Comparative evaluation of the performance of motorized and pole and Knife oil palm fruit bunch harvester

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Abstract: In this study the performance of a motorized palm fruit bunch harvester (MBH) was evaluated in comparison with the bamboo-pole-and-knife harvester (BPK). The MBH was first tested on Nigerian plantations for the palm trees it could reach. The average time taken to harvest a bunch and the time taken per hectare of plantation were determined. The best orientation and the cutting angle for the harvester were also determined. The exact height which the harvester could reach was also determined on the plantations. The harvester was later used in comparison with (BPK) method on palms of moderate height and the average time of harvest per bunch, field capacity, as well as cost of operation was determined for the two methods. Time study (TS) of the two methods was also carried out.

The result showed that MBH could harvest between the height of 2.5 m and 4.5 m of palm conveniently. The average time of harvest per tree and speed of harvest for MBH and BPK were 98.86 s and 66 bunches/h; and 166.93 s and 40 bunches/h, respectively. This shows that time of harvest for motorized harvester is over 60% lower, and the speed of harvest is over 50% higher than bamboo pole and knife. The time of harvest per hectare for both MBH and BPK are approximately 4 h/ha and 7 h/ha, respectively. The rate of fuel consumption was estimated to be 1.03 L/h. Moreover, the cost of operation for MBH and BPK was estimated to be ₦ 10,223.46 and ₦ 16,950 per hectare, respectively. The cost of operation using the BPK is over 60 per cent more than that of the MBH. Statistical analysis of the effect of time of harvest on methods indicated that the effect was significant ($p < 0.05$). The study concluded that motorized oil palm bunch cutter can effectively and efficiently handle palms of moderate height in Nigerian oil palm plantations and performed better than the bamboo pole and knife.

Keywords: oil palm, harvesting; motorized-harvester;; pole-and-knife; efficiency

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1 Introduction

The oil palm (Elaeis guineensis) is one of the important economic crops in the tropics (Ibitoye et al., 2011). It belongs to the family palmae (having 225 genera with over 2600 species), and the subfamily cocoideae of which it is the most important member (Ibitoye et al., 2011). The oil palm is a versatile tree crop with almost all parts of the tree being useful and of economic value. The principal product of oil palm is the palm fruit, which is processed to obtain three commercial products. These include palm oil, palm kernel oil and palm kernel cake. The uses of palm oil are many and varied (Adegbola et al., 1979; Ibitoye et al., 2011). Locally, it is used for cooking, soap- making, metal-plating and lamp oil. The palm kernel oil however, is used for soap- making, as a source of glycerine, for manufacturing margarine, cooking fats and for making lubricants. The residue obtained after extraction of oil is called kernel cake, which is useful in livestock feed production. The midribs and rachis of oil palm are used for making brooms and roofing materials. The thicker leaf stalk is used for making the walls of village huts. The bark of the frond is peeled and woven into baskets while the trunk (main stem) can be split and used as supporting frames in buildings. A sap tapped from the male flower is drunk as palm wine, which is a source of yeast. The spent fruit bunch and fibre that

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remains after oil extraction can be used for mulching, as manure and as fuel (Ibitoye et al., 2011).

Oil palm is tree without branches, but with many wide leaves at its top. The fruits are compactly packed in bunches which are hidden in leave axis in crown that may be over 12 m in height. Each of thebunches contains over a thousand fruits, which are held in the axils of the leaves and are arranged in a rosette around the crown. It takes prominent among the family of tree crop and has become the world's number one oil producing crop because of its unparallelled productivity. Oil palm could thrive in severe climatic and ecological condition and gives the highest yield of oil per unit area when compared to other oil- producing plant. Known to be the most productive oil crop, oil palm produces up to 7 t of crude palm oil per hectare. This is 5 to 10 times more than the yield of any commercially grown oil crop (WWF Report, 2012). The palm oil industry in Nigeria, with a potential at full-scale development could play a significant role in improving the country's balance of payments through the production of palm oil as import substitutes and as a major export.

