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On Farm Demonstration, Testing and Evaluation of Maize Sheller in Meru County

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Abstract: Maize shelling activity by the small scale farmers is done manually by either stripping with fingers, beating bagged cops with sticks or rubbing two cobs against each other. Shelling forms part of maize post-harvest losses which span from harvesting to consumption. The objective of this research was to demonstrate, test and evaluate the maize shellers in Meru County. The scope applied to one diesel (control) and three locally fabricated gasoline-powered throw-in type maize shellers and was performed on-farm at three different commercial villages (CVs). Traditional methods of shelling were compared to motorized shellers followed by the comparison between the 8 horsepower (hp) diesel (control) and 5 hp locally fabricated gasoline-powered shellers. The average shelling capacity (1,384 kg/h) and shelling efficiency (97.8%) of the locally fabricated shellers were lower as compared to the control (2,138 kg/h) with a shelling efficiency of 99.93%. The average scattering losses for the locally fabricated shellers were high (12.6%) compared to the control (0.053%). The analysis of variance (ANOVA) revealed control had the highest mean (9.23) and p value > 0.05 hence more efficient compared to locally fabricated (9.15). The shellers lacked the cleaning component, hence shelled maize required cleaning by winnowing manually and were not gender friendly since women and people enabled differently (PED) could not operate the machine due to height of the feeding hopper compared to control. It took traditional methods longer (59.4 s) to perform a shelling operation compared to using motorized shellers (15 s). The efficient control sheller demonstrated reduced farmers' drudgery and post-harvest losses and was recommended for use by the small scale farmers in the county.

Key words: Shelling, fabricated, traditional, horsepower, farmers.

1. Introduction

Maize (*Zea mays)* farming in Kenya dates back to the late 19th century and was adopted as a staple food crop by Kenyans from 1900-25. Maize which is a cereal crop is grown throughout the world with the United States, China and Brazil being the top three maize producing countries in the world with production estimates of 563 of the 717 million metric tons per year [1]. In Africa, maize production was estimated at 75 million tons in 2018 representing 7.5% of the world's production [2]. In Kenya, the production is at around 3 million tons per year [3] with small scale farmers contributing about 70% [4]. Maize grains have great nutritional value as they contain 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3.0% sugar, 1.7% ash [5] and Vitamins B-complex, A, C, and K together with beta-carotene, selenium and potassium which is a major nutrient present in maize with diuretic properties [6]. It is the main staple food crop in Kenya accounting for nearly 40% of cultivated area and forms 2.4% of Kenya's gross domestic product (GDP) and 12.65% of agricultural GDP [7] and its consumption is estimated at 88 kg/capita/year [8].

Maize shelling activity by the small scale farmers is done manually by either stripping with fingers, beating bagged cops with sticks where shelling 1 bag takes 8 h of a woman's time or rubbing two cobs against each other (shelling only a few kilograms per hour) [9]. Small tools often made by local artisans are sometimes used. With these tools, a worker can shell 8 to 15 kg/h [9]. Women, who already have significant duties in agricultural production, water collection,

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child-rearing and cooking tend to be responsible for these labor-intensive tasks [10]. All these methods are tedious, inefficient, labour intensive and slow with a few kilograms per hour output. The shelled maize from these methods is usually contaminated thus reducing the value of the grain and shelf live, mixed with broken cobs and grains which increases the post-harvest losses and affects the health of consumers. According to Eduardo *et al*. [11] broken maize grains enhance aflatoxin contamination levels. As mentioned by Tekeste and Degu [12], maize shelling is one of the main problems encountered by farmers in maize production and post-harvest handling. This problem may be solved by the use of motorized maize sheller.

According to Food and Agriculture Organization of the United Nations (FAO) [13] report on maize in human nutrition, maize is harvested when its moisture content is in the range of 18 to 24% and damage to kernels is related to moisture content at harvest, the lower the moisture content the less the damage. Further, the effective shelling capacity increases with an increase of the sheller's cylinder speed but decreases with the increase of the moisture content [14]. This makes the shelling cost to increase with the increase in moisture content. Salih [15] in his study on factors affecting the threshing machine types settled for 15% as the significantly superior level of moisture content.

