MODIFICATION OF IAR AXIAL FLOW SORGHUM THRESHER

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ABSTRACT

Despite the high level of production of sorghum in Nigeria its threshing and cleaning operation remains among the major challenges to farmers especially in the northern part of the country. Efficient sorghum threshers are not available to Nigerian farmers. The prototype thresher developed at Institute of Agricultural Research (IAR) was associated with many problems such as: low capacity, and higher mechanical grain damage. To address these problems a modified model was designed, constructed and evaluated. The major components modified include feed hopper, cylinder and concave. The machine performance was evaluated at various levels of moisture contents, speed and feed rates. The results showed that threshing efficiency and throughput capacity of the modified thresher were 99.980 % and 253.960 kg/hr respectively while that for mechanical grain damage was 3.700 %. In comparison with the existing IAR thresher the results indicated an increased by 0.980, and 56.960 % for threshing efficiency and throughput capacity respectively While mechanical grain damage decreased by 3.840 %. The best combinations of independent variable for optimum operations were 13.000 % moisture content, 12.670 m/s cylinder speed and 5.000 kg/min feed rate. At these levels the improved prototype sorghum thresher gave performance values of 297.000 kg/hr throughput capacity, while threshing efficiency and mechanical grain damage were 99.800 and 3.400 % respectively.

Keywords: Modification, IAR, Axial Flow, Sorghum and Thresher

1.0 INTRODUCTION

Agriculture is the main occupation of people in Nigeria and is identified as a major driver of growth in the Nigerian economy (Yusuf, 2011). It plays a crucial role in the development of living standards of the citizens. Nigeria is one of the major sorghum producing countries in the world ranking as the second largest sorghum producer in the world (USAID, 2006) with over six millions tonnes annually (NAERLS, 2012). However, studies by Mustapha (2008) revealed that threshing of sorghum is still by manual method. This includes: spreading the sorghum heads on the ground and beating them strenuously with sticks at different spots in or near the farm or using pestle and mortar or by putting the sorghum head inside bag and beating with sticks. All these processes result in drudgery and grain losses. Odigboh (2004) gave post harvest losses estimate
in Nigeria to be up to 25% for food grains.

FAO (2003) explained that one approach of increasing food supply is by reducing heavy losses of food grains at post harvest stage. Ojha and Micheal (2003) also pointed out that indigenous threshing of sorghum is one of the time consuming, laborious and uneconomical activities. NAERLS (2012) reported that traditional farm tools still dominate agricultural production and processing in Nigeria which limit productivity and discouraged of youth in agriculture.

Efficient sorghum threshers at affordable price are not available to Nigerians farmers especially in northern part of the country where large amount of sorghum are being produced. On enquired the farmers revealed that threshers were not available (Lawan, 2008). Yusuf (2011) reported that lack of suitable machinery packages for the operations remain among the major problems of agricultural mechanization in Nigeria. Despite the effort of importing different types of threshers over the years such machines have their own challenges such as difficulty in maintenance, lack of spare parts or costly beyond affordable to farmers (Lawan, 2008).

For these reasons several prototypes sorghum threshers have been developed at Institute of Agricultural Research, Samaru, Zaria purposely to address the problems but yet some of these problems still exist or persist. Most of the problems associated with such prototypes threshers are low operating performance such as high grain losses and mechanical grain damage, low throughput capacity, low threshing and cleaning efficiencies. Although some of the above mentioned problems have been addressed by the previous IAR prototype sorghum thresher; but there is still need for modification of the existing IAR Sorghum thresher. The main challenges of this prototype sorghum thresher (Plate 1) were low throughput capacity and high mechanical grain damage beyond acceptable levels to farmers. This research work is aimed at addressing such problems by redesigning some of the components to improve on the performance.

