methods

2.1 Methodology

The experiment was carried out during the 2012 farming season at the research farm of the National Centre for Agricultural Mechanization (NCAM), Ilorin (8°26'N4°30'E). Ahaneku and Ogunjirin (2005) reported that Ilorin lies within the southern Guinea Savannah agro ecological zone of Nigeria and is characterized by a tropical climate with distinct wet and dry seasons and mean annual rainfall of about 1000 mm. The laboratory analysis of the soil sample taken from the field revealed that it is a loamy sand soil. The result of the analysis is presented in Table 1.

Table 1 Analysis of soil sample

S/No	*Parameters*	*Value*
1.	*pH*	*5.6*
2.	*Nitrogen, %*	*2.54*
3.	*Organic Carbon,%*	*2.43*
4.	*Organic Matter, %*	*2.63*
5.	*Sand, %*	*82.8*
6.	*Silt, %*	*5.0*
7.	*Clay, %*	*12.2*
8.	*Texture, $USDA_{std\Delta}$*	*Loamy sand soil*
9.	*Calcium, mg/kg*	*172.55*
10.	*Magnesium, mg/kg*	*197.43*
11.	*Sodium, mg/kg*	*126.77*
12.	*Potassium, mg/kg*	*149.67*
13.	*Acidity, mg/kg*	*10.1*
14.	*Phosphorus, mg/kg*	*20.33*
15.	*Effective cation exchange capacity ECEC, meq/100g*	*64.67*

The cassava field was established in the 2010 farming season by planting TMS 0581 specie of cassava stem cuttings acquired from the Root and Tuber Expansion Programme (RTEP) station in Ajase Ipo, Kwara State, Nigeria after the field was conventionally tilled. Fertilizer (NPK: 20:10:10) was applied on the cassava field at the rate of 200 kg/ha. After eighteen months, the field was fully matured and ready for harvesting.

2.2 Calibration of load cell, speed knob and variable speed gear motor

Calibration of instruments and gadgets to be deployed for taking readings in experiments is very important as it would prevent the instrument from giving wrong readout values. Calibration is to cross check whether the readout from the instrument could be relied upon to be the correct values. The calibration of the knob, variable speed gear motor and load cell for the determination of the lifting force at varied speed of lifting were important because the read out from the instruments have great impact on the result of the study

2.2.1 Load cell calibration using universal testing machine

The calibration of the load cell was carried out using two methods. The first was by using the known weights and the universal testing machine (Testometric model, 100 kN capacity) was also utilized (Plate 1). The two methods produced two separate curves which were superimposed as shown in Figure 1. The calibration curves' response by the UTM and the data logger were the same thus the data logger is considered suitable for the experiment.

