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Development and evaluation of motorized maize sheller

Candia A., Lubwama F., Saasa R. and Muzei J.
Agricultural Engineering and Appropriate Technology Research Institute
P.O. Box 7144 Kampala.

Abstract

Production of maize in Uganda has constantly been increasing since 1991. The bulk of the crop is shelled using traditional methods, which cause high drudgery, and results into products of low market value. According to the Participatory Rural Appraisal survey conducted in 1995 by Agricultural Engineering and Appropriated Technology Research Institute, AEATRI, lack of appropriate maize sheller was identified among factors that impair this positive production trend. Following the survey, AEATRI embarked on developing a motorised maize sheller with a view to solving this problem. A proto-type was designed, fabricated and tested on-station. This did not give expected results. It was bulky with low throughput (670kg/hr) and rather expensive. Major changes were made in its shelling mechanism to produce the second proto-type. This was tested both on-station and on-farm mainly with Longe-I maize variety. There was significant improvement in performance. Its output was 1 ton/hr of clean grain and fuel consumption was 1 lt/ton of clean grain. This proto-type was further improved. The on-station and on-farm tests on the third proto-type using Longe-I maize variety yielded satisfactory results with an output of 1.25 tons/hr of clean grain with a fuel consumption of 0.77 lt/ton of clean grain. Shelling efficiency was 99.7% and unbroken grain was 2%. After these tests, the institute has recommended that the third proto-type may now be released for mass production.

Keywords: Shelling drudgery, maize sheller

Introduction

Maize is one of the leading crops and the most important staple food in the East and Southern African countries. It is also a substantial raw material in livestock feed and for a wide range of industrial bi-products. In Uganda the crop strongly supplements the traditional staples and is widely used in large communities such as schools, hospitals and prisons. It is grown through out the country except in the relatively dry districts to the North and North Eastern parts. According to the FAO (1999) production records, there had been a steady increase in maize production from 598,000 metric tonnes in 1991 to 780,000 metric tonnes in 1999, Figure 1.

The bulk of the maize in the country is primarily processed by traditional methods: beating the crop either on bare ground or loosely packed in sacks or hand priming of the cobs. The beating method is highly productive, but results in high physical damage of the grain and reduces both the shelf life and economic value of the crop. Hand priming produces unbroken grain but the process is extremely slow and causes scorching of the palm (Odogola et. al, 1991). The few manually operated shellers available tend to subject the grain to less mechanical stress, however, they have limited output, 10-100kg/hr (Odogola et. al, 1991) with high drudgery especially on women and children. The motorised shellers in the market are expensive, cannot easily be fabricated by local artisans and cause high damage to kernels. The objective of this study was, therefore, to develop a motorised maize sheller to reduce drudgery, improve productivity, quality and market value of the crop.

Materials And methods

Problem diagnosis

AEATRI conducted a Participatory Rural Appraisal, PRA survey in 1995 to identify engineering problems

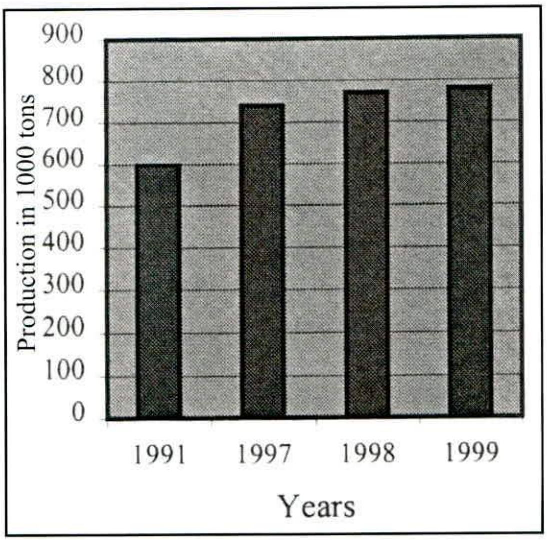


Fig 1: Maize production in Uganda,1991- 1999 Source: FAO Production Year-Book Vol. 53-1999

associated with maize production in Uganda. The survey was carried out in mid western and eastern regions, which are the main maize growing areas in the country. One of the main constraints identified by farmers was difficulty in shelling the crop. This prompted AEATRI to initiate development of a motorised maize sheller appropriate to farmers' needs.