2.0 MATERIALS AND METHODS

During modification there were some factors considered while modifying the sorghum thresher which include: The prime mover of rated power and speed of 6.080 kW and 1200.000 rpm respectively was used so that to achieve in a desire cylinder speed (Jain and Grace, 2003). Threshing Cylinder diameter was chosen as 22.000 cm while its speed was 10.000 m/s for sorghum (Jain and Grace, 2003). The size of pegs on the cylinder and cylinder covers were changed from round iron steel 20.000 mm to 12.000 mm so as to reduce high impact force on sorghum grain which contribute the increase in mechanical grain damage. For easy crushing of sorghum ear head, the space between and within the stationary and rotational pegs of beaters and cylinder cover was reduce from 60.000 and 30.000 to 50.000 mm and 10.000 mm respectively. The number of pegs around the cylinder was increased from 4 to 6 thereby reducing the threshing time and increase throughput capacity. 5.000 mm was used as concave opening to insure free passing of threshed grain which aid to the increase of throughput capacity and reducing mechanical grain damage. The dimension of the hopper was chose based on the power from the prime mover as stated by (Jain and Grace, 2003). The size of the other components was maintained from the existing machine. After these modifications, the modified machine (Plate 2) was evaluated and the performance was also deter-
mine using equation 1.0, 1.1 and 1.2, as given by (NSAE/NCAM/SON, 1995) and (Ndrika, 1994)

\[
T_e = 100 - \frac{Q_u}{Q_t} \times 100 \quad \ldots \quad (1.0)
\]

\[Q_u = \text{quantity of unthreshed grains in sample (kg)}\]
\[Q_t = \text{Total quantity of grain in sample (kg)}\]

\[
M_D = \frac{Q_b}{Q_t} \times 100 \quad \ldots \quad (1.1)
\]

\[Q_b = \text{quantity of broken grains in sample (kg)}\]
\[Q_t = \text{Total quantity of grain in sample (kg)}\]

\[
T_c = \frac{Q_s}{T} \quad \ldots \quad (1.2)
\]

\[Q_s = \text{Quantity of threshed grain collected after a threshing operation (kg)}\]
\[T = \text{Time taken for a complete threshing operation (hr)}\]

During evaluation the procedure stated by (Jain and Grace, 2003) was adopted which include the use of Stop watch for time taken while threshing, a tachometer for taking the cylinder shaft speed.

Mechanical and electronic weighing scale to measure the weight of the crop fed into the machine per unit time and measures the quantity of mechanical grain damage.

The operation was started by putting on the prime mover. A batch of a weighed sorghum heads were fed into the machine through the hopper. After each operation, samples were collected at the grain outlet and non-grain outlets. Grains and non-grain materials were separated for all the samples and weight separately in order to calculate the performance indices as given earlier.

### 3.0 RESULTS AND DISCUSSION

#### 3.1 Effect of Moisture Content on Threshing Efficiency and Grain Damage

The mean threshing efficiencies at different moisture contents and feed rate is illustrated in Figure 1.0. The highest threshing efficiency of 99.980 % was obtained at the least moisture content of 11.000 % (wet basis) and feed rate of 3.000 kg/min. This is agreeing with the result of Timothy (2012) which obtained the highest threshing efficiency of 99.600% at lowest moisture content and feed rate of 9.000 % and 1 .000 kg/min respectively. Similarly the lowest threshing efficiency of 91.870 % was recorded at highest moisture content (15.000 %) and feed rate of 5.000 kg/min. This also agreed with the Timothy (2012) results and Abiodun (2000) results. The authors reported that the lowest threshing efficiency was obtained at higher moisture content. The threshing efficiency increased with decrease in moisture content and feed rate which is associated with the bidding force between the sorghum grain and ear head. At low moisture content the bidding force is decreased hence require very little force for detaching the grain and vice visa. Similarly from figure 1.0 it can be seen that the threshing efficiency is also higher at 3.000 kg than at 5.000 kg feed rate as reported by Agunsaye (2007) and Kebede and Mishra (1990). The authors stated that the threshing efficiency increased with decrease in feed rate. This is due to the fact that higher feed rate may result in overloading the drum thereby reducing the impact on material hence, reducing the threshing efficiency. The R\(^2\) values at 0.930 and 0.990 show the good relation between the moisture content and threshing efficiency.
Figure 1.0 Effect of Moisture content on threshing efficiency at different feed rate