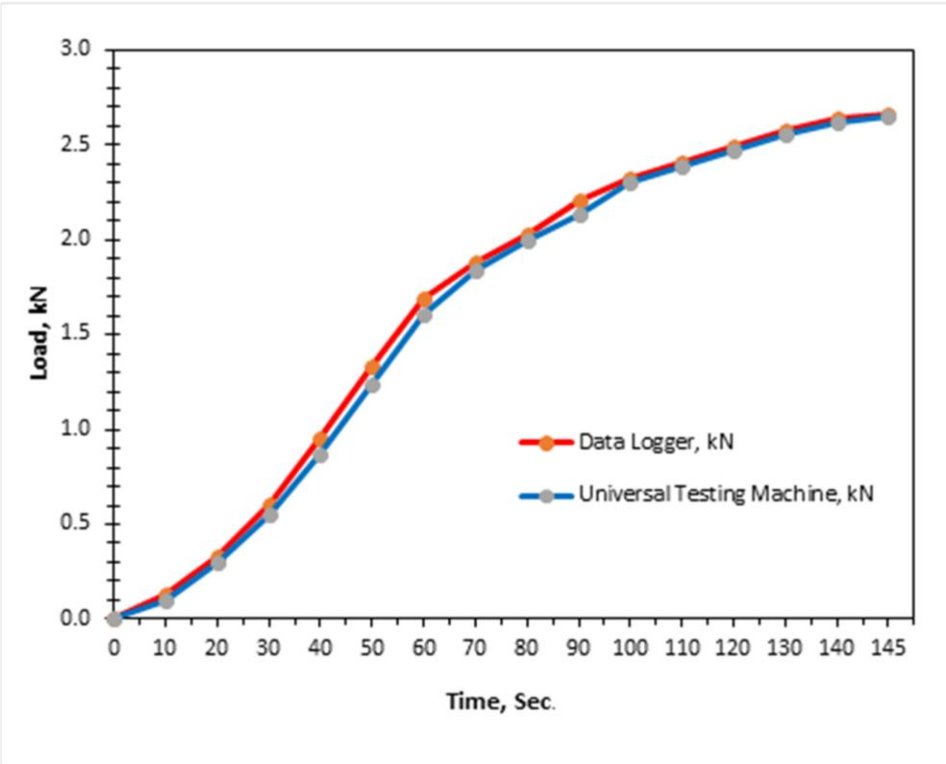

Figure 1 Calibration of load cell readout from UTM and data logger

2.2.2 Load cell calibration results using two point loading

The calibration curve produced by plotting the known weights against the read out values from the DI-1000 data logger is shown in Figure 2. The response of the load cell to the two (2) points loading revealed that the readout from the data logger is reliable. The load cell responded to the known weights with minimal error and linear graph with coefficient of determination of 1.

2.2.3 Calibration results of the variable speed knob

The calibration of the variable speed gear motor knob allowed the speed of lifting to be steady and varied at the turning of the knob either clockwise or anti clockwise. The calibration curve for the 0.37 kW variable speed reduction gear electric motor at varied knob position is shown in Figure 3.

2.3 Description of the rig

The experimental rig consists of the gantry, chain block, chains, hook, variable speed electric motor, 5 kN load cell, DI-1000U data logger (interface for the load cell). The experimental rig was trapezoidal in shape and consisted of two end supports inclined at 30^{o} to the vertical such that it can be operated in a stable form. It is 2 m high and 1.5 m wide. The right end of the gantry had a horizontal projected bar of about 1.3 m high and 0.8

m wide on which the variable speed electric gear motor is mounted.

The driving chain for the chain block was connected to the flywheel of the variable speed electric motor which provided steady speed during cassava tuber lifting. The load cell was connected to the hook from one end and at the other end, the wire twine (fisher) was tied to the cassava stem through which the cassava tuber was lifted out of the soil. The fisher was used to hook the cassava stem from its base and connected to the hook of the load cell.

The linear lifting of the cassava tuber was carried out at a steady speed provided by a variable speed electric gear motor which allowed the variation of the lifting speed as calibrated on the knob. The rotational motion of the chain block was converted to translational motion of the lifting hook as the variable speed electric gear motor, powered with a 2.2 kVA generator, rotates.

The load cell is interfaced between the cassava tuber to be lifted and the chain block such as the chain block provides the necessary force required to uproot the cassava, the load cell senses the force and time taken to uproot cassava tuber and log the reading to the laptop through the data logger.

