Performance evaluation and optimization of the maize shelling operation of the multi-purpose farm vehicle

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Abstract: Small-scale farmers register high postharvest losses partly due to failure to carry out primary processing operations. Most of the maize shellers on the Ugandan market lead to high percentage of broken maize grains thus raising the risk of aflatoxin infection during storage. In this study, the operation of an existing maize sheller on the market with a shelling speed of 870 rpm for maize at 13% moisture content was tested. The main objective of this study therefore was twofold; (i) to develop and evaluate a maize sheller and (ii) to optimize the multi-purpose vehicle shelling operation. The improved maize sheller was designed, fabricated, evaluated and optimized using a factorial experiment with shelling speed and moisture content as the main effects at three levels. Analysis of variance was done using R-studio. A cost-benefit analysis of the shelling technology was conducted. The obtained results showed that a reduction in moisture content and an increase in shelling speed increased the shelling efficiency, the grain damage percentage, output capacity and the cleaning efficiency. The optimum moisture content and the shelling speed of the multi-purpose vehicle maize shelling were 13% and 896 rpm respectively. Except the shelling efficiency, the results of the modified maize sheller were significantly different ($p<0.05$) from those of the market sheller. The payback period was 1.37 years while the benefit-cost ratio was 1.07. The optimized maize shelling operation of the multi-purpose vehicle is therefore economically viable.
Keywords: maize shelling, multipurpose vehicle, physical properties, engineering properties.

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1 Introduction

Maize is the third most important cereal grain in the world after wheat and rice (Oriaku et al., 2014). It provides nutrients for humans and animals and serves as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners, and more recently biofuels (Hadera, 2016). The central role of maize as a staple food in Sub Saharan Africa is comparable to that of rice or wheat in Asia, with consumption rates being highest in Eastern and Southern Africa. An estimated 208 million people in SSA depend on maize as a source of food security and economic well-being (Macauley, 2017). Of the 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet, sixteen of them are in Africa (Macauley, 2017), making maize a cereal of pertinent importance to the continent. However

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maize postharvest have reduced its availability among farmers on the continent. In Uganda post-harvest maize losses are estimated to be 30% (SEATINI, 2014) which has increased hunger especially among the poor in rural areas.

The main post-harvest operations of maize include; drying, de-husking, shelling, storing, and milling (Okure and Ssekanyo, 2017). Among them, shelling is still the biggest challenge with more work still needed to improve this operation (Okure and Ssekanyo, 2017). A number of locally designed and fabricated maize shellers have been designed to improve the shelling operation although their performance has not satisfied the farmers. The poor performance of locally fabricated maize shellers is attributed to the fact that many of the shellers are designed and fabricated by local artisans who have limited knowledge of both crop characteristics and machine parameters suitable for optimum maize sheller performance (Ojomo and Alemu, 2012). In addition, farmers face a challenge of inadequate power to run these locally available motorized maize sheller. Therefore, there is need to locally design a highly efficient motorized maize sheller for the small-scale farmers with adequate power to run them.

In an effort to improve primary processing at farm level, a multi-purpose vehicle that allowed for hitching a maize sheller was developed. The multi-purpose vehicle was tested using a maize sheller brought from the market. Results indicated the mean broken percentage of the shelled maize was 8.43% which was unsatisfactory to potential buyers and higher than the recommended maize shelling damaged kernel percentage of less than 2% (EAC, 2017). In addition, maize cobs clogged in the shelling unit, which had to be manually removed after opening the shelling unit. This increases processing time, calls for more people increasing the labor bill, and is tiresome processing rendering the equipment not user friendly. These inefficiencies limited the full adoption of the multi-purpose vehicle shelling technology and hence created need for research to optimize the technology. The main objective of this study therefore was twofold; (i) to develop and evaluate a maize sheller and (ii) to optimize the multi-purpose vehicle shelling operation.

