Technical and Economic Evaluation of a Mechanical Cassava Harvester in Busia County of Kenya

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Citation: Njue R, Maingi S, Wawire N, Bett C. (2023) Technical and Economic Evaluation of a mechanical Cassava harvester in Busia County of Kenya. FARA Research Report *Vol 7(13):120-127*.
https://doi.org/10.59101/frr072313

Abstract
Cassava harvesting is the most challenging operation across the entire value chain. It is done manually, making it tedious, costly and time-consuming especially if the plantation is medium to large scale where manual work may take some time. Currently, there is no known harvester in Kenya to address this gap. Hence, the Kenya Agricultural and Livestock Research Organization (KALRO) collaborated with Agricultural Technology Development Centre (ATDC) in Siaya County to design and fabricate a mechanical cassava harvester. To validate the harvester its performance was assessed in comparison with the manual methods, in Busia County. Data on the area harvested, time taken, working depth and broken tubers were collected from the demo plots to achieve the parameters for the two harvesting methods and comparisons were made drawn from the averages. Comparatively, the mechanical harvester took 1.28 minutes while manual harvesting took 9.53 minutes to harvest an area of 62.4m². The working depth of the harvester was almost uniform (22cm) signifying that the soil type in the three plots was identical. In terms of post-harvest losses, the manual method was inferior with the 13.6% broken roots against the harvester's 7.07%. The harvester performed better in cassava planted in ridged rows. A comparative cost-benefit analysis for the mechanical harvester showed that its gross margin was (Ksh 31,490) per acre and was relatively higher than manual harvesting (Ksh. 21,000 per acre). Thus, if the mechanical harvester is adopted it could save farmers time, and cost of labour, reduce drudgery and increase income.

1. Introduction

Cassava harvesting being the most difficult operation across the entire value chain is done manually in Kenya. This work is tedious, costly and time consuming especially if the plantation is medium to large scale where manual work may take some time. This makes the cassava tubers to deteriorate as they have a short post-harvest lifespan of up to 4 days owing to the fact that they are highly perishable (https://www.fao.org; Masamba, *et al* 2022). Therefore, harvesting should always be timely and properly done to avoid destroying the crop and increasing losses that arise from breakage of the roots. Cassava is mostly harvested by lifting the lower part of stem and pulling the roots out of the ground, then removing them from the base of the plant by hand (Amponsa, *et al* 2017). The upper parts of the stems with the leaves are removed before harvesting. Hoes and machetes are the tools used to assist in this manual harvesting. In most parts of Kenya especially the western part, cassava has increased demand as a subsistence crop for home consumption as well as commercial for rural and urban markets (FAO, 2015). This increase in demand calls for more crop hence high manual labour required which comprises of women and youth. Currently, there is no known mechanical harvester in Kenya to address this gap. This calls for an intervention to address these constraints. To address this gap, the Kenya Agricultural and Livestock Research Organization (KALRO) in collaboration with Agricultural Technology Development Centre (ATDC) of Siaya County designed and fabricated a mechanical cassava harvester (Figure 1). This was made possible through funding from International Development Research Centre (IDRC) market driven agri-mechanization solutions for small holder women farmers and youth entrepreneurs project.

2. Methodology

2.1 Study site

The study was conducted in Aten, Munongo and Tangakona commercial villages in Busia County. Busia is situated at longitudes (34.1114620°) E and latitudes (0.40769°) N at an altitude of 1219 m above sea level (https://www.countrycoordinates.com). The study areas are fairly hot (21-23°C) and moist (760 to over 1,750 mm precipitation annually) throughout. The three demonstration plots were established by KALRO-FCI under the agri-mechanization project funded by the IDRC. Data was collected from the demo plots so as to achieve the parameters for the two methods of harvesting (mechanized and manual). The data collected was then compared for the two types of harvesting and conclusions made. The details of experimental methodology and measurement techniques adopted during the research were described in different sections as below.

2.2 Setting up demonstration Plots

The cassava crop was planted and raised as per recommended agronomic practices in the demo plots. The crop was grown in rows and ridges of a height of about 0.3m and spaced between 1metre crest to crest to allow for ease of movement of the back pack weeder and tractor during weeding and harvesting operations. The demonstration plots were of size 26m by 38m (Aten) 26m by 38m (Munongo) and 16m by 43m in (Tanga Kona) in Busia County.