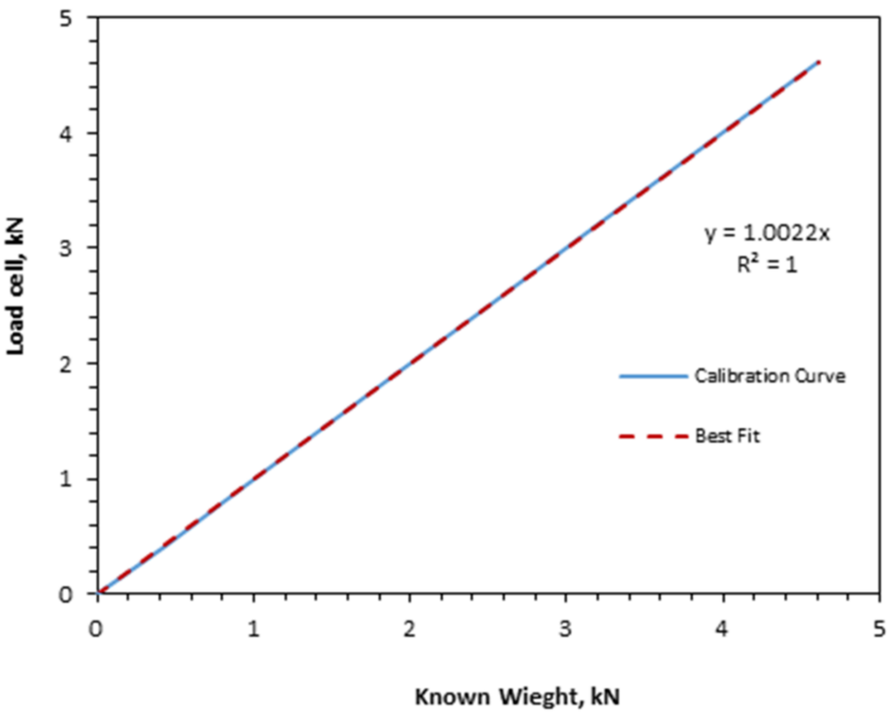

Figure 2 Calibration curve for the 5 kN load cell

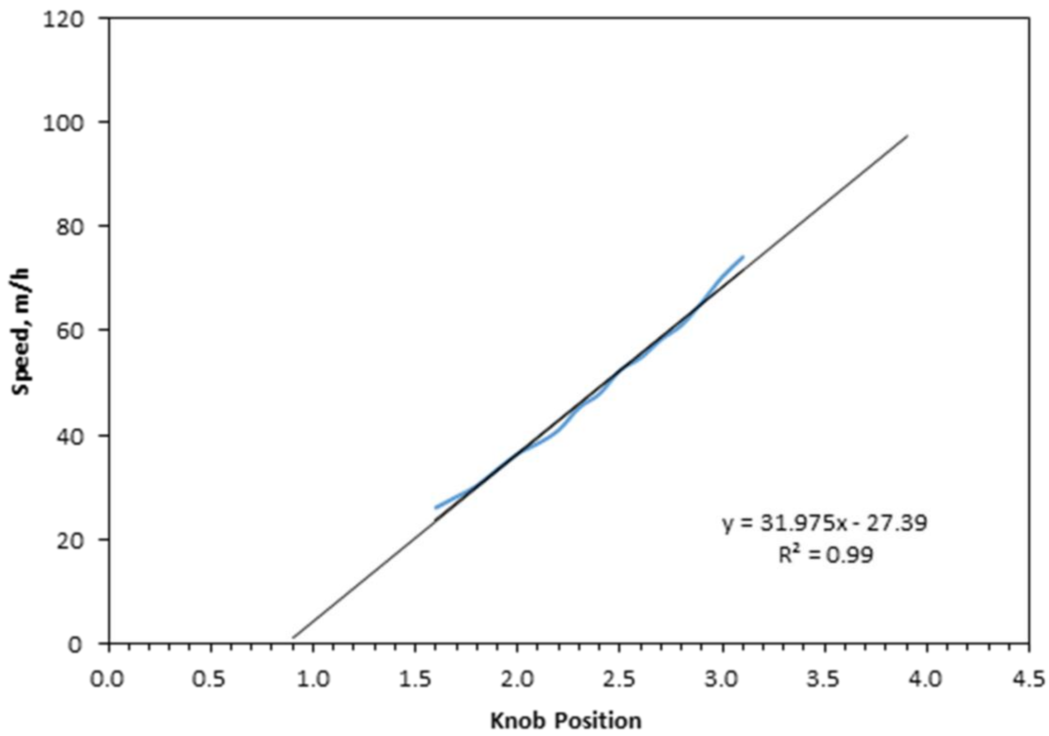

Figure 3 Calibration curve for the knob of variable speed reduction gear electric motor

In the design of the experimental rig, the following factors were considered: -

i. The maximum height of lifting was assumed to be 2 m in order to have enough degree of freedom to efficiently lift the cassava tuber out of the soil.

ii. The ground width of the experimental rig was taken to be 1.5 m in order to accommodate the cassava planting distance of 1.0 m x 1.0 m and also to avoid the experimental rig from clamping down the tubers to be lifted during operation

iii. For the measurement of accurate force required for lifting cassava tuber, the experimental rig was equipped with a 5 kN load cell along with its data acquisition system.

iv. In order to operate the experimental rig at a steady speed, a variable speed electric geared motor was incorporated on the experimental rig.

v. For ease of operation (shifting from one point to the other), a hollow mild steel pipe material was designed and made of detachable joints in order to ease the assembling and disassembling of the experimental rig.

2.4 Design calculations

In design of the experimental rig, the following equations were utilized as obtained from Adler (2004) and Khurmi and Gupta (2005).

$$Bending\ moment(M) = \frac{WL}{4} \quad (1)$$

$$Design\ stress(\sigma) = \frac{M}{Z} \quad (2)$$

Sectional modulus for circular pipe,

$$Z = \frac{\pi}{32} \times \frac{D^4 - d^4}{D} = 0.098\left[\frac{D^4 - d^4}{D}\right] \quad (3)$$

$$Yield\ stress = 230 \times 10^6 Pa\ for\ mild\ steel. \quad (4)$$

$$\sigma = \frac{M}{Z} = \frac{Bending\ moment}{Sectional\ modulus} \quad (5)$$

Where ,

W is load, kN

L is length, (m)

The pictorial drawing of the experimental rig is as shown in Figure 4.