2 Materials and methods

The study was conducted at Makerere University Agricultural Research Institute Kabanyoro using the multi-purpose farm vehicle a power source. A market maize sheller was tested with the vehicle, and accordingly, required modifications were done to produce a modified sheller. The study was limited to three varieties of maize *Zea mays*; Longe 5 H, Longe 7 H, and Longe 10 H at moisture contents of 17%, 13%, and 10%. The shelling speeds considered in this study were 760, 870, and 950 rpm which are within a widely applied range of 623 and 1350 rpm for maize shelling (Alarm and Momin, 2009; Aremu et al., 2015; Pavasiya et al., 2018).

2.1 Testing and evaluation of the market and the improved maize sheller

The market maize sheller powered by the multi-purpose vehicle was evaluated using a standard procedure described by Naveenkumar (2011). The difference sheller performance indices were calculated using Equations 1-4 according to Chaudhary (2016).

2.1.1 Output capacity of the maize sheller

$$C_p=(Q_T)/t \tag{1}$$

Where C_p is output capacity (kg h^{-1}), Q_T is weight of whole grain collected (kg) and t is shelling time (h).

2.1.2 Shelling Efficiency

$$\eta_T = 100-(D/A)\times 100\% \tag{2}$$

Where η_T is shelling efficiency (%), D is quantity of unshelled grains obtained from all outlets per unit time (kg) and A is total weight of grain input per unit time (kg).

2.1.3 Cleaning efficiency

$$\eta_c = (M/F)\times 100\% \tag{3}$$

Where η_C is cleaning efficiency (%), M is weight of whole clean grains obtained from the main grain outlet in unit time (kg) and F is total quantity of sample obtained from main grain outlet per unit time (kg).

2.1.4 Grain damage percentage

$$Dg=(C/A)\times 100\% \quad (4)$$

Where D_g is damaged grain (%), C is quantity of broken grains from all outlets per unit time (kg) and A is total weight of the grain input per unit time (kg).

The improved maize sheller was tested as seen in Figure 1. To study the effect of selected operational parameters of moisture content and the shelling speed on the performance of the modified maize sheller, a 3^2 factorial experiment was used to study the effect of the independent variables (shelling and moisture content) at different levels on shelling efficiency, cleaning efficiency, broken damage percentage and output capacity. Moisture content and shelling speeds at three levels of 17%, 13%, and 10% moisture content and 760, 870, and 950 rpm, respectively at a constant feeding rate of 2.5 th^{-1}.

Figure 1 Testing the improved maize sheller

2.2 Improvement of the market maize sheller operations

To improve the operations of the market maize sheller, the physical and engineering properties of maize were determined first. These properties provided a basis for limits while redesigning the different market sheller parts.

2.2.1 Determination of physical and engineering properties of maize

The physical and engineering properties of the three maize varieties were determined using three replications for each variety (Mullen, 2016). The maximum and minimum diameters of the de-husked maize cob (mm) and linear dimensions of the maize grains (length, width and thickness) in mm were measured using a Vernier caliper with an accuracy of 0.01 mm. The arithmetic mean diameter (D_a) and geometric mean diameter (D_g) of the grains were calculated using a standard equation described by Tarighi et al. (2011). Sphericity was determined using a standard equation described by Chhabra and Kaur (2017) while surface area was calculated using standard equation described by Ashwin et al. (2017). The bulky density (ρ_b) of maize was determined using the standard test procedure reported by Chaudhary (2016) and calculated using a standard equation described by Chhabra and Kaur (2017). The moisture content of maize grains was determined by oven drying method and calculated using a standard equation described by Chaudhary (2016). The mean terminal velocity of 15.2 m s^{-1} (Chaudhary, 2016) was used for this study due to unavailability of the terminal velocity equipment. A standard procedure and equation used by Wani et al. (2017) for determining the angle of repose for maize grain was used to determine the angle of response.

2.2.2 Designing the selected sheller parts

Mild steel was used because it is smooth textured, mechanically stable, easily cleanable and readily available at a low cost according to Bako and Boman (2017). Akoy and Ahmed (2015) noted that mild steel can be used to produce the desired equipment objective at the lowest cost possible. Cast iron was used for pulleys in the power transfer system as recommended by Mogaji (2016). Modifications were designed for the hopper, shelling drum and the blower.