Harvesting is important in oil palm plantation; if it is done appropriately and efficiently, it will help to maximize profit, increase productivity, improve quality, and reduce cost. However, oil palm harvesting still defies the best attempt of mechanization (Russ, 1998). Efficient harvesting of fresh fruit bunches (FFB) plays a vital role towards improving the quality of the harvested fruits. There had been previous work on development and modification of the existing methods of harvesting oil palm. According to Abdul Razak et al. (2008), harvesting from oil palm is grouped into two. The first is harvesting from palms below 3 m in height (short palms) in which a chisel attached to a short steel pole is used. The tool is usually aimed at the target point (frond base or bunch stalk) at a very high speed to effect the cutting. The weight of tool coupled with the very high speed of chopping creates high momentum, which provides enough energy to cut through the frond or the bunch stalk. The second is harvesting FFB from palms of more than 3 m height which requires a different method and technique in which a long pole with a sickle at the end is used. Two activities are carried out: lifting the pole upright, and cutting the frond and / or fruit bunch. This operation demands that the operator be highly skilled in handling the tool and having enough energy to carry out cutting operation throughout the day.

From inception, bamboo was the common pole used with Malaysian knife for harvesting FFB from tall palms. This is called bamboo- pole- and- knife method (Adetan and Adekoya, 1995). The greater mass and length of poles made harvesting uncomfortable with this method. When trees are beyond 6.5 m in height, pole bending becomes very pronounced. Transportation of long and heavy harvesting poles to, from, and on the field is an onerous task. There is also the accompanying risk of injuring other field workers with the Malaysian knife on a long pole (Adetan and Adekoya, 1995).

Realizing the problem, Malaysian Palm Oil Board (MPOB) developed a motorized bunch cutter (Cantas^{TM}) for oil palms. It has been tested on some plantations in Malaysia and observed to be effective on some palms Abdul Razak et al. (2008). The main objective of this study is to identify how effective the cutter will be on Nigerian plantations and to ascertaining its capacity and limitations.

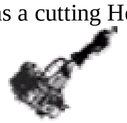
2 Materials and methods

By local practice, harvesting of oil palm is carried out by a crew of three, comprising one bunch and frond cutter who also stacks the cut fronds along the row, one fruit collector who searches for and picks both the fruit bunches and the scattered loose fruits and a transporter who uses a head pan to carry the fruit bunches and the loose fruits to the truck collection centres on the field.

Based on previous work (Adetan and Adekoya, 1995), harvesting of oil palm was broken down into five separate activities which can be classified as: (i) locating, reaching and cutting of the ripe fruit bunches and underlying fronds; (ii) stacking of the cut fronds along the row; (iii) searching for and collecting the cut fruit bunches and the scattered loose fruits from the ground; (iv) transporting the fruit bunches and the loose fruits to the collection centres on the field; and (v) loading the fruit bunches and the loose fruits into vehicles. In this study, data were collected only on the first activity.

Prior to this study, the use of MBH was demonstrated to some farmers on some plantations in Nigeria. The reactions of the farmers indicated willingness to adopt the harvester but its performance needs to be ascertained particularly in comparison with that of the existing pole- and- knife method which many farmers are familiar with. Hence the study was carried out on the oil palm plantations of the Obafemi Awolowo University, Investment Unit, in Ile-Ife, Osun state Nigeria. The farm is a standard plantation and a representation of the farms with palms of moderate heights visited. The heights of the palms are between 0.5 m and 5 m. The height of the each palm was taken before harvesting was carried out. The motorized palm fruit bunch harvester was then used to harvest bunches on each of the palms. The time taken to harvest each palm tree, the number of bunches harvested per tree, and the relative topography of the plantation was all noted. Table 1 shows the features of the two harvesting devices

Table 1 Features of Cantas™ and bamboo pole and knife

Motorized Bunch Harvester	Bamboo Pole and Knife
 It has C-sickle	 It has normal sickle No cutting head
 It has a cutting Head	
 Two stroke petrol engine(fuel capacity = 440 cm^3	No engine is required. Energy required for cutting depends on the strength of the operator.
 Telescopic pole(maximum length= 3.6 m)	 Bamboo pole of length 4 m is used.
Total weight= 7.5 kg	Total weight= 7.0 kg

Time studies (TS) on the two systems (bamboo pole and knife vs. Cantas™ see Figure 1) were carried out to compare the time taken for the cutting operation by the two methods. Specifically, it was the time taken by workers to cut fronds and bunches from one point to another. In the studies, the time was recorded when the worker started cutting from the first palm until the last palm on the row (Figure 2). Referring to Figure 2, the operator would start cutting from point A and finish at point B. At the same time the average height of palm, the number of FFB harvested and total numbers of palms visited were also recorded, being the method first adopted by Abdul Razak et al. (2008).