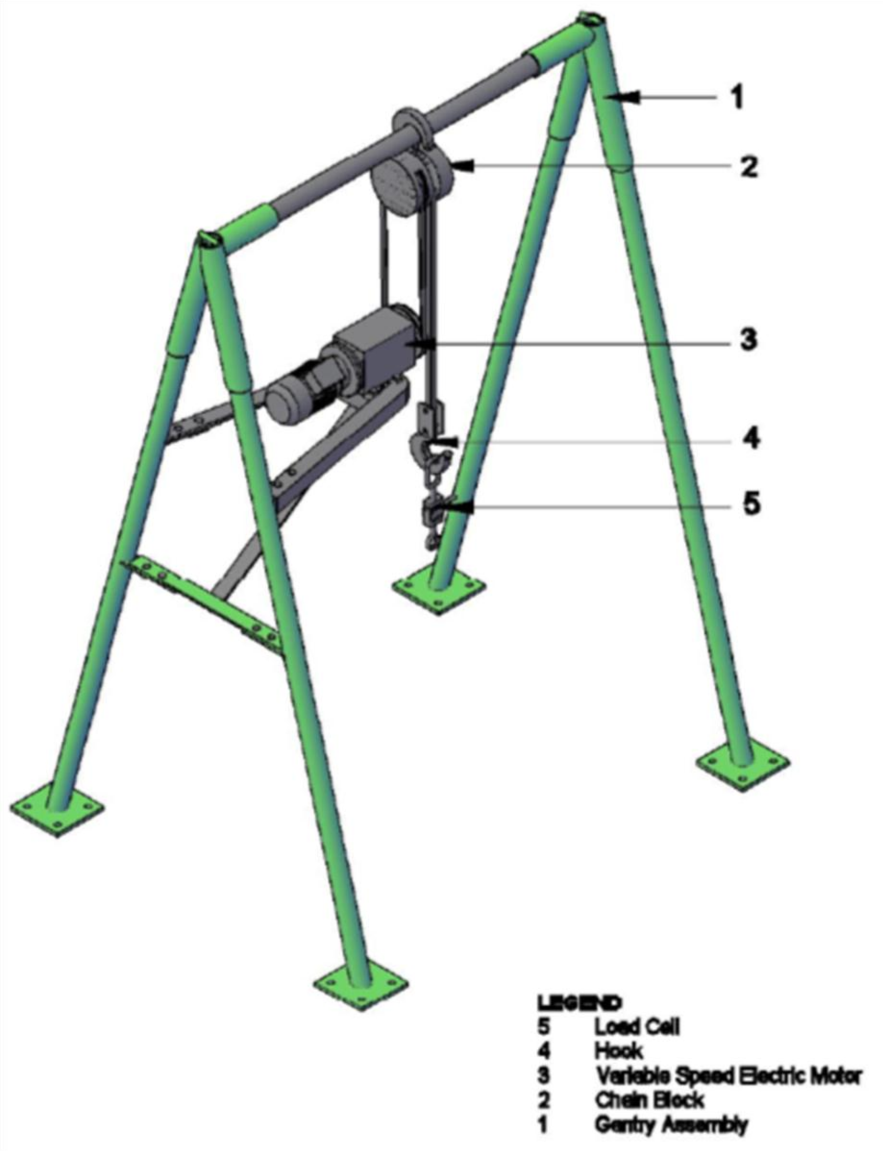

Figure 4 Pictorial drawing of the experimental rig

3 Results and discussion

3.1 Evaluation of the test rig in the field

The instrumented rig was taken into a matured cassava field with the objective of uprooting cassava tuber while the force and time required to carry out the operation would be read and displayed on a personal computer via the data logger (Plate 2). The field moisture content was 11.96% at harvest while variable speed electric gear motor operated at the speed of 8 mm/s. The variable speed electric gear motor was powered by electricity generating set but the data logger has an in-built back-up battery that can allow it work in remote areas, where electricity is not available, for about 24 hrs. The instrumented rig uprooted cassava tuber effectively in 10 seconds and required a force of 678 N to uproot the cassava tuber. The plot of the force against time of uprooting in an excel format and also the data utilized to plot the curve is stored on the system via the data logger. A representation of the result obtained while uprooting cassava tuber with the rig (data and curve) is as presented in Table 2 and Figure 5.