Figure 1.1 presented the effect of moisture content on mechanical grain damage at different feed rate. The maximum grain damage of 3.810 % was obtained at highest moisture content and feed rate of 15.000 % and 3.000 kg/min respectively. While the minimum value of 1.980 % was found at the lowest moisture content and second feed rate of 11.000 % and 5.000 kg/min respectively. This indicates that the damp of the sorghum heads the more grain damage obtained. It could be due to the decrease in hardness and sheer force of the grain at higher moisture content. As the moisture content of the sorghum grain decreases the resistance of the grain to shear is increases this causes more grain damage at higher moisture content and this is agree with the finding of Matouk et al; (2006) the author state that the hardness, shear force and shear stress decreases with increase of moisture content. However result obtained is not in line with Timothy (2012) result who recorded a maximum grain damage of 7.090 % at lowest moisture content level of (9.000 %) 1.000 kg/min feed rate and Abiodun (2000) obtained the highest grain damage of 7.000 % at lower moisture content (7.220 %) and 2.000 kg/min feed rate. Similarly from Figure 1.1 indicated that the mechanical grain damage increased with decreased in feed rate which may be associated with at lower feed rate the ratio of material to cylinder volume is low as compare to higher feed rate thereby material receive high impact than at higher feed rate thus, contributed to the more grain damage. However this study recorded a decrease in mechanical grain damage which could be attributed to the change of the spike tooth sizes which reduce the impact force on the material thereby, reducing the grain damage. The $R^2$ values of 0.941 and 0.941 show the good linear correlation between the moisture content and mechanical grain damage.
From Figure 1.0 and Fig. 1.1 can be understood that both threshing efficiency and grain damage have a perfect relation with moisture contents. As moisture contents decreased the threshing efficiency increased while the reverse is the cases for grain damage. Therefore the optimum moisture content can be determined by considering the two graphs. 13 % was obtained as optimum moisture content this may be due to the fact that at that level the grain damages are within the acceptable level (not more than 2.000 %) and the threshing efficiency was above 97.000 %.

3.2 Effect of Moisture content on throughput capacity at different feed rate

Figure 1.2 shows the effect of moisture content and feed rate on throughput capacity. The throughput capacity increases with decrease in moisture content. The maximum throughput capacity of 250.000 kg/hr was recorded at 11.000 % moisture content levels and 5.000 kg/min feed rate while the lowest value of 148.950 kg/hr at 3.000 kg/min and 15.000 % moisture content level. This show that the capacity increases with decreases in moisture content which could be at low moisture level sorghum ear head requiring less force for grain to detach hence, throughput capacity increases. Timothy (2012) reported similar result and obtained the highest throughput capacity of 110.000 kg/hr at the lowest moisture content of (9.000 %) and the minimum throughput capacity of 43.000 kg/hr at the highest moisture content of (16.000 %), however, this research observes an increased of throughput capacity from 110.000 kg/hr to 250.000 Kg/hr which may be connected to redesign of cylinder, spike tooth arrangement and concave opening.
Figure 1.2 Effect of moisture content on Throughput capacity at different feed rate

Figure 1.2 also illustrated that the throughput capacity increases with an increase of feed rate and is agreed with Abiodun (2000) the author stated that the throughput capacity decreases with decreases in feed rate and found the highest throughput capacity of 66.000 kg/hr at the highest feed rate level (4.000 kg/min). This it could be due to at higher feed rate more threshed material is obtained which lead to the more output per unit time hence increased the throughput capacity. The $R^2$ 0.738 and 0.833 values indicate that a linear relation between the moisture content and throughput capacity.