Motorized maize shellers were first introduced in Nigeria in 2002 and Uganda in 2012 [16]. In Kenya, the introduction of powered maize sheller has been one of the newest technologies in the country and the technology has been adopted by most of the small scale farmers in the region. With the shellers being fabricated by the local (*Jua kali*) artisans there is need for the government agencies to come up with better ways of protecting the production of the machine. This can be achieved by testing and evaluation of the machine to produce standard products and design parameters for uniform fabrication and shelling results geared towards reduced drudgery and post-harvest losses. The testing and evaluation was performed on-farm to access different machines available in the market and demonstrate to the farmers their performance. Testing in which the engineering parameters are determined is essential to assess the functional handling and performance characteristics, suitability under varying conditions and establishment of performance data [17].

The overall objective of the research work was to test and evaluate the maize sheller in Meru County and the specific objectives were:

- To determine the shelling and cleaning efficiency of locally fabricated motorized sheller and diesel-powered one (control);
- To determine the percentage loss, percentage grain damage and quantity of chaff of the locally fabricated shellers and the control, based on the moisture content of the grains;
- To determine the fuel consumption of the locally fabricated shellers and control in litres per hour for the testing period.

2. Methodology

The scope of this testing and evaluation applied to one stationary diesel and 3 other gasoline-powered throw-in type maize shellers and they were performed on the farm at three different commercial villages (CVs) (Marega, Kimachia and Konju) in Meru County.

2.1 Description of the Maize Sheller

2.1.1 Diesel Powered

The sheller used was initially made by ZhengZhou machinery equipment (Model MX 1200, Henam Vanmay Industry Company limited, China), for shelling maize. The indicated average capacity of the maize sheller was 2,000 kg/h, with shelling efficiency of 98.3%. The sheller used 8 horsepower (hp) diesel engine and the speed of the main shaft was 900-1,000 rev/min. The weight of the sheller was 70 kg and its dimensions were 1,010 × 580 × 1,000 mm. The main components of the sheller included: feeding hopper, shelling drum with perforated concave, blower, grain discharging auger, power transmission system and diesel engine. The sheller was operated on the principle of axial flow movement of material. Shelling was done by the impact between a high-speed cylindrical drum and a perforated concave, equipped with three radial arranged bars at 120° along the axis mounted on its periphery. At the one end of the cylindrical drum, the profile of the radial bars was changed to eject the shelled cob through the shelled cob outlet. The shelled grain and fine chaff passed through the perforated concave and the air coming from the blower removed the chaff and other lighter materials. The clean grain fell to the lower chamber, and the grain discharging auger moved it through the outlet. The sheller operation required a total of 1 operator and 2 assistants. The 2 assistants were required to feed the hopper with unshelled cobs, 1 operator to work on the grain outlet, and the cob outlet side. The sheller is as shown in Fig. 1.

Fig. 1 Diesel power maize sheller (control).

2.1.2 Locally Fabricated Gasoline Powered Sheller

The sheller was locally fabricated and the prime mover was a 5.5 hp gasoline engine. The shelling capacity and efficiency were not indicated on the machine and therefore not known. The weight of the sheller was 85 kg and the dimensions were 1,200 × 700 × 1,200 mm. The main components were the feeding hopper, perforated concave shelling drum with, power transmission system and a gasoline engine. The sheller's principle of operation was axial flow movement of material and the shelling was achieved by impacts between a high cylindrical drum and a perforated concave equipped with three welded radial bars at 120° along the axis mounted on the periphery. At one end of the cylindrical drum, the profile of the radial bars was changed to eject the shelled cob through the shelled cob outlet. The clean grain fell to the lower chamber, and the grain discharging auger moved the grain through the outlet. The sheller is as shown in Fig. 2.

Fig. 2 Locally fabricated maize sheller.

2.2 Testing of the Shellers Preliminaries

Before any test work began, the operator and his assistant familiarized themselves with the manufacturer's specifications detailed in the manual and safety issues. The machine was then operated under a no-load condition for more than 1 h to enable the operator to familiarize himself with the machine and make observations on ease of feeding, start/stop and other control knobs, operation and outlet arrangements. This also ascertained the smoothness of operating parts. At this stage, the observation was made on aspects of repairs, adjustments and ease of material flow through the machine. The operator then took note of the type of drive train and transmission systems, details of feeding arrangements, and shelling unit, type and number of sieve, details of fans and blower, type of elevator, method of transport and safety arrangements of all the machine's revolving parts.

The testing of the machine was preceded by cleaning the surface where it was operated on and arranging the sackcloth to receive the shelled maize. Sufficient quantities of dry maize were provided to carry out the complete test series. Samples were taken from each batch and the following were specified:

(a) moisture content;

(b) percentage damage of grains.