Table 2 Data generated in the field while using instrumented rig to uproot cassava tuber

Loadstar Sensors LoadVUE - Log File				
Units:	N			
Logging Interval: 1 sec				
Use custom format 'hh:mm:ss. 000' in Microsoft Excel to display the time stamp.				
Time	2192-13336	Total	Peak	Low
58:53.6	-87.82	-87.82	-87.82	-90
58:54.6	5.7	5.7	5.7	-90
58:55.6	194.16	194.16	194.16	-90
58:56.6	311.66	311.66	311.66	-90
58:57.6	384.04	384.04	384.04	-90
58:58.6	489.76	489.76	489.76	-90
58:59.6	546.61	546.61	546.61	-90
59:00.6	638.05	638.05	638.05	-90
59:01.6	627.25	627.25	677.72	-90
59:02.6	612.12	612.12	677.72	-90
59:03.6	598.69	598.69	677.72	-90
59:04.6	548.07	548.07	677.72	-90
59:05.6	504.96	504.96	677.72	-90
59:06.6	451.69	451.69	677.72	-90
59:07.6	357.37	357.37	677.72	-90
59:08.6	341.44	341.44	677.72	-90
59:09.6	334.51	334.51	677.72	-90
59:10.6	327.02	327.02	677.72	-90
59:11.6	308.79	308.79	677.72	-90
59:12.6	298.97	298.97	677.72	-90
59:13.6	282.37	282.37	677.72	-90
59:14.6	276.65	276.65	677.72	-90
59:15.6	265.99	265.99	677.72	-90
59:16.6	262.57	262.57	677.72	-90
59:17.6	261.37	261.37	677.72	-90
59:18.6	255.7	255.7	677.72	-90
59:19.6	250.4	250.4	677.72	-90
59:20.6	248.45	248.45	677.72	-90

Loadstar Sensors LoadVUE - Log File				
Units:	N			
Logging Interval: 1 sec				
Use custom format 'hh:mm:ss. 000' in Microsoft Excel to display the time stamp.				
Time	2192-13336	Total	Peak	Low
59:21.6	242.19	242.19	677.72	-90
59:22.6	231.95	231.95	677.72	-90
59:23.6	227.89	227.89	677.72	-90
59:24.6	215.15	215.15	677.72	-90
59:25.6	202.98	202.98	677.72	-90
59:26.6	186.52	186.52	677.72	-90
59:27.6	185.01	185.01	677.72	-90
59:28.6	172.69	172.69	677.72	-90
59:29.6	149.69	149.69	677.72	-90
59:30.6	148.76	148.76	677.72	-90
59:31.6	133.25	133.25	677.72	-90
59:32.6	109.04	109.04	677.72	-90
59:33.6	94.09	94.09	677.72	-90
59:34.6	90.54	90.54	677.72	-90
59:35.6	85.82	85.82	677.72	-90
59:36.6	80.53	80.53	677.72	-90
59:37.6	79.51	79.51	677.72	-90
59:38.6	73.25	73.25	677.72	-90
59:39.6	67.37	67.37	677.72	-90
59:40.6	57.98	57.98	677.72	-90
59:41.6	55.55	55.55	677.72	-90
59:42.6	38.84	38.84	677.72	-90
59:43.6	32.19	32.19	677.72	-90
59:44.6	26.82	26.82	677.72	-90
59:45.6	16.79	16.79	677.72	-90
59:46.6	3.7	3.7	677.72	-90
59:47.6	2.19	2.19	677.72	-90
59:48.6	3.14	3.14	677.72	-90
59:49.6	-1.55	-1.55	677.72	-90

