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Improving the AEATRI-motorized maize sheller to meet the market demands of commercial maize farmers

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Abstract

The importance of maize (*Zea mays*) in Ugandan economy has been increasing since 1990's. The crop is grown for both local and foreign markets by mainly small-scale farmers. The bulk of the crop is shelled using the rudimentary traditional methods, which have low productivity and result into maize grain of low market value. Earlier studies conducted by Agricultural Engineering and Appropriate Technology Research Institute (AEATRI) in 1995 identified lack of appropriate maize shellers to meet the market demands of commercial farmers as one of the major constraints that mitigate the increased trends of maize production in Uganda. AEATRI responded by developing a motorized maize sheller, which had a mean output of 1,100kg/hr/lt of fuel, shelling efficiency of 98.8% and mean damaged grain of 2%. The shelling unit of this model was later re-designed and fabricated to give a new model of the sheller. Comparative evaluation of shelling units of these two models was done using Longe-5 maize variety. Commercial maize farmers, extension agents and local political leaders were involved in the evaluation. The machine parameters evaluated were output in kg/hr/lt of fuel, percentage of broken grain, shelling efficiency and seed germination percentage. The new model had higher mean output (1,490kg/hr/lt of fuel) and shelling efficiency (99.7%) than the old one ($p<0.5$). There was inadequate evidence to show that the percentage of broken grain caused by the two models were significantly different ($p>0.5$). However the mean value of broken grain from the new model was 1.8% while from the old sheller stood at 2%. The mean seed germination tests were 90.8% and 90.4% for the new and old shellers respectively. The stakeholders especially farmers present during the evaluation were satisfied with the performance of the new maize sheller model. The institute has consequently recommended it for release to the private sector agro-processing equipment manufacturers for scaling up.

Key words: Agro-processing, Germination, grain, farmers, percentage

Introduction

The importance of maize in Uganda has been increasing since early 1990's. It strongly supplements the traditional diet crops and is widely used in large communities such as schools, hospitals and prisons. The crop is grown mainly by smallholder farmers targeting both local and foreign markets. According to FAO (2003) agricultural production records, there had been a steady increase in maize production from 759,000 metric tons in 1995 to 1,200,000 metric tons in 2003. Earlier studies conducted by Agricultural Engineering and Appropriate Technology Research Institute (AEATRI) in 1995 identified lack of appropriate maize shellers as one of the major constraints affecting commercial maize production in Uganda. Farmers shell the bulk of the maize using the traditional method of beating on the bare ground or loosely packed in sacks. The method has low productivity, causes high physical damage and contamination with foreign matter resulting in low market value and reduced shelf-life of the crop. Other methods such as hand priming, shelling using manual maize shellers are not productive for commercial farming. AEATRI developed a motorized maize sheller, which did not fully meet the market requirements of commercial farmers following the base line survey carried by in 1995. The sheller had a mean output of 1,100kg/hr/lt of fuel, shelling efficiency of 98.7% and percentage of damaged grain of 2.1% (Candia *et al.*, 2003). The objective of the study was therefore to improve this model of the sheller to meet the market requirements of the commercial maize farmers, agro-processors and maize grain traders.

Materials and methods

Understanding the problem

Two methods were used to identify and understand the problem. The first method was farmer feedback in which some of the farmers who had adopted the maize sheller gave feedback on the technical performance of the sheller directly to the scientists at AEATRI. The second method was technical backstopping by AEATRI scientists to the farmers who were using the maize sheller. Four farmers from Masindi and Kapchorwa districts using the old model sheller were purposively selected to confirm the feedback information received from the other farmers. Inadequate output and shelling efficiency were identified as the major problems with the model calling for improvement in the design of the shelling unit.