Figure 1.The developed mechanical cassava harvester

2.3 Performance evaluation of the cassava harvester

2.3.1 Technical Evaluation

The cassava plants were first coppiced to stock level of about 30cm prior to harvesting to allow the tractor operator's clear view. The field was made free from hidden weeds and obstructions like rocks or roots stumps which would interfere with tubers and cause undue breakages. Using a machete, the tubers were detached from the clusters and manually collected, sorted to set aside broken tubers and weighed.

2.3.2 Actual test operation

The harvester was drawn by a 55 horse power tractor. The harvester was hitched to the tractor's 3- point linkage system. The top link was then adjusted in order to obtain the desired depth of penetration when working in the soil. The harvester was then drawn by the tractor along the rows and it loosened the cassava root clusters and lifted them up to about 30cm. The time taken to harvest each test row was recorded using a stop watch and the total area harvested for comparative data was 62.4m². Data was also collected to calculate the harvester's efficiency, the time taken, fuel consumed and the area covered. Sorting of the cassava tubers was done at the end of each test and the weights recorded. The weight of whole tubers was also recorded and the percentage of broken tubers calculated. For performance comparison, the harvester was tested on cassava planted on flat land (non-ridged). The time taken to harvest one row, weight of broken tubers, weight of whole tubers, fuel consumed was recorded and the percentage of broken tubers calculated. The harvester's working depth was measured in every row using a steel rule and recorded. The traditional methods of harvesting cassava were put into consideration by selecting a youth, male and female at random. Equal measurements of test plot rows covering an area of 62.4 m² were assigned and the time taken to complete the task was recorded using a stop watch. The weight of broken tubers and that of whole tubers for each gender was recorded and the percentage broken calculated. Comparison on time taken and the percentage broken based on gender was done.

2.4 Economic evaluation

To compare the benefits and costs of the technologies being disseminated a simple gross margin analysis was undertaken when the cassava harvester was used and compared with the human circumstances. Gross margins are total sales (revenue) minus the total variable costs of producing the goods. Data used for the gross margins was obtained from on-station and on-farm experiments and included yields, farm operations and their costs, cost of inputs and product prices. All the yields were considered in the calculation irrespective of whether it was sold or consumed. Similarly, all the labor was costed including family labour. The prices used were the farm gate prices. A simple design used was the establishment of two experiments, one with the technology and the other without the technology. Data was collected on the cost of conventional (manual/ without the technology) versus the improved (mechanized) operations.

3 Results and Discussion

3.1 Performance evaluation on the demonstration plots

The average time taken to coppice the cassava stems to a stock level of 30cm in one row was 2.04 minutes, while that of removing the stems from the field was 4.31 minutes as shown in Table 1.

Table 1: Average time taken to coppice and remove the cassava stems in respective plots

Plot	Time taken (min) to cut the stems	Time taken (min) to remove the stems
Aten	2.04	4.31
Munongo	3.24	5.23
Tangakona	2.86	4.09

From the area harvested, the average time taken in minutes and working depth in cm was presented in Table 2.

Table 2. Average Time taken in minutes and the working depth

Demonstration plot	**Average working depth (cm)**	**Average time taken by harvester (min)**
Aten	22	6.5
Tangakona	23	4.81
Munongo	22	6.39

From the results in Table 2, the harvester took an average of 6.5 minutes to harvest an area of 200m² in Aten and 4.81 minutes in Tanga Kona and 6.39 minutes in Munongo. Each test was for the same area. The average working depth of the harvester was almost uniform signifying that the soil type in the three plots were identical.

3.1.2 Harvested weights, broken weights and the percentage broken per plot.

The harvested clusters were collected, and the tubers detached. Sorting of the tubers was done to remove the broken ones and the weights for the three plots were as shown in Figure 2.