Equipment development

A proto-type motorised maize sheller was designed and fabricated. It had a double shelling roller with flat rocking sieve and was driven by a 6hp petrol engine. This proto-type was tested on-station and did not yield the expected results. It was bulky and rather expensive and had low capacity of 670 kg/hr, consequently major changes were made in the shelling mechanism to produce the second proto-type.

This proto-type had a single rotating shelling shaft on to which spikes were welded. Its concave was fixed and had numerous 15mm diameter holes thus serving as a sieve as well. It was run by a 9hp-petrol engine. The on-station and on-farm tests produced promising output but it did not still yield most of the expected results. It was improved to give proto-type three.

The third proto-type had a shelling shaft similar to that of the second proto-type. It had two types of concaves one of them was like that of the second proto-type but shorter in length. The second type is a rasp bar concave, which also served as a sieve. During tests, one concave was used after the other. The sieve type of concave was the control concave. This proto-type was run by a 7.5hp petrol engine. All the three proto-types were separating the spent cobs before the shelled maize passes into a duct that leads it to cleaning section by the fan.

Experimental design

Second and third proto-types were tested using Longe-I maize variety developed by Namulonge Agricultural and Animal production Research Institute. Both male and female farmers, extension agents, artisans and fabricators were involved in the tests. Because the second proto-type had one concave while the third had two different designs of concaves, two different experimental layouts were used. All tests were carried out in Nakasongola and Masindi districts. Tests were conducted for second proto-type in 1999 and the third proto-type in 2000. The shellers were tested for the parameters shown in Table 1.

Table 1: Parameters for testing the shellers

Parameters	Unit	Level
Independent variable		
Shelling speed	**rpm**	**5 and 6 levels**
Dependent variables		
Broken grain	%	Corresponding
Shelling efficiency	%	to shelling
Unshelled grain	%	speed levels
Capacity	kg grain/hr	
Fuel consumption	litre/ton grain	

Experiments were carried out when farmers had dried the maize to a moisture level of 14 - 15%-wet basis. This was measured using a multi-grain moisture meter Dickey-John Model 46233-1247.

Experimental layout for second proto-type

One by five factorial treatment was used with one machine treatment and five levels of shelling speed for all the experiments. Every level of shelling speed was replicated four times on the same farm. Each replication lasted for at least 65 minutes.

Experimental layout for third proto-type

Two by six factorial treatment was used with two concave treatments and six levels of shelling speed for all the experiments. Every level of shelling speed was replicated five times on the same farm. Each replication lasted for at least 70 minutes.

Determination of the dependent variables

The shelling speed, which is an independent variable, was measured using an electronic Dynapa tachometer Model HT50. Since the shelling speed varied with load at any moment, the recorded value was the mean between the maximum and minimum tachometer readings at that setting of the engine speed.

During replication of every shelling speed, the necessary measurements for computing the dependent variables were taken and were used as detailed below.

Broken grain

Five samples each weighing about 600 to 800g were randomly collected from five different gunny bags in which, some of the clean shelled maize was kept. All physically damaged grain was sorted manually by hand after naked eye observation. The sorted damaged grain from each sample was measured using mechanical triple beam balance single pan, three graduated beams and capacity 2610g. The damaged grain was expressed as a percentage of total sample weight. The final recording of broken grain at that replicate was the average of these five percentage values, which later were averaged to give final broken grain percentage at the shelling speed level.

Shelling efficiency and unshelled grain

During every replicate, while the sheller was in operation, material exiting from all outlets (fan, clean grain delivery chute and spent cobs chute) of the sheller was trapped to enable collection of the different ingredients of the shelling process. The grain, which escaped from the fan outlet and from the spent cobs chute was sorted by hand and its weight separately recorded. The weight of the grain from the clean grain delivery chute was also measured using a spring balance of capacity 100kg (Hanson make). The unshelled cobs from the spent cobs chute were sorted and maize grain on them shelled by hand and its weight taken. The total weight of grain at that shelling speed level was obtained by summing the weights of grain from the three outlets including that shelled by hand from the unshelled cobs.