2.2.3 The hopper

The actual dimensions of the hopper were calculated basing on the required input capacity of the sheller and the determined angle of repose for maize grains as recommended by Aremu et. (2015). The hopper had a shape of frustum. The volume of the frustum (hopper) was calculated as the difference between the volume of the big pyramid and the small pyramid using Equation 5 (Arthur and Reginald, 1926).

$$V=(1/3)bh \quad (5)$$

Where V is Volume of the Pyramid(m^3); b is the base area (m^2); h is the Pyramid height (m).

2.2.4 Determination of the main shaft diameters and shaft strength

A hollow shaft was used for study because of its lower weight, better at taking up torsional loads and has a greater strength to weight ratio compared to solid shafts. Torsion theory as shown by Equation 6 was used to calculate the minimum and maximum shaft diameters.

From the torsion theory (Hearn, 2000),

$$T/J=\tau/R \quad (6)$$

Where T is applied external torque (N m); J is polar second moment of area of the shaft cross section; τ is the Shear stress at radius R and is the maximum value for both solid and hollow shafts; R is the outer radius if the shafts. For this research, J for a hollow shaft was calculated using a standard equation described by Hearn (2000).

Calculation of the Torque required to shell the maize, generated by the available 11.5 hp from the multi-purpose farm vehicle was done using Equation 7.

$$P=T\omega \quad (7)$$

Where ω was the angular velocity (rad s^{-1}) with N being taken as 870 rpm (Aremu et al., 2015).

For mild steel hollow shafts, the maximum allowable shear stress τ_{max} is 42 MNm^{-2} and d which is 0.833 times D were used (Hearn, 2000).

The maximum bending moment $M_{b\max}$ was calculated by taking moment about a given point along the shaft considering all the forces acting on the shaft and their respective distances from an arbitrary point. A shear force diagram and bending moment diagram were drawn from which the maximum bending moment was read.

The torsional moment, bending stress and lateral rigidity of the main shaft were calculated using standard equations described by Chaudhary (2016). The torsional stress, torsional rigidity and lateral rigidity of the main shaft were calculated using standard equations described by Hassan et al. (2009).

2.2.5 The power transfer system

The power transfer system was designed using the standard power transfer equation. The length of the V-belt was calculated basing on the driver and the driven pulleys and the center distances using a standard equation as described by Chaudhary (2016).

2.2.6 Cleaning unit

The cleaning unit was made of a straight blade-type blower which received rotary power from the rotating drum using a class B V-belt and the pulleys. The actual air flow rate was estimated by Equation 8.

$$Q=VDW \quad (8)$$

Where Q is actual air flow rate (m^3 s^{-1}); V is velocity of air (m s^{-1}); D is depth of cleaning air stream (m): W is width over which air is required for cleaning (m). To achieve the required air flow rate, the blower operating speed was calculated using the standard power transfer equation

2.2.7 Data analysis

Analysis of variance (ANOVA) was done using R-studio to establish if both moisture and shelling speed significantly affected the shelling efficiency, grain damage percentage, output capacity and cleaning efficiency. It was also used to establish if there were significant differences between other variables Optimum performance indicators at optimum shelling speed and moisture content were determined from the graphs.

2.3 Cost - benefit analysis

The cost-benefit analysis of the multi-purpose vehicle shelling technology using the modified maize sheller was conducted using the payback period and the benefit-cost ratio. The payback period was calculated using Equation 10 while the benefit-cost ratio was calculated using Equation 9.

$$P=(I)/(NA) \quad (9)$$

$$BC=(DB)/(DC) \quad (10)$$

Where P is the payback period (years), I is the investment cost (USD), NA is net annual return (USD), BC is benefit-cost ratio, DB is discounted benefits (USD) and DC is discounted costs (USD).

3 Results and discussion

3.1 Performance evaluation of the market maize sheller

The results for the performance evaluation of the market maize sheller when powered by the multipurpose vehicle are presented in Table 1.