3.3 Effect of cylinder speed on threshing efficiency and Grain Damage at different feed rate

Figure 1.3 shows the effect of cylinder speed on threshing efficiency at different feed rate. The threshing efficiency increased with increased of cylinder speed. The highest threshing efficiency of 99.960 % was obtained at 1100.000 rpm cylinder speed and feed rate of 3.000 kg/min while the lowest value of 90.390 % was recorded at a cylinder speed of 700.000 rpm and feed rate of 5.000 kg/min. This result is agreed with the result of Timothy (2012) the author state that the threshing efficiency increased with increased of cylinder speed. And found the highest threshing efficiency of 99.800 % at highest speed level of 700.000 rpm and 9.000 % moisture content. A slight increase of threshing efficiency was recorded which may be due to the increased of the number and arrangement of spike tooth and higher energy imparted to the sorghum ear head. The $R^2$ values of 0.990 and 0.991 indicate a strong relation between threshing efficiency and cylinder speed.
Figure 1.3 Effect of speed on threshing efficiency at different feed rate

Figure 1.4 illustrated the effect of cylinder speed on mechanical grain damage. From the figure, the mechanical grain damage increased with increased of cylinder speed which is due to the high impact force from the spike and concave cylinder clearance. The highest grain damage of 3.760% was obtained at the speed level of 1100.000 rpm and lowest feed rate of 3.000 kg/min while the lower grain damage value of 2.110% was recorded at speed level of 700.000 rpm and feed rate of 5.000 kg/min. Timothy (2012) reported similar result with the maximum grain damage of 5.090% at the speed level of 700.000 rpm and obtained a minimum grain damage value at 300.000 rpm cylinder speed. R² value of 0.965 and 0.977 illustrated very close relation between the cylinder speed and mechanical grain damage.

Figure 1.4 Effect of speed on Mechanical grain damage at different feed rate

However, the relationship between the two parameters i.e. threshing efficiency and grain damage against cylinder speed indicated a strong relation therefore the optimum cylinder speed can chose...
3.4 Effect of cylinder speed on throughput capacity at different feed rate

Figure 1.5 presented the effect of cylinder speed on throughput capacity from the graph the throughput capacity increased with increase of cylinder speed which could be due to the fast rotation of the drum and high energy from the engine to make high impact on the Sorghum ear head at a time hence increasing the level of grain detachment from ear head. The maximum of 235.960 kg/hr was obtained at the cylinder speed of 1100.000 rpm and feed rate of 5.000 kg/min while the minimum throughput capacity of 96.500 kg/hr was observed at the speed level of 700.000 rpm and feed rate of 3.000 kg/min. The results show an increase of throughput capacity from 110.000 kg/hr to 2305.960 kg/hr when compared with the previous IAR sorghum thresher. This may be associated with the redesign of cylinder, concave, spike and spike tooth arrangement thereby increasing the rate of crushing and shattering of the material hence increasing the throughput capacity. The $R^2$ values of 0.936 and 0.884 show a strong correlation between throughput capacity and cylinder speed.

![Figure 1.5 Effect of speed on throughput capacity at different feed rate](image)

4.0 CONCLUSION

An IAR prototype sorghum thresher was modified and evaluated. The performance achieved were 99.980 %, 3.700% and 250.000 kg/h for threshing efficiency, grain damage and throughput capacity respectively. However, as compared the result with the existing IAR sorghum thresher a decrease in mechanical grained damage from 5.080% to 3.700% was obtained. Similarly the throughput capacity has increased from 110.000 kg/hr to 250.000 kg/hr. A slight increased of threshing was achieved from 99.800 to 99.980 %. The best combination of the independent variables for optimum operation was observed at 13% moisture content 12.670 m/s cylinder speed and 5.000 kg/min feed rate.
Plate 1: Existing IAR Sorghum thresher

Plate 2: Modified IAR Sorghum thresher
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