2.3 Shelling Performance

The shelling performance was carried out in three different locations (Kagaene, Konju and Marega) in Meru County at Tigania East and Central sub-counties.

Weighed bunches of dry maize (50 kg) were divided into ten (5 kg) samples after determination of the moisture content. The performance tests were carried out at various engine shelling speeds of 1,000 rpm and 900 rpm. With constant mass input of 5 kg the overall results obtained were recorded as follows:

(a) shelling efficiency;

(b) percentage of damaged seed;

(c) percentage of blown seeds;

(d) percentage of seed loss and throughput capacity.

The cleaning efficiency was expected to decrease as the engine speed increased at the ideal moisture content of 15%. The test runs were for the 30 min duration and were carried out using 2 different sheller speeds, during this test period, samples of shelled grain, straw and chaff were taken at their respective outlets. The time over which the sampling was done was recorded. Any time of the stoppage was recorded with total testing time. Observations on factors affecting the operation of the machine were recorded together with any adjustments and repairs. At the end of the test, the machine was operated idle for 2 to 3 min to clear residue from the outlet. The traditional methods of shelling (beating bagged cobs with sticks) were also considered where three categories picked at random (woman, man and youth) were allocated batches of 5 kg and the time taken to shell was recorded. The tests using the locally fabricated sheller and the control sheller were replicated in the three CVs of Konju, Kagaene and Marega.

The test parameters were as follows:

- shelling efficiency (SE);
- shelling capacity (SC);
- cleaning efficiency (CE);
- time taken in one activity (T);
- percentage of grain damage (GD);
- percentage scattering loss (SL);
- fuel consumption (FC);
- quantity of chaff in the shelled maize (KC).

These parameters were obtained after recording the following measurements:

- the feed rate of cobs in kilograms per unit time;
- weight of the shelled grains at all outlets per unit time;
- weight of grain and residue mixture per unit time;
- weight of the shelled and unshelled grains at cob outlet per unit time.

The measurements were obtained using the following:

- digital weighing balance of 0-40 kg with an accuracy of ± 0.001 kg to measure grain and cob samples before and after shelling;
- graduated cylinder with an accuracy of ± 1 mL to measure the quantity of fuel added. The fuel consumption was measured by filling the engine tank at the start and end of each shelling period.
- stopwatch to measure the time taken.

For ease of calculations, the following abbreviations were adopted:

W_a = weight of the shelled grain per unit time at all outlets;

U_g = percentage unshelled grain;

W_u = weight of the unshelled kernel;

W_m = weight of the shelled grain per unit time at the main outlet;

W_r = weight of grain and residue mixture per unit time at the main outlet;

G_d = percentage grain damage;

W_d = weight of the damaged grain;

W_c = weight of the grain collected at dust and cob outlet;

TWK = total weight of kernel fed into the hopper;

W_{ch} = weight of the chaff;

Q_f = the amount of fuel in litres;

T = time taken to shell maize cobs.

Calculated parameters using Tekeste and Degu [12], and Smith *et al.* [17] were as follows:

$$SC = W_a/S_t \quad (1)$$

$$SE = 100 - U_g(\%) \quad (2)$$

$$U_g = (W_u/TWK) * 100 \quad (3)$$

$$CE = (W_m/W_r) * 100 \quad (4)$$

$$G_d = (W_d/W_m) * 100 \quad (5)$$

$$SL = (W_c/TWK) * 100 \quad (6)$$

$$FC = Q_f/T \quad (7)$$

$$KC = (W_{ch}/W_m) * 100 \quad (8)$$

In total, for three CVs, 6 tests were performed using the 5.5 hp locally fabricated sheller and control. For comparison, each test was performed and recorded separately. A sample size of 5 kg was used for each test and the starting and stopping times recorded using a stop watch. The feed rate in kg/h and the quantities of shelled samples in kg from the main grain outlet and chaff outlet were recorded. The unshelled cobs, shelled grains after winnowing and weight of chaff after sieving manually were recorded.

3. Results and Discussion

3.1 Marega, Kimachia and Konju CV

The demonstration, testing and evaluation shelling performances were carried out using the locally fabricated gasoline 5.5 hp motorized sheller, diesel powered 10 hp sheller fitted with chaff blower (control) and traditional methods of beating bagged cobs with sticks. The shelling parameters were analyzed under the moisture content of 12.3 (Marega), 14.75 (Kimachia) and 11.75 (Konju). The data obtained were recorded as shown in Table 1.