Maize sheller improvement

The old model of the sheller has a feeding hopper, which rests on a cylindrical maize shelling unit. The shelling unit rests on a metallic frame that is connected to axial flow fan, used cobs and clean grain delivery outlets and power unit. The power unit is either 5.5hp, high-speed single-phase electric motor or an 8hp gasoline engine. The shelling unit has shelling drum fitted with pegs and concave made of sheet metal through, which holes of 14 cm diameters at spacing of 10 cm are drilled. An initial attempt was made to re-design and fabricate the concave using rod bars only. This attempt gave promising results of machine parameters (e.g. output was 1,280kg/hr/lt of fuel) but the concave was unable to withstand the forces in the shelling unit (Candia *et al*., 2003). The new concave was then re-designed and fabricated using a combination of 8 mm diameter rod and 6 mm thick flat bars to produce the new prototype. The shelling drum and other parts of the sheller remained unchanged. The concave was designed such that it provided rubbing action on the cobs during shelling allows easy dropping of grain off the shelling unit and also acted as a sieve.

Experimental design for field evaluation

Comparative evaluation of the two sheller models was carried out on the farms of two farmers who had reported the problem with the old maize sheller. The field evaluation took place in February 2004 in Kacheera sub-county, Kooki county Rakai district. The parameters compared were output in kg/hr/lt of fuel, shelling efficiency (%), physically seen damaged grain and seed germination test (%). The parameters from each model were compared at the same 6 levels of shelling speed (rpm) and repeated on two farms. Longe-V maize variety was used for the evaluation. The shelling experiments were carried out when farmers had dried the maize on cob to mean moisture content of 15.5% (w.b.), which was measured using a multi-grain moisture meter Dickey-John model 46233-1247.

Determination of the performance variables

The independent variables were the sheller models and shelling speed. The two sheller models were: one whose concave was made of sheet metal and the other whose concave was made of rod and flat bars. The shelling speed had six levels 906, 946, 969, 1002, 1020 and 1064 rpm. The shelling speed 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. Every shelling speed was replicated twice on each of the farms for every sheller model. During shelling and replication of every shelling speed, the necessary data for computing the dependent variables were taken and used as follows:

1) Sheller output in kg/hr/lt of fuel.

During the shelling exercises the total weight of shelled grain from both the clean grain delivery chute and spent cobs delivery chute was measured using Salter spring balance of capacity 100kg and the corresponding time was also recorded in minutes using the ordinary wristwatch. Since during every set shelling speed, the sheller was run for 77 – 85 minutes, the corresponding weight of shelled grain for one hour was then computed. Then mean value from the replicates from the two farms was obtained to give the output of the sheller at that shelling speed. This output was first adjusted to standard moisture content of maize (13% w.b.) according to FAO requirements using equation below (Smith *et al*, 1994).

$$W_c = \frac{W(100 - M)}{100 - SMC}$$

Where:

W_c = Adjusted output to SMC (kg/hr)

W = Not adjusted output (kg/hr)

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

M = Shelling moisture content (% w.b.)

Fuel consumptions by the sheller models were taken during maize shelling exercises. Before starting shelling maize, the fuel tank was filled to maximum tank capacity and level marked. After shelling for a specified time, a known quantity of fuel was used to re-fill the engine fuel tank to the original fuel level. The quantity of refilled fuel was considered equal to the fuel consumed by the sheller to shell the corresponding quantity of shelled maize at that shelling speed replicate. The mean of fuel used at a particular shelling speed from the two farms was obtained and later used to express the sheller output in kg/hr/lt of fuel.

2) Shelling efficiency

During every replicate of shelling speed, 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 fan outlet and from spent cobs chute, was sorted by hand and its weight separately recorded. The weight of grain from clean grain delivery chute was also measured using a spring balance of 100kg capacity (Salter make). The unshelled cobs from 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 three outlets including that shelled by hand from unshelled cobs. The shelling efficiency was calculated by

Figure 1. The old concave

Figure 2. The new concave

expressing the weight of all grain shelled by the machine as a percentage of the total grain shelled at that shelling speed. The mean values from the shelling speed replicates from the two farms gave the final value for shelling efficiency at that shelling speed level for each sheller model.

Broken grain

For every shelling speed three samples each weighing about 550 - 780g were randomly collected from three 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 percentage of broken grain recorded at that shelling speed replicate was the average of these three percentage values, which later were averaged across the farms to give the final broken grain percentage at that shelling speed level.