Table 1 Performance evaluation of the market maize sheller

Performance Indicator	Mean values for market maize sheller
Sheller capacity, kg h^{-1}	608.0 ± 15
Shelling efficiency, %	97.4 ± 0.46
Cleaning efficiency, %	18.4 ± 2.57
Grain damage percentage, %	8.4 ± 1.25

As summarized in Table 1, it can be noted that the output capacity of the market maize sheller was 608 (kg h^{-1}). Similar results of 623.99 kg h^{-1} were observed by Aremu et al. (2015) under similar operating conditions of moisture content and shelling speed. However, both authors recommended that further research could be done to improve the shelling capacity so that more maize cobs can be shelled per unit time. Hence, more work needs to be done to improve on this shelling capacity.

The shelling efficiency was determined to be 97.4% (Table 1) which is similar the shelling efficiencies of 98.51% obtained by Pavasiya et al. (2018) at a shelling speed of 886 rpm and moisture content of 13%. Adewole et al. (2015) obtained a shelling speed of 87.08% at a shelling speed of 886 rpm and a moisture content of 13%. The difference in these shelling efficiencies could have been due to the differences in the feeding rates. The mean cleaning efficiency observed in this study was 18.4%. This value of cleaning efficiency was very low compared to 95.9% obtained by Aremu et al. (2015) and the 96.4% recorded by Ilori et al. (2013). The low cleaning efficiency of the market maize sheller was attributed to a number of factors. These include inadequate air inflow into the cleaning unit due to slow fan speed because the impeller was not centered with the inlet, the fan had only four straight blades and the fan belt was not tightly fitted into the pulleys due to poor fabrication. These causes of fan failure are similar to those pointed out by Kamutzki and An (2016).

From Table 1, the grain damage percentage was 8.4% which was higher compared to the grain damage percentage of 1.6% reported by Naveenkumar (2011). The high grain damage percentage of the market maize sheller was attributed to the smaller holes (12 mm) in the screen that could not immediately let maize grains fall through after being shelled from the maize cob. Besides the small holes in the screen, there was clogging of maize cobs during maize shelling as a result of imperfections in fabricating the shelling drum. These cobs blocked the screen holes and the grains were impacted by the shelling forces longer than expected hence breaking them.

3.2 Modification of the market maize sheller

3.2.1 Physical and engineering properties of maize

The physical and engineering properties for the three maize varieties are presented in Table 2. ANOVA of the physical and engineering properties indicated that there was no significant difference (p>0.05) between the different properties for the three selected maize varieties. Hence any of the three maize varieties could have been used for the performance evaluation of both the market maize sheller and the modified maize sheller. According to Ajambo et al. (2017), of the three varieties, Longe 5 H is the most preferred variety by farmers in Uganda hence its values in Table 2 were used to calculate the arithmetic mean diameter, geometric mean diameter, sphericity, surface area and bulky density and in the performance evaluation of the two shellers.

Table 2 Physical and engineering properties of three maize varieties in Uganda

Particulars	Mean property values based on raw data		
Variety Name	Longe 5 H	Longe 7 H	Longe 10 H
Max. cob diameter, mm	52.60 ± 1.91	49.76 ± 2.78	49.20 ± 1.93
Min. cob diameter, mm	24.67 ± 1.03	27.47 ± 1.15	27.04 ± 0.95
Maize grain length, mm	10.57 ± 0.81	11.71 ± 0.64	11.72 ± 0.28
Maize grain width, mm	9.98 ± 0.71	9.37 ± 0.33	9.26 ± 0.22
Maize grain thickness, mm	6.16 ± 0.72	6.34 ± 2.62	6.33 ± 0.38
Angle of repose, degrees	20.38 ± 0.97	21.39 ± 0.05	21.39 ± 0.01
Moisture content, %	13.1 ± 0.21	12.4 ± 0.35	13.4 ± 0.24

Note: p>0.05 for all the properties of the three maize varieties considered in this study

The Arithmetic mean diameter and the geometric mean diameter were 8.90 mm and 8.66 mm values similar to those obtained by Tarighi et al. (2011) and Brar et al.