The shelling efficiency was calculated by expressing the weight of all the grain shelled by the machine that exited from the various outlets as a percentage of the total grain shelled at that shelling speed. The percentage of unshelled grain was obtained by expressing the weight of the unshelled grain as a percentage of the total grain shelled at that shelling speed. The mean values of these parameters from the replicates gave the final value for shelling efficiency and percentage of unshelled maize at that shelling speed level.

Capacity of the sheller

During every replicate the total weight of shelled grain from both the clean grain delivery chute and spent cobs delivery chute was measured using spring balance of capacity 100kg and the corresponding time was also recorded in hours using the ordinary wristwatch. Since during every replicate, the sheller was run for more than one hour, the corresponding weight for one hour was then computed. The mean value from the replicates was then obtained to give the capacity of the sheller at that shelling speed level. However, this capacity was adjusted to standard moisture content of maize (13% w.b.) according to FAO requirements using equation (1) (Smith et al, 1994).

$$W_C = \frac{W(100 - m)}{100 - SMC} \quad \text{...............(1)}$$

where: Wc = Adajusted capacity to SMC (Kg/hr)

W = Not adjusted capacity (Kg/hr)

SMC = Standard moisture content (% w.b.)

M = Shelling mosture content (% w.b)

Fuel consumption

Before starting the shelling of maize, the fuel tank was filled to the maximum tank capacity and its level was marked. After shelling the earmarked quantity of unshelled maize, the fuel tank was re-filled to the original level using a one litre-measuring cylinder. The quantity of refilled fuel is considered equal to the fuel consumed by the sheller to shell the corresponding quantity of maize at that replicate. This was expressed as one litre of fuel per tons of shelled maize. Averaging these values from the replicates gave the fuel consumption at that shelling speed.

Comparison of second and third proto-type

Since the shellers were tested during different years, the common dependent parameters in Table 1 at the recommended shelling speed were used as basis for comparison of the proto-types.

Results and discussions

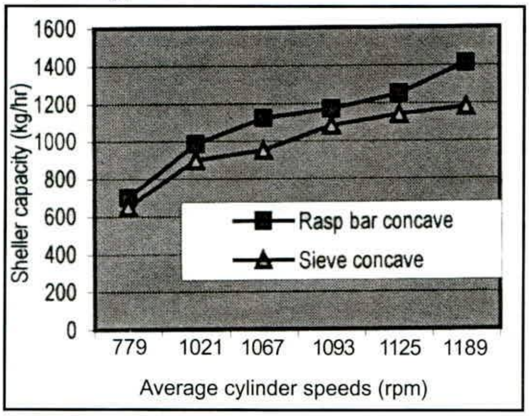
Results and discussions of second proto-type

The average values of broken grain percentage, shelling efficiency, unshelled grain, adjusted capacity and fuel consumption of the second proto-type are shown in Table 2. The 95% confidence interval using t-distribution indicated that the adjusted sheller capacity

Table 2: Average values of dependent variables of the second proto-type.

Dependent	Shelling speed (rpm)				
variables	500	650	700	779	1000
Broken grain, %	1.8	1.9	2.0	2.2	2.6
Shelling efficiency, %	96.8	97.2	97.7	98.1	98.2
Unshelled grain, %	3.2	2.8	2.3	1.9	1.9
Adjusted capacity, kg/hr	596	680	827	1003	1050
Fuel consumption, (tons-grain per litre)	0.6	0.67	0.8	1.0	1.02

Fig.2: Capacity reflected by the two concaves of proto-type three



at shelling speeds of 779 and 1000rpm are 1003 kg/hr and 1050 kg/hr respectively. At shelling speeds of 779 and 1000rpm, there is no difference in unshelled grain and shelling efficiency, however, there is a difference in broken grain. The shelling speed of 1000rpm was obtained at the maximum engine speed and had the highest quantity of broken grain. It is therefore recommended that, the sheller should be operated at shelling speed close to 779 rpm so as to tap the optimum benefits of low percentage of broken grain, low fuel consumption and high sheller efficiency.