4) ***Seed germination test.***

In determining the seed germination tests, it was assumed that other factors, which affect seed germination were constant and had no or negligible effect on the germination of the seeds. Three samples of shelled grain each weighing 4 –6 kg were randomly collected from shelled grain. Earlier seed germination tests at shelling speed of 1000 rpm and below had a germination percentage of 89 – 91 for the old sheller model. This sampling was therefore made for the grain shelled at the highest shelling speed of 1064 rpm for each of the sheller models. Samples of unshelled maize were also randomly collected from the unshelled maize batch and hand shelled. These exercises were done for both farms. The National Seed Certification Services carried out the seed germination tests.

Data analysis

The two models of the maize shellers were tested at the same six levels of shelling speeds using Longe-V maize variety as test the crop. Paired t-test at 5% significance level was then the statistical tool used for comparing the means of the dependent maize sheller test variables. SPSS statistical computer software was used to aid the data analysis.

Results and discussions

The improved sheller model

Figure 1 shows the old concave that was re-designed to give the new model shown as Figure 2. When the maize sheller is in operation, the new concave causes rubbing action on the cobs and acts as a sieve. The removal of maize grain from the un-spent cobs is therefore through impact on the grain by shelling drum and rubbing by the concave, while the grain removal in the old model is only by impact. Since the design of the other parts of the sheller remained un-changed, the physical appearance (pictorial look) of the two sheller models are alike.

Operation of the shellers

The shellers shell maize and automatically separate the used cobs and chaff from the grain. They deliver clean grain, used cobs and chaff through different outlets. This enables the farmer to obtain clean grain and used cobs for other uses at the same time and without additional labour.

Maize shelling experiments

Some of the commercial men and women farmers who had reported the problem with the old model of the sheller fully participated in the evaluation. Other categories of stakeholders who participated in the evaluation were youth, district extension, local political leaders and civil society. Figure 3 shows women, men and youth field testing one of the models of the sheller in Kacheera sub-county, Rakai district.

Since the performance of human beings decreases with time, each maize shelling exercise took at least seventy seven minutes. Loss in concentration by operators during maize shelling period, which could have resulted into large errors if the data was extrapolated were therefore eliminated. In addition the involvement of all the key gender in field evaluation produced a resultant data across gender. Consequently the values of sheller output that also depends on feed rate presented here are of the real field situations. To obtain the best output, the sheller needs at least four people for operation. One person feeds the maize cobs into the sheller, two people supply maize cobs to the person feeding and remove spent cobs, and the fourth person collects the clean grain from clean grain delivery chute.

Analysis of evaluation parameters

The machine parameters evaluated were output in kg/hr/lt of fuel, shelling efficiency, percentage of broken grain and seed germination percentage.

1) ***Sheller output***

As shown in Figure 4, the new sheller model had significantly higher mean output than the old model ($p<0.5$) at all the shelling speeds. The new model has mean output of 1,490kg/hr/lt of fuel, while the old model has mean output of 1,150 kg/hr/lt of fuel at shelling speed of 1064 rpm. The higher output of the new sheller is due to the design of its concave that contributes to the removal of grain from cobs. The maize grain is removed by impact of the shelling drum and the rubbing action of the concave. The design of the concave also makes grain to drop off the shelling unit as soon as it is removed from the cob thus reducing resistive forces in the shelling unit. Whereas in the old model sheller grain removal from the cobs is only by impact of the shelling drum and the design of the concave does not allow grain to drop off the shelling unit as soon as it is removed from the cob thus increasing the resistive forces. The output of the shellers increased with increasing shelling speed. At high shelling speed the rate of removal of grain from the cobs is high due to the increased force of impact on the grain.