(a)

(b)

Figure 1 The use of Bamboo pole and knife vs Cantas™ (a)-Cantas; (b) pole-and –knife

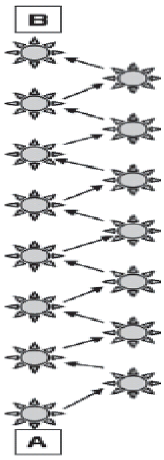


Figure 2 Working procedure of the operator (Abdul Razak et al., 2008)

Both methods were evaluated based on cost, taking into consideration the following parameters:

i. Cost of labour : Locally, harvesters collect wages on a per bunch basis, therefore to know the cost of labour for each day, Equation (1) below was used;

$$C_L = n_b \times W \quad (1)$$

Where C_L = Cost of labour per day

n_b = Number of bunches harvested per day

W = Wage per bunch

ii. Cost of fuel: The motorized harvester has a single-cylinder, spark-ignition engine which runs on a mixture of petrol and oil (petroil). A quarter of a litre of engine oil was mixed with 4 litre of petrol. To determine the cost of fuel, the following Equation (2) was therefore used;

$$C_F = (C_p \times n_p) + (C_e \times n_e) \quad (2)$$

Where C_F = Cost of fuel

C_p = Cost of petrol

C_e = Cost of engine oil

n_p = Number of litres of petrol

n_e = Number of litres of engine oil

The various parameters were evaluated for each method and a comparison was carried out to determine the more effective of the two.

The data collected were subjected to independent t-test to compare difference between harvesting parameters of Motorized- bunch- harvester and Bamboo- pole- and- knife methods. The analysis was carried out through Statistical Analysis Software (SAS, 2002).

3 Results and discussion

The result of Time Study (TS) presented in Table 2 indicates that for bamboo pole and knife method, the average time of harvest per bunch increases as the harvester moves from one block to the other, except at the third and the forth block where it remained constant. The average time of harvest per bunch increases from 1.30 min to 1.40 min as the harvester moved from the first block to the second block. Moreover, it could be observed from Table 2 that as the height of palms increases the time of harvest also increases. This increment in time of harvest could be both due to the fact that the harvester had to exert force and much energy was expended before the harvest was done, and this could be tiresome over time or it could be due to the changes in the height of the palms. The overall average time of harvest per bunch, and the speed of harvest for this method are 1.50 min and 40 FFB/h, respectively. This is very close to the result obtained by Adul Razak et al. (2008), in which the average time of harvest per bunch, and the speed of harvest for manual method are 1.23 min and 50 FFB/h, respectively.

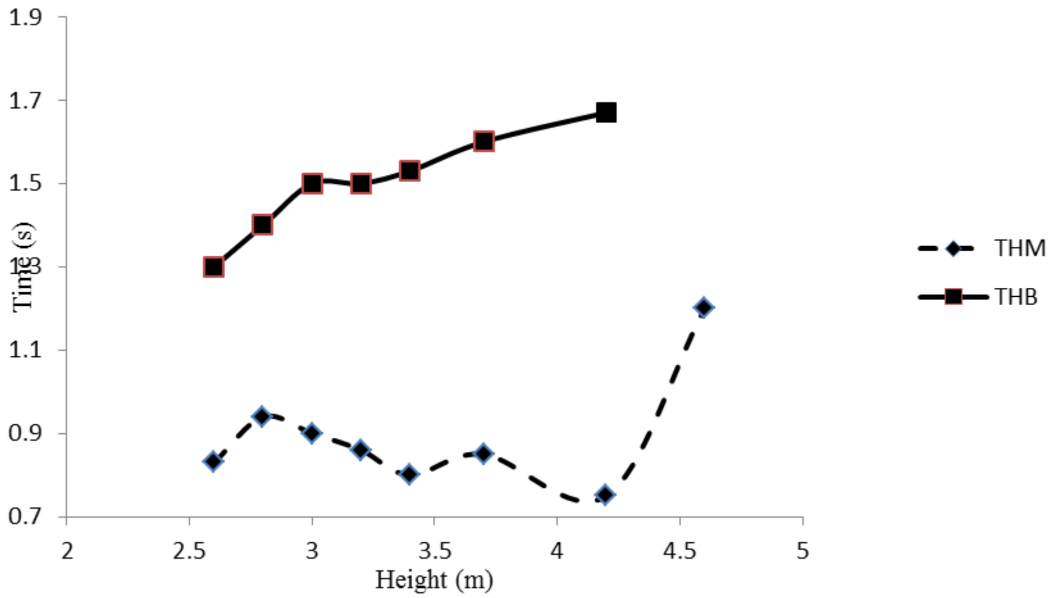
Table 2 Time study on the use of bamboo pole and knife method for harvesting