Results and discussions of the third proto-type

The average values of broken grain percentage, shelling efficiency, unshelled grain, adjusted capacity and fuel consumption are as shown in Table 3. Variations in the adjusted sheller capacity as reflected by the two types of concaves at various shelling speeds are shown in Figure 2. Similar plot of quantity of unshelled maize versus shelling speed is shown in Figure 3.

Table 3: Average values dependent variables of third proto-type

Concave type	Dependent variable	Levels of shelling speed					
		779	1021	1067	1093	1125	1189
Sieve concave	Broken grain %	1.9	1.9	2.0	2.1	2.1	2.3
	Shelling efficiency %	97.9	98.2	98.5	98.6	99.05	99.1
	Unshelled grain %	2.1	1.8	1.5	1.2	0.95	0.48
	Adjusted capacity kg/hr	650	900	950	1080	1140	1180
	Fuel consumption tons-grain/hr	0.75	0.89	0.92	1.02	1.1	1.17
Rasp bar concave	Broken grain %	1.8	2.0	2.01	2.1	2.1	2.2
	Shelling efficiency %	99.56	99.59	99.64	99.68	99.73	99.76
	Unshelled grain %	0.44	0.41	0.36	0.32	0.27	0.24
	Adjusted capacity kg/hr	698	985	1122	1170	1250	1411
	Fuel consumption tons-grain/hr	0.8	0.9	1.1	1.19	1.28	1.39

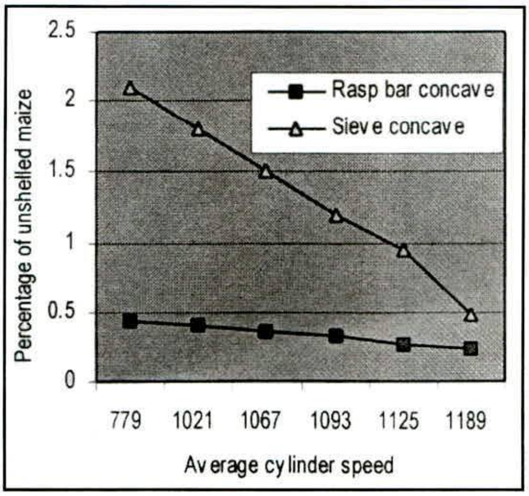


Fig3: Unshelled maize reflected by the concaves of proto-type three

Paired t-test was used to compare the performance of the two concaves and 95% confidence interval using t-distribution was used to test the adjusted capacities at shelling speeds of 1125 and 1189 rpm for the two concaves.

There was significant difference in the adjusted capacity of the sheller produced by the two concaves at the shelling speeds of 1125 and 1189 rpm. In all the levels of shelling speed, there was also significant difference in the quantity of unshelled maize and the shelling efficiency produced by the two concaves. These differences are clearly illustrated by Figures 2 and 3.

The confidence interval test proved that the average adjusted capacity of the sheller reflected by the two concaves at the shelling speeds of 1125 and 1189 are the ones, which appear in Table 3.

Across the shelling speed levels, there was no significant difference between the broken grain produced by the two concaves. It was, therefore, recommended that the sheller should be operated at shelling speed between 1125 and 1189 rpm and with the rasp bar concave.

Comparison of second and third proto-types

Comparison was made between the two proto-types using figures of the depended variables at their recommended shelling speeds and these are summarised in Table 4. For proto-type three the values for rasp bar concave were used.

From Table 4, it is clearly seen that the third proto-type sheller performed technically better than proto-type two.

Table 4. Parameters for comparison of the proto-types two and three

Parameters	Proto-types	
	II	III
Broken grain (%)	2.2	2.1
Shelling efficiency (%)	98.1	99.73
Unshelled grain (%)	1.9	0.27
Capacity (kg/hr)	1003	1250
Fuel consumption (lt/ton-grain)	1.0	1.28

Conclusion

Appropriate motorised maize sheller significantly reduces labour requirements and improves timeliness of maize shelling. Among all the three proto-types, the third proto-type produced the best technical performance with the rasp bar concave.

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