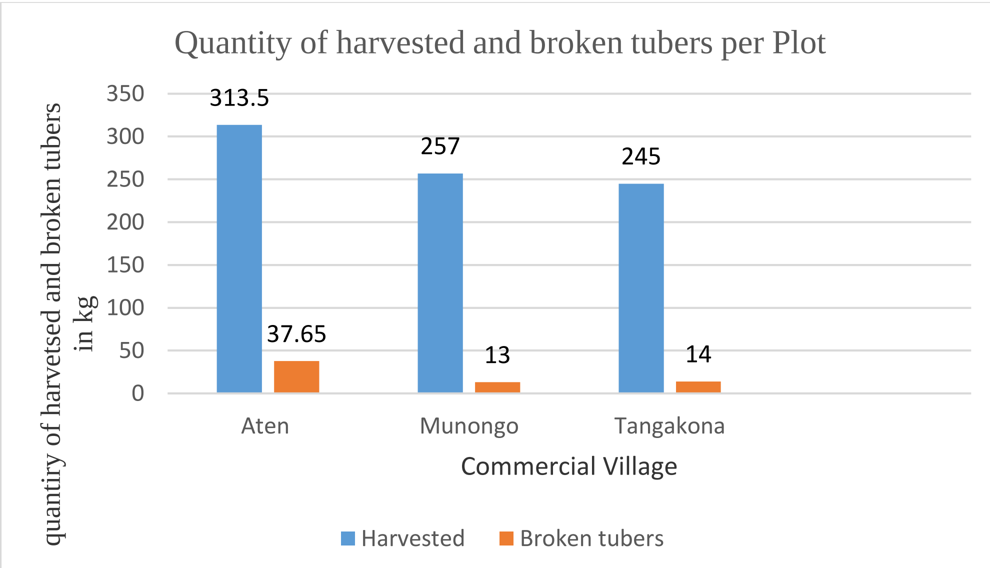

Figure 2. Harvested weights, broken weights and the percentage broken per plot

From figure 2, Aten had the highest yield as compared to the other plots. In this case, all the agronomical practices were followed and weeding was done at the right time. However, the plot had the highest quantity of broken tubers at 37.65 kg because it was the first plot to be tested on harvesting and the tractor operator didn't have experience on its usage and therefore was not well conversant with the necessary settings for optimal results. The same operator was used in the other two plots and the percentage broken was significantly low compared to Aten.

3.1.3 Harvester performance across the demo plots

The harvester performance across the demo plots was as in Table 3. The average time taken to harvest equal plot sizes was higher in Aten as compared to the other two. This owes to the reason given in the section on harvested weights per plot above. From the fuel consumption per acre and the time taken, it can be deduced that the harvesting task using the developed mechanical cassava harvester was not demanding a lot of power from the tractor.

Table 3: Harvester performance across the demo plots

	Working depth(cm)	Time taken(min)	Field capacity(ha/h)	Fuel consumption(ltr/acre)
Aten	22	6.5	4.74	0.538
Tangakona	23	4.81	4.62	0.624
Munongo	22	6.39	4.79	0.589

The obtained parameters were in agreement with Amponsah *et al* 2014 findings of working depth of 23cm and field capacity of 4.81 ha/h.

3.1.4 Comparison of the percentage broken tubers across the gender and the harvester,

The results (Figure 4) for the manual harvesting disaggregated by gender versus use of the harvester show that the youth had the highest percentage broken tuber at 28.2%, 16.6 % and 12.7 % in the three plots respectively while the female had the least at 2.63 %. This demonstrated the experience and expertise women had in cassava harvesting compared to the other gender and the youth.