(2017), respectively. The mean sphericity and surface area values were 0.82 and 235.62 mm^2. The sphericity was similar to 0.79 obtained by Brar et al. (2017) and 0.76 obtained by Atere et al. (2016) while the surface area was 147.06 mm^2 which was slightly different from what Atere et al. (2016) obtained. The difference could have been attributed to the different varieties of maize considered for the three studies and the difference in the growing conditions. The mean bulky density was 680 kg cm^{-3}. This bulky density value was found similar to the one obtained by Tarighi et al. (2011) who reported a value of 679.1 kg cm^{-3}. The mean moisture content for Longe 5H maize grains was 13.10%. This value was similar 13.0% used by Chaudhary (2016) in the evaluation a locally fabricated maize shelling machine.

The minimum and maximum diameter results from Table 2 were used to determine the clearance between the spikes and concave. Design consideration was taken to ensure that the clearance was just enough to all allow detachment of the grains from the cob without damaging them or without leaving them on the cob. Hence the clearance for this study was 25 mm in agreement with Chaudhary (2016).

3.3 Performance evaluation of the improved sheller in relation to market sheller

From Table 3, it was noted that the mean output capacity of the modified maize sheller was significantly different (p<0.05) from that of market maize sheller (Table 3). This was attributed to the modification of the hopper from wedge shaped hopper consisting of a trough with a narrow outlet (200 mm × 150 mm) to a conical shaped hopper with a larger outlet (250 mm × 200 mm) that allowed more maize to be fed into the shelling unit. The significant difference could also have been attributed to the bigger shelling chamber of the modified maize sheller (270 mm diameter and 1,100 mm long) compared to the 220 mm diameter and 1,000 mm long shelling chamber for the market maize sheller.

There was no significant difference between the shelling efficiency of the modified sheller and the market maize sheller. This was attributed to the fact that both the market maize sheller and the modified maize sheller used the same mechanism of shelling. In both machines, shelling was a result of impact forces by the spikes due to shelling drum rotation and the friction created between the shelling drum and the sieve.

Table 3 Market maize sheller versus the improved maize sheller

Performance indicator	market maize sheller	Improved maize sheller	p-values
Output capacity, kg h^{-3}	608.0±15	1,581.0±5.67	p<0.05
Shelling efficiency, %	97.4±0.46	98.0±0.38	p>0.05
Cleaning efficiency, %	18.4±2.57	98.3±0.17	p<0.05
Grain damage percentage, %	8.4±1.25	0.7±0.13	p<0.05

There was a significant difference between the cleaning efficiency of the modified maize sheller and the market maize sheller. This was attributed to increased number of the blower blades from four for the market maize sheller to eight for the modified maize sheller on addition to the improved power transfer system. This generated the required air inflow of 0.206 m^3 s^{-1} to sack and blow out the chaff out of the sheller through the blower outlet. Aremu et al. (2015) designed a blower with eight blades and obtained a cleaning efficiency of 95.89% whereas Chaudhary (2016) designed a blower with four blades recorded a cleaning a efficiency of 93.48 %.

There was a significant difference between the grain damage percentage of the modified maize sheller and the market maize sheller. This was attributed to the increased screen holes from 12 mm for the market maize sheller to 15 mm for the modified maize sheller. As a result of increased sieve holes, maize grain went through the screen holes easily preventing them from being impacted on by shelling forces than required for shelling.

3.4 Variation of moisture content and shelling speed with four performance indicators

3.4.1 Shelling efficiency and grain damage percentage

From Figure 2, it was observed that the shelling efficiency varied with both moisture content and shelling speed from 96.4% to 99.1%. These findings were in agreement with Oriaku et al. (2014) and Ogunlade et al. (2014). When the moisture content reduced, it resulted into an increase in the shelling efficiency of the modified sheller as shown in Figure 2. This may be due to the reduction in the resistance to detachment from the cobs and the operational energy required to remove the grains from the cobs as moisture content reduced. Also increased shelling speed increased the shelling efficiency. This may be due to the increased ease of detachment of the maize grains from the cobs with higher impacts and friction created between the shelling drum and the concave as the shelling speed increases. The moisture content and the shelling speed significantly affected the shelling efficiency ($p<0.05$). However, the interaction between the moisture content and the shelling speed did not significantly affect the shelling efficiency ($p>0.05$).