Time in	Time out	Total time(min)	Average	No of FFB Harvested	No of Palms Visited	Time/FFB (min)
08.00	08.26	26	2.50	20	10	1.30
08.35	09.10	35	2.80	25	10	1.40
09.20	09.35	15	300	10	10	1.50
09.50	10.02	12	3.20	08	10	1.50
10.30	11.16	46	3.40	30	10	1.53
11.20	11.28	08	3.70	05	10	1.60
11.35	12.00	25	4.20	15	10	1.67
Total		167		113	70	
Average	FFB/h=	40				1.50

Table 3 shows the result obtained from the motorized bunch harvester. The overall average time of harvest per bunch, and the speed of harvest for this method are 0.89 min and 66 FFB/h, respectively. This result is also in agreement with the findings of Abdul Razak et al., (2008) which stated average time of harvest per bunch and speed of harvest for motorized bunch harvester, as 0.80 min and 75 FFB/h, respectively. It is generally observed that the time of harvest per bunch decreases as the harvester moves from one block to the other, despite the increase in height of the palms. This is because the bulk of the work was done by the machine. However there is a slight difference in the second and seventh blocks as the time of harvest increases in both blocks. The irregularity or the topography of the field may be responsible for this. Moreover when harvesting palms above 4.5 m in height, it became cumbersome and laborious and time of harvest per bunch increases greatly. The relationship between the motorized and manual harvest is represented by the graph shown in the Figure 3. The average of overall time of harvest per tree for motorized harvester and bamboo pole and knife, respectively, are 98.86 s and 166 s This shows that time of harvest for motorized harvester is over 60 percent lower than time of harvest for bamboo pole and knife. The time of harvest per hectare for both MBH and BPK are approximately 4h/ha and 7h/ha, respectively. MBH could harvest 0.25 ha/h, while BPK could harvest 0.14 ha/h. From Table 4, it could be deduced that the average height of palms harvested is 3.25 m, the average number of bunches harvested is approximately 2 bunches, by each of the methods. Looking at mean of time of harvest for both methods, the difference confirms that motorized bunch harvester (MBH) is better than bamboo pole and knife (BPK).

Table 3 Time study on the use of motorized bunch harvester for harvesting

Time in	Time out	Total time (min)	Average height (m)	No of FFB Harvested	No of Palms visited	Time/FFB (min)
08.00 am	08.25 am	25	2.50	30	10	0.83
08.35 am	08.50 am	15	2.80	16	10	0.94
09.00 am	09.06 am	06	4.60	05	10	1.20
09.15 am	09.33 am	18	3.00	20	10	0.90
09.45 am	09.58 am	13	3.20	15	10	0.86
10.10 am	10.18 am	08	3.40	10	10	0.80
10.25 am	10.31 am	06	3.70	07	10	0.85
10.40 am	10.46 am	06	4.20	08	10	0.75
Total		97		108	80	
Average		FFB/h =	66			0.89



THM: time of harvest for motorized. THB: time of harvest for bamboo pole

Figure 3 The relationship between the motorized and manual harvest methods

From the result of statistical analysis between bamboo pole & knife (BPK) and motorized bunch harvester (MBH) shown in Table 5, the effect of height and number of bunches harvested were not significant. However, the effect of time of harvest was significant.

The means of these dependent variables (height, no of bunches, and time of harvest) were also compared; this is shown in Table 4. The Table confirms that there is no significant difference in both heights and number of bunches.

Table 4 Comparison between motorized harvester and bamboo pole & knife

	Average	
Dependent Variables	**MBH**	**BPK**
Height, m	3.2542	3.2483
No of Bunches	1.8814	1.8833
Time of Harvest, s	98.86	166.93

Note: MBH --- Motorised harvester method BPK --- Bamboo pole & knife method.