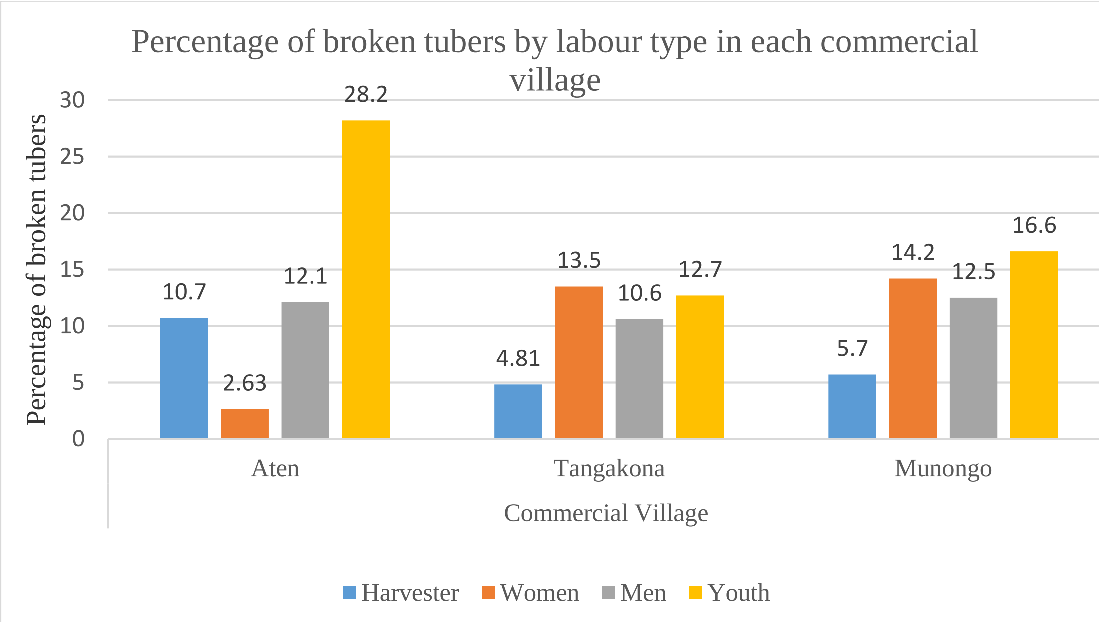

Figure 3: Comparison of the percentage broken across the gender and the harvester

Using an area of 62.4 m^2 the for comparative data results showed that, the total time taken to harvest manually was on average was 9.53 minutes with an average broken tuber of 14.3%. For the mechanical cassava harvester, it was observed that it took an average of 1.28 minutes with 7.07% broken tubers. From the results it was observed that the mechanical cassava harvester saved the farmer's time, cost of labor and reduced the drudgery associated with traditional manual harvesting of cassava tubers.

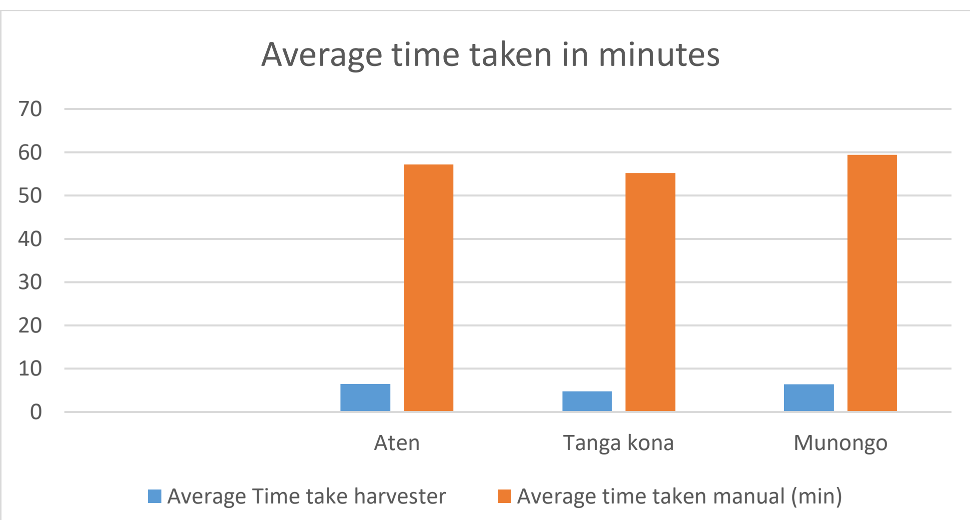

Figure 4. Comparative average time take using both methods of harvesting

Further, the harvester saved the crops post-harvest losses by having a lower percentage of broken tubers compared to using traditional manual methods of harvesting.

3.2 Performance evaluation on flat land (non- ridged)

For performance comparison between the ridged and non-ridged plots, the harvester was used to harvest cassava planted on a flat non ridged rows plot. The same procedure used on the field planted in ridged rows was replicated. The time taken to coppice and remove the cassava stems in one row per plot was as shown in table 4.

Table 4: Average time taken to coppice and remove the cassava stems in respective plots

Plot	Time taken (min) to cut the stems	Time taken (min) to remove the stems
Aten	2.10	5.21
Munongo	3.65	5.83
Tanga kona	2.97	4.84

Compared to the ridged plots, it can be observed that it took more time to coppice and remove the cassava stems from the non- ridged plots. The rows in the non-ridged field were not uniformly spaced. From the five rows harvested, the time taken in seconds and depth working depth in cm is presented in Table 4.

Table 5: Average Time taken in minutes and the working depth

Demonstration plot	Average working depth (cm)	Average time take harvester (min)
Aten	23	4.96
Tangakona	23	4.89
Munongo	22	6.49

The harvested clusters were collected, and the tubers detached. Sorting of the tubers was done to remove the broken ones and the weights of the whole and broken percentage were in Figure 5.