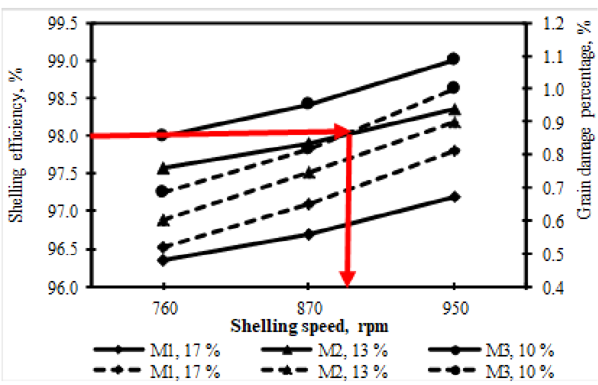

Figure 2 Effect of shelling speed and moisture content on shelling efficiency and grain damage percentage

It was also observed that the grain damage percentage varied from 0.52% to 1.09% (Figure 2). These values were less than 5.23% obtained by Ilori et al. (2013) and Ogunlade et al. (2014) which is an advantage. The reduction in the broken percentage could be attributed to the increase in the sieve holes from 12 mm to 15 mm. Therefore, the maize grains would fall through the sieve immediately after shelling. A reduction in moisture content increased the grain damage percentage. This may be due to the reduction in deformability of the grains which reduces the resistance to breakage as the moisture content reduces. The percentage of broken grains increased with an increase in the shelling speed. This may be due to increased force to the maize grains on the cob with increased cylinder speed and higher frequency of impacts for the same shelling length which resulted in severity of rubbing action at higher speed (Chaudhary, 2016). Both moisture content and shelling speed significantly affected the grain damage percentage ($p<0.05$). The interaction between the moisture content and shelling speed (main effects) did not significantly affect the grain damage percentage ($p>0.05$).

3.4.2 Optimization of the moisture content and shelling speed

From Figure 2, all the grain damage percentage results presented were below the recommended value of 2% (SEATINI, 2014). Therefore, during the optimization process, the grain damage percentage values were not used. According to Oriaku et al. (2014), the recommended shelling efficiency is 98% and above. The equilibrium moisture content of maize in Uganda is 13.3% (FAO, 2013). Therefore, the optimum moisture content out of the 10%, 13% and 17% was 13%. At 98% shelling speed and 13% moisture content, the optimum shelling speed is 896 rpm as shown by Figure 2.

3.4.3 Output capacity

The output capacity varied from 1,200 to 1,799 kg h^{-1} for all tested treatment combinations as seen in Figure 3. These results were in agreement with the findings of Roy et al. (2017). A reduction in moisture resulted into an increase in the output capacity of the modified maize sheller at the same shelling speed. This may be due to less time required to detach the maize grains from the cob as the moisture content reduced as explained by Chaudhary (2016). The output capacity was greatest at a moisture content of 10% and lowest at 17%.

Increase in shelling speed caused an increase in the output capacity of the modified sheller. This may be due to the increased detachment of the grains from the maize cobs as a result of higher impacts and friction created between the shelling drum and the concave as the shelling speed increases. This was an observation noted by Chaudhary (2016). At the optimum shelling speed of 896 rpm and optimum shelling speed of 13%, the optimum output capacity was 1,620 kg h^{-1} and shown in Figure 3. Both shelling speed and moisture content significantly affected the output capacity ($p<0.05$) while the interaction between moisture content and shelling speed did not significantly affect the output capacity (p>0.05).