The data obtained in Table 1 were used to calculate evaluation parameters result for the 5.5 hp locally fabricated sheller in the 3 CVs and the results were as shown in Table 2.

For performance comparison, the same tests were replicated using the 8 hp diesel powered (control) sheller fitted with a chaff blower and the results were as recorded in Table 3.

Using the values obtained from Table 3, the calculated parameters results for the control sheller were as shown in Table 4.

After running the two tests, farmers were requested to perform the shelling using the convention method of beating bagged cobs with sticks. One male, female and youth were selected at random and the time taken to perform task for each of them was recorded. The data collected were as recorded in Table 5.

The average results figures obtained in Table 5 indicated that the male had the highest average shelling efficiency (93.8%) followed by female (93.4%) and then the youth (92.4%).

Table 1 Test data sheet—Marega, Kimachia and Konju commercial village (CV) using 5.5 hp gasoline motorized sheller.

Quantity of samples, kg	Marega	Kimachia	Konju
Moisture content	12.3	14.72	11.75
Main grain outlet	49.26	49.75	52.8
After winnowing	46.9	45.72	50.9
Chaff after winnowing manually	2.36	4.08	1.9
Chaff outlet	11.93	7.77	6.83
Unshelled cobs	4.46	0	0
Time taken in seconds	106.7	134.87	164.66

Table 2 Calculated parameters results for 5.5 hp gasoline locally fabricated sheller in the 3 CVs.

Measure	Symbol	Units	Marega	Kimachia	Konju
Moisture content	MC	%	12.3	14.7	11.75
Shelling capacity	SC	kg/h	1,698	1,881	1,541.8
Cleaning efficiency	SE	%	78.2	79.41	85.35
Percentage of grain damage	G_d	%	0	0	0
Percentage scattering loss	SL	%	17	11.1	9.75
Quantity of chaff in the shelled maize	KC	%	4.79	8.19	3.22
Unshelled grains	U_g	%	0.22	0.22	0.22
Fuel consumption	QT	L/h	6	4	4.3

Table 3 Test data sheet—Marega, Kimachia, and Konju CV using 8 hp diesel motorized sheller.

Quantity of samples, kg	Marega	Kimachia	Konju
Main grain outlet	55.68	65.71	65.61
After sieving	55.62	65.65	65.57
Chaff after sieving manually	0.055	0.05	0.05
Chaff outlet	0.03	0.045	0.042
Unshelled cobs	0.155	0.2	0.2
Time taken in seconds	102	102	129

Table 4 Calculated parameters results for the control sheller.

Measure	Symbol	Units	Marega	Kimachia	Konju
Moisture content	MC	%	12.3	14.72	11.75
Shelling capacity	SC	kg/h	1,988	2,473	1,955
Cleaning efficiency	SE	%	100	99.94	99.94
Percentage of grain damage	G_d	%	0	0	0
Percentage scattering loss	SL	%	0.04	0.06	0.06
Quantity of chaff in the shelled maize	KC	%	0.098	0.098	0.098
Unshelled grains	U_g	%	0.22	0.06	0.28
Fuel consumption	QT	L/h	5.35	4.2	3.35

Table 5 Shelling using conventional methods involving both gender and one youth in Marega, Kimachia and Konju CV.

CV	Gender	Time taken	Sample size (kg)	Shelling efficiency (%)
Marega	Male	1:54:00	10	92.4
	Female	2:01:01	10	90.7
	Youth	1:58:00	10	91.8
Kagaene	Male	1:53:00	10	92.7
	Female	1:54:38	10	92.5
	Youth	1:43:04	10	90.7
Konju	Male	1:53:16	10	96.5
	Female	1:34:06	10	97.1
	Youth	2:03:57	10	94.8

Table 6 Summary of test results.

			Test 1		Test 2		Test 3	
Measure	Symbol	units	Locally fabricated	Diesel powered	Locally fabricated	Diesel powered	Locally fabricated	Diesel powered
Moisture content	MC	%	12.3	12.3	14.7	14.7	11.75	11.75
Shelling capacity	SC	kg/h	1,698	1,988	945.9	2,473	1,554	1,955
Cleaning efficiency	CE	%	78.2	99.9	79.41	99.9	85.35	99.93
Percentage scattering loss	SL	%	17	0.04	11.1	0.06	9.75	0.06
Quantity of chaff in shelled maize	KC	%	4.79	0.098	8.19	0.09	3.22	0.098
Fuel consumption	FC	L/h	6	5.35	4	4.2	4.3	3.35
Time taken	T	h	0.0296	0.028	0.037	0.028	0.045	0.035
Shelling efficiency	SE	%	93.6	99.94	100	99.94	100	99.93

3.2 Data Summary—Motorized Shelling

The summary of the test results using the locally fabricated shellers and the control was as recorded in Table 6.

