Modification and Performance Evaluation of Cleaning System for IAR Sorghum Thresher

[*1]Nura A. Sale, [2]U. S Muhammed, [2]M. A Gwarzo and [1]S. I. Idris
1National Agricultural Extension and Research Liaison service, Ahmadu Bello University, Zaria
2Agricultural Engineering Department, Ahmadu Bello University, Zaria
{nuraalhajisale|usmgambo|idrisyaro500}@yahoo.com

Abstract— Sorghum is a major source of food for most families and as raw material to many industries in Nigeria. Cleaning is among the most important post-harvest operation after threshing. However, manual cleaning of crop is quite tedious, time and labour intensive. A prototype thresher has already been developed at Institute of Agricultural Research (IAR) but yet it has been associated with many difficulties during operation. Among the problems of IAR prototype sorghum thresher are low operating performance such as higher scatter loss and low cleaning efficiency thus the need for modification to improve the above mentioned parameters. This study was undertaken to modify the cleaning system of the IAR sorghum thresher with the aim of minimizing the drudgery involved in its operation and to improve its performance. The major modifications were on shaking mechanism and sieves. The number of sieves was increased from one to three while the connecting rode for shaking mechanism was changed from horizontal to vertical orientation. The sizes of the pulleys were also changed. Randomized Complete Block Design (RCBD) experimental design was used for determining the effect of moisture content, speed and feed rate on the cleaning performance of the machine. The maximum performance achieved were 99.95 %, 5.45 %, and 250 kg/h for cleaning efficiency, scatter loss and throughput capacity respectively

Keywords— Cleaning system, IAR Sorghum thresher, Modification,

1 Introduction

Sorghum is a major source of food to most families and raw material to many agro-based industries and is grown in the Sudan, northern and southern guinea savanna zones in Nigeria (Reoney, 2003). Rohrbach (2004) reported that there has been an increasing demand for its usage in the production of food, feed products, alcoholic and non-alcoholic beverage both locally and internationally. Cleaning is an important operation undertaken to remove foreign and undesirable materials from threshed crops (seeds/grains). Grain cleaning is a material separation process in which foreign material and undesired produce are separated leaving the produce cleaned for storage or further processing (Rohrbarch, 2004). According to Wimberly (1983), grains are cleaned to reduce drying and storage cost and minimize deterioration during storage which can reduce market value. In addition, cleaning remove materials that could damage processing machines (such as conveyor and milling machine). Rohrbarch (2004) reported that clean grains have great potential both on the domestic and international markets due to their increased demand for the production of food /feed products and alcoholic/non-alcoholic (beverage).

Traditional methods of threshing and subsequent cleaning of grains are physically demanding and energy consuming (Ali, 1986). Manual cleaning of crops is an arduous, time and labor consuming operation. Although several efforts have been made to improve threshing and cleaning of sorghum using motorize thresher, efficient and affordable prototype sorghum threshers of dual operations (threshing and cleaning) have not been readily available in Nigeria. The major challenges of existing prototype sorghum threshers are unsatisfactory cleaning efficiency and higher grains losses. Therefore, they are not widely adopted by local farmers.

There is an urgent need to develop a machine that would be capable of threshing and cleaning grains so as to reduce human labor in post-harvest operations and to add more market value to the grains. Therefore, the objective of this study was to improve the cleaning efficiency and minimize scatter losses of the grains within acceptable level (less than 5 %). This would enhance production and reduce the risk of losses at post-harvest.

2 Materials and Methods

2.1 Design Consideration

The speed of prime mover of 1200 rpm was used based on the recommendation by Jain and Grace (2003). The pulley diameter of 104 mm was considered. The machine consists of three set of sieves. The first sieve (straw sieved) has hole diameter of 6 mm while the second (chaff sieved) and third (cleaned sieved) have diameter of 4.5 mm and 4 mm respectively.

2.2 Material Selection

The materials used for the modification of cleaning mechanism were: metal sheet, bearing, belt, pulleys and iron rode. These materials were selected based on, strength, availability and costs. Belts were selected according to the standard size that fits the chosen pulleys (V-belts) while mild steel rods of 12 mm were used as connecting rod. The selection was based on the resistance to all possible stress which may be subjected to during operation. The metal sheets were selected by considering failure due to shearing and crushing. Tilt angle was selected according to Jain and Grace (2003). The sieve hole/shape was chosen based on the physical properties of the sorghum grain as quoted by Simonyan and Yiljep 2006.