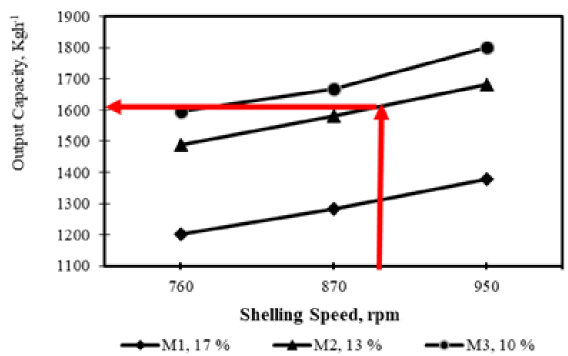

Figure 3 Effect of the shelling speed and moisture content on output capacity

3.4.4 Cleaning efficiency

It was observed that the cleaning efficiency varied from 97.9% to 98.5% (Figure 4).These results were in agreement with the results obtained by Chaudhary (2016) and Ogunlade et al. (2014). Cleaning efficiency increased with decreasing moisture content but the difference between the cleaning efficiency values as a result of moisture content was not significant (p>0.05). This may be due to the low moisture content within the chaff which is almost negligible. Therefore, there was no significant variation in the terminal velocity of the chaff as result of moisture content variation.

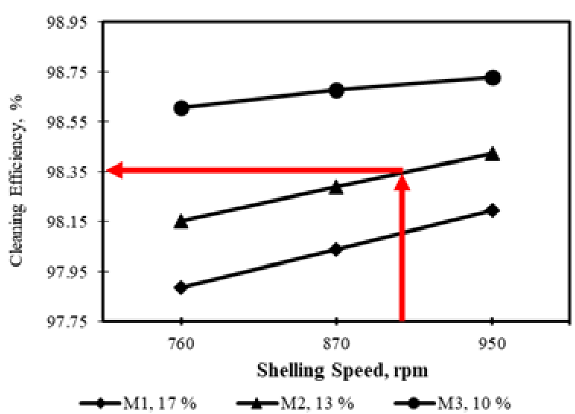

Figure 4 Effect of shelling speed and moisture content on cleaning efficiency

Cleaning efficiency increased with increase in the shelling speed. This may be explained by the increase in the airflow rate generated by the modified sheller blower compared with the market sheller blower. The increased blower speed was as a result of increased shelling speed. At the optimum shelling speed of 896 rpm and optimum moisture content of 13%, the optimum cleaning efficiency is 98.38% (Figure 4). Moisture content did not significantly (p>0.05) affect the cleaning efficiency while shelling speed significantly affected the cleaning efficiency (p<0.05). The interaction between moisture content and shelling speed did not significantly affect the output capacity (p>0.05).

3.5 Cost-benefit analysis of the multi-purpose vehicle shelling technology

The results of the benefit-cost analysis of the modified maize sheller powered by the multi-purpose farm vehicle are presented in Table 4 and Table 5.

Table 4 Various costs for the modified maize sheller.

Particulars	Cost, USD
Fixed Cost (cost of the sheller)	577.0
Annual variable cost	2,982.9
Annual gross income from shelling	3,405.4
Annual net returns	422.6

Table 5 Payback period and benefit-cost ratio of the modified maize sheller.

Particulars	Details
Payback Period (years)	1.37
Benefit-Cost Ratio	1.07

The benefit-cost ratio and payback period of the shelling technology were 1.07 and 1.37 years respectively. These results were in agreement with Milufarzana et al. (2015) who observed a benefit -cost ratio of 2.34 for a maize sheller for which is required to be greater than one. In addition, the sheller investment would pay back itself within 1.5 years or approximately three growing seasons, a relatively short payback period. Hence maize shelling using modified maize sheller powered by the multipurpose vehicle is a profitable venture for the entrepreneurs.

4 Conclusions

The poor performance of the market maize was attributed to small size of the shelling chamber, the wedge-shaped hopper consisting of a trough and a narrow inlet, small sieve holes, poorly designed shelling drum and the blower. To improve the maize shelling operation of the market maize sheller, these issued were dealt with and the multi-purpose maize shelling operation was optimized. The optimum shelling efficiency, moisture content, output capacity and cleaning efficiency was 896 rpm, 13%, 1620 kg h^{-1} and 98.3% respectively. The technology was found to be economically viable with a benefit-cost ratio of 1.07 and a payback period of 1.37 years.

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