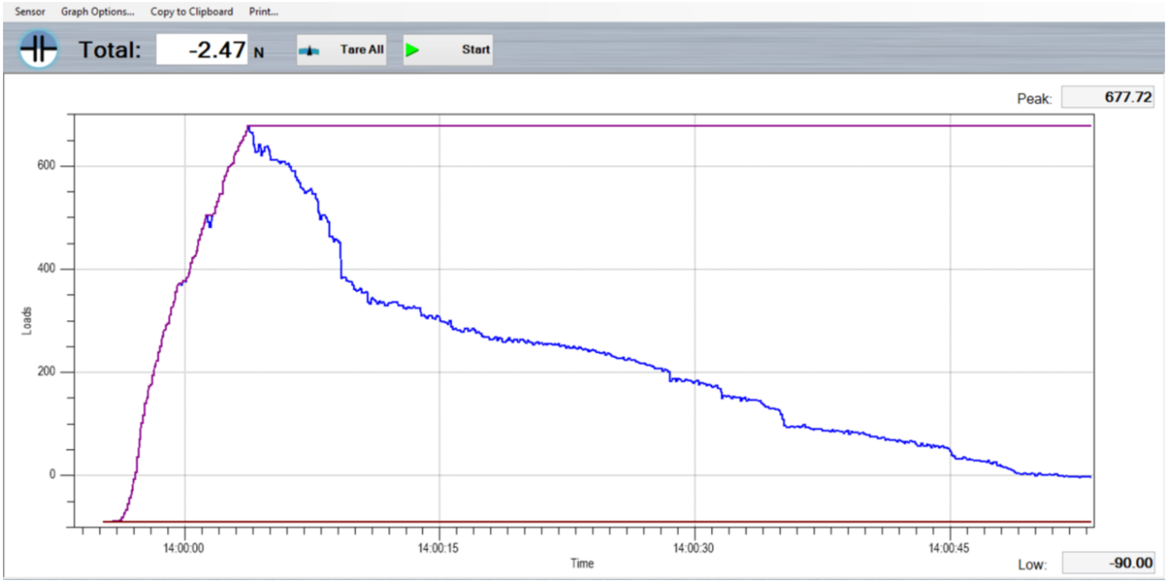

Figure 5 Curve of the harvesting operation in the field.

4 Conclusion and recommendation

In order to effectively uproot cassava tuber in the field, a cost effective and efficient cassava harvester is needed. However, in coming up with such machine or tool there is the need to know the force that the harvester would be working against before designing of the machine. Therefore the need to come up with an instrumented rig which would measure accurately the force required to uproot cassava tuber and time taken to uproot the cassava tuber at varying speed of uprooting became imperative. An instrumented rig was developed in this study and evaluated in the cassava field of a loamy sand soil. The result revealed that the rig logged the uprooting force and time as well as the curve of uprooting onto a personal computer interfaced with the data logger and the load cell. It is recommended that the rig should be utilized to uproot cassava tuber in other soil types so that it could be universally applied. The data generated could form the base line data for the development of viable hand held and tractor drawn cassava harvester.

References

Adler, D. (2004) Structure In Metric Handbook: Planning and design data. 2nd Edition. Architectural Press, Imprint of Elsevier, Linacre House, Jordan Hill, Oxford. 41:1-59

Agbetoye, L.A.S, J. Dyson and J. Kilgour (2000). Prediction of the lifting forces for cassava harvesting. *Journal of Agricultural Engineering Research*, 75(1):39-48.

Agbetoye, L.A.S. (1999). Developments in cassava harvesting mechanization. *West Indian Journal of Engineering*. 22(1):11-19.

Ahaneku, I.E. and O.A. Ogunjirin (2005). Effect of tractor forward speed on sandy loam soil physical conditions during tillage. *Nigerian Journal of Technology*. 24(1): 51-57.

Markham D. (2016). Test rigs. Prince of Wales Road, Darnall, Sheffield, South Yorkshire, United Kingdom. S9 4EX http://www.davymarkham.com/testrigs.htm.

Khurmi, R.S. and J.K. Gupta (2005). A Textbook of Machine Design. 14th Edition. Eurasia Publishing House (PVT.) Ltd. Ram Nagar, New Delhi-110 055, 1251pp.

Ogunjirin, O.A. (2016). Development and evaluation of instrumented rig for cassava harvesting data acquisition. Unpublished Ph.D. Thesis submitted in the School of Post Graduate School, Federal University of Technology, Akure, Nigeria.

Ogunjirin, O.A., L.A.S. Agbetoye and O.C. Ademosun (2014). Estimation of the volume of soil disturbed in the cassava tuber zone in loamy soil during cassava harvesting. *Transactions of NSE*. 48(2):24-32.

Plate 1 5 kN load cell under calibration using the 100 kN Universal Testing Machine

Plate 2 Instrumented rig under operation in the matured cassava field