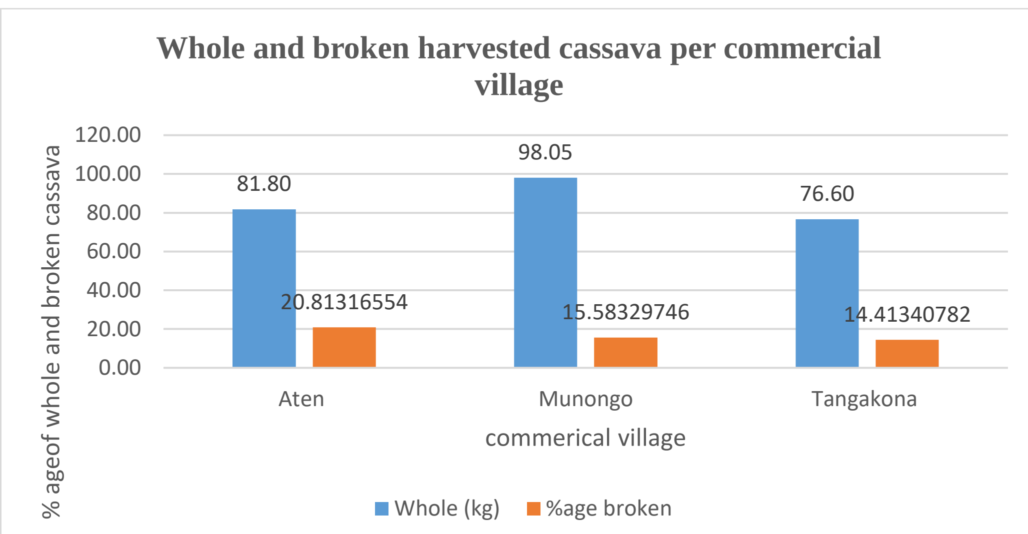

Figure 5. Whole and broken harvested cassava per commercial village

It was observed that the percentage broken tubers across the non-ridged plots was higher (16.9 %) in non-ridged than in ridged ones (7.07%). This therefore indicated that the harvester performed better in cassava planted in ridged rows.

3.3 Economic evaluation

Two simple experiments were set, where one area of mature cassava was harvested mechanically while the other were harvested manually using labour of different gender, female and youth farmers. Results reveal that using a cassava harvester increases yield and reduces labour costs resulting in a positive net change in profit (Table 6). The gross margin for cassava harvesting (Ksh 31,490 per acres is relatively bigger that manual harvesting (Ksh21,000/ per acre)

The benefits of using the cassava harvester included the following:

i. Increased yield because harvester removes all the roots
ii. Improved quality of the roots due to minimal breakages and reduced wastage that results when piecemeal harvesting is adopted.
iii. Saves on time which can be used to perform other activities
iv. Saves on labour cost because when you use harvester you need only 3 people while manual harvesting you need 15 man-days

Use of a cassava harvested, however, has some disadvantages (costs) that include:

i. Increased maintenance costs
ii. Cost of marketing - produce must be taken to the market immediately as opposed to piece meal harvesting
iii. Food security aspect of the crop of being available throughout the year reduced due to wholesome harvesting.

Despite some of the disadvantages, the use of a cassava harvester, is recommended for use by farmers because the benefits outweigh the costs as seen in the positive net change in profit.

Table 6. *Comparative benefit cost analysis for the use of the cassava harvester and conventional* ***methods in the cassava value chain***

A)Use of cassava harvester for harvesting					**b) Use of manual labour for harvesting**				
Enterprise output	**Unit**	**Quantity**	**Price**	**Total revenue**	**Enterprise output**	**Unit**	**quantity**	**price**	**total revenue**
Yield	kg/Acre	4000	10	40,000.00	yield	kg/Acre	2500	10.00	25,000.00
VARIABLE COST Intermediate Inputs					**VARIABLE COST Intermediate Inputs**				
fuel (litres)	Litres	10	101	1,010.00	Labour for harvesting	Mandays	8	500	4000
Maintenance costs		1	7500	7,500.00					
Total Variable costs				**8,510.00**	**Total Variable costs**				4000
Gross Margin				**31,490.00**	**Gross Margin**				21,000

4. **Conclusions and recommendations**

The mechanical cassava harvester performed better with lower percentage of broken tubers on ridged cultivated rows than in non-ridged. Ridged rows cultivation was recommended for better results. Farmers were advised to adopt the spacing of 1.4m by 0.7m for better orientation of the tractor. The harvester saved farmers time, cost of harvesting and post-harvesting losses resulting from low percentage of broken tubers as compared to traditional methods and was recommended to the farmers in the County.

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