Figure 3. Farmers testing one of the maize sheller

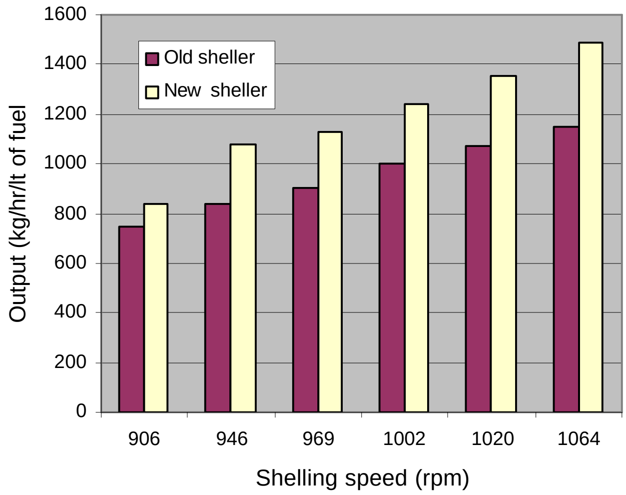

Figure 4. Output of the shellers at the various shelling speeds

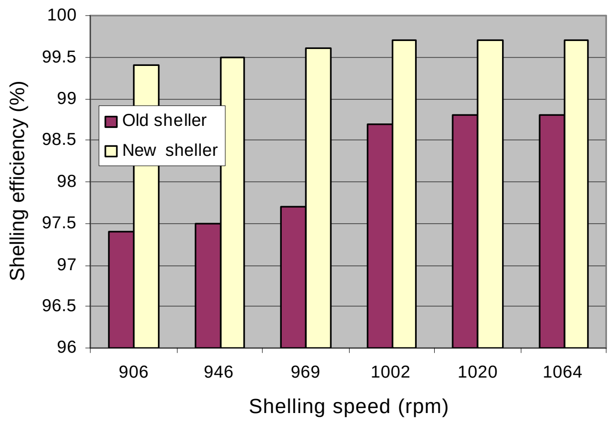

Figure 5. Shelling efficiency of the shellers at the various shelling speeds

2) ***Shelling efficiency***

The new sheller model had a higher shelling efficiency than the old one at all the shelling speeds ($p<0.5$). Maize shelling in the new sheller is both by impact force of the shelling drum and rubbing effect of the concave. In the old sheller, the rubbing effect of the concave is very negligible and shelling solely depends on the impact of the shelling drum. Due to the increased force of impact at higher shelling speeds, the shellers showed increased shelling efficiency with increasing shelling speed (Figure 5). At speeds of 1020 and 1064 the shelling efficiencies were 99.7% and 98.8% for new and old sheller respectively indicating that any additional shelling will not increase the shellers' shelling efficiencies.

3) ***Broken grain***

There was inadequate evidence to show that the percentage of broken grain caused by the two models were significantly different ($p>0.5$). The variations in the broken with the increasing shelling speed were negligible. However the mean value of broken grain from the new model was 1.8% while from the old sheller stood at 2%.

4) ***Seed germination test***

There is no difference in the seed germination tests from the two shellers. The mean seed germination tests were 90.8% and 90.4% for the new and old shellers respectively. The mean germination tests for the hand-shelled maize were 92.6%. The difference in germination percentage between the machine and hand shelled maize is due to the effect of impact force on the grain exerted by the shellers.

Views of the stakeholders

All the stakeholders present during the field evaluation were satisfied with the performance of the new maize sheller model. They were satisfied especially with the sheller out, fuel consumption rate and shelling efficiency, which was proved by very negligible unshelled grain on the cobs

Conclusions

Five conclusions were drawn from this study. (1) The new sheller model performs better than the old model. It has higher output and shelling efficiency and damages grain less than the old model. Labour productivity of the users will therefore increase resulting into improved timeliness of maize production and its market value. (2) The output of the maize shellers was best at the highest shelling speed and it requires at least four persons to operate it. (3) The variations in percentage of damaged grain across shelling speeds were negligible. (4) Stakeholders present during the field evaluation were satisfied with the performance of the new maize sheller. (5) Since the difference in seed germination tests between hand and machine shelled maize is small, the effect of impact force on the grain exerted by the shellers is negligible.

Recommendations

Three recommendations are made from this study.

(1) The highest output of the shellers was at shelling speed of 1064 rpm and the variations in percentage of damaged grain across shelling speeds were negligible. The new maize sheller should be operated at around shelling speed of 1064 rpm. This will result into better labour productivity of the users and faster economic returns on the investment.

(2) Since the stakeholders present during the field evaluation were satisfied with the technical performance of the new maize sheller, it is now recommended for packaging and eventual release to the agro-machinery manufacturers for scaling up purposes and subsequent marketing.

(3) Since the difference between the germination percentage of hand and machine shelled grain is small (2%) and seed germination was more than 90%, the maize sheller is also ideal for seed processing industry.

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