From the above analysis, the average shelling capacity of the locally fabricated shellers was lower (1,384 kg/h) as compared to the diesel powered sheller

Table 7 Analysis of variance (ANOVA).

	Village	Mean		Sheller	Mean						
Variable	CV1	CV2	CV3	5.5 hp	Control 8 hp	d.f.	s.e.	cv%	s.s.	m.s.	*p*
After winnowing	6.616	7.956	8.319	6.834	8.426	36	0.4021	5.3	5.8203	0.1617	0.07
Chaff after winnowing	0.46	0.295	0.137	0.396	0.199	36	0.3124	105	3.51397	0.09761	0.29
Chaff outlet	1.407	0.558	0.491	1.263	0.374	36	0.2074	25.3	1.54883	0.04302	
Duration	17.26	18.63	20.98	19.34	18.57	36	2.248	11.9	181.951	5.054	
Shelling capacity	2,046	1,871	1,750	1,877	1,901	36	463.6	24.5	7,738,193	214,950	
Main grain outlet	6.86	8.03	8.46	7.09	8.48	36	0.716	9.2	18.4695	0.513	
Stopping time	17.26	18.63	20.98	19.34	18.57	36	2.248	11.9	181.951	5.054	
Unshelled cobs	0.319	0.014	0.014	0.213	0.019	36	0.0832	71.8	0.249114	0.00692	

(2,138 kg/h) and the same was observed for the shelling efficiency whose average was 97.8% and 99.93% respectively. From the comparison of the results, the following points were observed.

- The locally fabricated shellers lacked the cleaning components, hence shelled maize needed cleaning by winnowing manually. The cleaning efficiency for the locally fabricated shellers was lower (80.9%) as compared to the diesel powered machine referred to as control sheller (99.91%).
- The locally fabricated shellers lacked machine specifications and speed regulation, hence grain breakages were high compared to the diesel powered machine.
- The locally fabricated shellers were not gender friendly because women and people enabled differently (PED) could not operate the machine due to height of the feeding hopper compared to the control machine which was women friendly due to its low hopper height.
- The average scattering losses for the locally fabricated shellers were high (12.6%) compared to the control sheller (0.053%).
- It took the traditional methods longer (1.61 min) to perform a shelling operation as compared to using motorized shellers (15 s). The motorized shellers reduced farmers' drudgery and saved operational time.
- The time taken to perform the test operation for the locally fabricated shellers on average was 0.0372 h as compared to control (0.0303 h).
- The fuel consumption in L/h for the locally fabricated 5.5 hp gasoline shellers was at an average of 4.7 L as compared to 4.3 L of the control 8 hp diesel powered sheller. From the pump price of gasoline and diesel fuels it was noted that operating the 8 hp diesel powered sheller was economical both on usage and the price.

3.3 Analysis of Variance (ANOVA)

To further establish whether the control sheller was more efficient than the locally fabricated ones, statistical difference between their mean values was carried out using ANOVA and the results were as shown in Table 7.

The table represents the mean variation of the variables at every CV using the two shellers. According to the data analyzed the result shows that the 8 hp sheller (control) had the highest mean (9.23) and the p value of > 0.05 hence more efficient than the 5.5 hp sheller with a mean of 9.15.

4. Conclusion and Recommendation

The main objective of this study was to test and evaluate the maize sheller. The study concluded that the control sheller was the most efficient compared to the locally fabricated one as observed in the study's specific objectives below:

- The shelling and cleaning efficiency of the control sheller was higher as compared to the locally fabricated one.
- The percentage loss, percentage grain damage and quantity of chaff from the control sheller were lower compared to the locally fabricated one.

- The fuel consumption of the locally fabricated sheller was higher compared to the control.
- It took the traditional methods longer to perform a shelling operation as compared to using motorized shellers. The motorized shellers reduced farmers' drudgery and saved operational time.
- The shelling capacity of the locally fabricated sheller was lower than the control.

The farmers present during the testing and evaluation appreciated the new technology exhibited by the diesel powered sheller fitted with chaff blower and were willing to adopt it.

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