Cost of harvesting

The cost of harvesting FFB on a farm is always calculated on a per bunch basis. For the BPK method, the cost of labour was determined by the number of bunches harvested. The existing charge per bunch by the local harvesters is ₦50. A total of 113 bunches were harvested using the BPK; therefore, the cost of harvest of the fifty palm trees tested is as Equation (3):

Table 5 Statistical analysis of comparison between motorized bunch harvester and bamboo pole & knife

Dependent Variable	Source	DF	S of Square	M of Square	F Value	Pr > F
Height	Mechanism	1	0.00103691	0.00103691	0.00	0.9536
	Error	117	35.75627401	0.30560918		
	Corrected Total	118	35.75731092			
Bunches	Mechanism	1	0.0001163	0.0001163	0.00	0.9915
	Error	117	120.3528249	1.0286566		
	Corrected Total	118	120.3529412			
	Mechanism	1	137833.2842	137833.2842	26.13	<.0001
	Error	117	617098.6486	5274.3474		
	Corrected Total	118	754931.9328			

$$C_L = n_b \times W \quad (3)$$

Where C_L = Cost of labour

n_b = Number of bunches harvested = 113

W = Wage per bunch = 50

Thus the cost of labour C_L = ₦ 5,650

This implies that the cost of harvest of fifty palms using the Malaysian knife is ₦ 5,650.

While for the MBH, the harvester is assumed to be provided by the farm owner and he bears the running cost of the harvester. A total of 108 bunches were harvested using the motorized harvester and the wage per bunch using the harvester is less due to the reduction in the time and energy required to harvest. The wage per bunch is ₦30; the cost of labor therefore is as Equation (4):

$$C_L = n_b \times W \quad (4)$$

Where C_L = Cost of labour per day

n_b = Number of bunches harvested = 108 bunches

W = Wage per bunch = 30

Thus the cost of labour C_L = ₦ 3,240

The motorized harvester runs on a petrol engine and therefore cost is also incurred on fuel. The cost of fuel is calculated using the Equation (5) below;

$$C_F = (C_p \times n_p) + (C_e \times n_e) \quad (5)$$

Where C_p = Cost of petrol = ₦ 87/L

C_e = Cost of engine oil = ₦ 350/L

n_p = Number of litres of petrol = 1.67 L

n_e = Number of litres of engine oil = 0.064375 L

C_F = Cost of fuel = ₦ 167.82

Total cost of operation of harvesting with the Motorized bunch harvester is therefore; the sum of the cost of labor and cost of fuel is as Equation (6):

$$C_T = C_L + C_F \quad (6)$$

C_T = ₦ 3,407.82

The total cost of harvesting operation carried out on 50 palms is ₦ 3,407.82. The cost of harvesting one hectare of land using the motorized harvester is ₦ 10,223.46, while that of the Malaysian knife is ₦ 16,950. This shows that the cost of harvest per hectare using the motorized harvester is over 60 per cent cheaper than using the bamboo pole and knife.

4 Conclusions

The study undertook a comparative evaluation of two methods of harvesting oil palm fruit bunches, namely, the use of the existing bamboo-pole- and- knife and the emerging motorized- bunch- harvester on a standard oil palm plantation with trees of moderate heights. The study revealed that the motorized bunch cutter method is faster, time- saving, energy- conserving and cost-effective when compared with the bamboo- pole- and-knife method. The maximum and the minimum heights that motorized bunch cutter could harvest conveniently are 4.5 and 2.5 m, respectively. The time of harvest per hectare for motorized- bunch- harvester and bamboo-pole –and- knife are approximately 4h/ha and 7h/ha, respectively. In terms of field capacity the motorized system could harvest 0.25 ha/h while the bamboo-pole-and-knife could harvest 0.14 ha/h. On the overall the motorized- bunch- cutter was found to be better than bamboo- pole- and -knife. Though the motorized system could only harvest conveniently oil palm as high as 4.5 m, it may not be adapted to many oil palm plantations in Nigeria where palms as high as 20 m are still considered productive and maintained. Hence, it is recommended that research should be carried out, such that the motorized –bunch- cutter could be adapted to harvesting taller Nigerian palms

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