*Corresponding Author

2.3 Determination of the Size of Component

2.3.1 Shaker displacement

The displacement of the shaker was determined as: (Abdulsalam, 2011)

$$r = \frac{\pm\sqrt{[L^2-(X-r\cos^2\theta)^2]}}{\sin 2\theta} \quad (1)$$

r = length of shaker displacement (mm)
L = length of connecting rod (mm)
X = length of the crank arm (mm)
θ = Tilt angle

2.3.2 Thickness of Metal sheet

$$\text{Shearing stress } (\tau) = \frac{P_s}{2bt} \quad (2)$$

Where:
Ps = Load on the metal sheet
bt = Area of the metal sheet

Failure due to crushing= $\frac{P_s}{\pi dt}$ (Hall et at, 1982)

Where
Ps = Load
πdt = Area

2.3.3 Determination of shaft diameter

The determination of the shaft diameter was obtained from the ASME code (1948):

$$d3 = \frac{16}{\pi S_s}\sqrt{(k_b M_b)^2 + (K_t M_t)^2} \quad (3)$$

Where:
Mb = bending moment, (Nm)
Mt = torsional moment, (Nm)
Kb = combined shock and fatigue factor applied to bending moment = 1.5
Kt = combined shock and fatigue factor applied for torsional moment = 1.0
Ss = allowable shear stress for shaft with keyway = 90.3 MN/m2
d = shaft diameter, m

2.4 Determination of pulley dimension

The dimension of the Pulley was determined on the speed ratio formula as recommended by Khurmi and Gupta (2007).

N1D1 = N2D2 (4)

Where:
N1 = Speed of drive (prime mover) rpm
D1 = diameter of drive pulley (mm)
N2 = Speed of cylinder pulley (rpm)
D2 = diameter of cylinder pulley (mm)

2.5 Experimental Procedure and Design

The operation 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 state below. A randomized completely block design experiments (RCBD) was used. A layout of 5 levels of fan speed (700 rpm, 800 rpm, 900 rpm 1000rpm and 1100 rpm) by 2 levels of feed rates (3kg/h and 5kg/h) and five levels of moisture contents (11%, 12%, 13%, 14% and 15%) in three replications was used. Total of 50 treatments was used. The results obtained from the experiments were subjected to some statistical package using SAS software 9.0 for the analysis of variance in respect to the various performance indices.

2.6 Performance evaluation

After modification the machine was evaluated for the following parameters

2.6.1 Cleaning efficiency Ce (%)

$$Ce = \frac{(W_t - W_c)}{W_t} \times 100 \quad (5)$$

Where:
Wt= Weight of total mixture of grain and chaff received at the grain outlet (kg)
Wc= Weight of chaff at the main outlet of the thresher (kg)

2.6.2 Scatter Loss, SL (%)

During the operation some grains were lost due to scattering through the sieved. The percentage of such grains was determined as

$$SL = \frac{Q_l}{Q_t} \times 100 \quad (6)$$

Where:
Ql= Quantity of grains scattered around the machine after operation (kg)
Qt= Total quantity of grain in sample (kg)

2.6.3 Grain throughput capacity, Te (kg/hr)

The capacity of the machine in terms of the total quantity of cleaned sample per unit time was determine as:

$$T = \frac{Q_s}{T}c \quad (7)$$

Where:
Qs= Quantity of grain collected after cleaning operation (kg)
T = Time taken for a complete cleaning operation (hr)

2.6.4 Determination of moisture content

The moisture content of the grain was determined using oven dry method in which the sample was dried at 130°C for 18 hours ASAE (1972). The moisture content was varied by drying the sorghum grain in batches using open sun drying.

$$Mc = \frac{W_i - W_d}{W_i} \times 100\% \quad (8)$$

Where:
Mc = moisture contain (%)
Wi = initial weight of sample (kg)
Wd = dried weight of sample (kg)

3 Results and Discussion

3.1 Effect Of Moisture Content on the Cleaning Efficiency at Different Feed Rate

The cleaning efficiency increased with decrease in moisture content reaching maximum (99.91 %) at moisture level of 11% and feed rate of 3 kg/min (Fig. 1). Yavini (2002) and Timothy (2012) reported similar result indicating that the cleaning efficiency increased with decrease in moisture content and obtained a maximum cleaning efficiency of 72.6%. However a minimum of 84.87% cleaning efficiency was recorded at highest moisture content level of (15%) and feed rate of 5 kg/min. This could be due to the increased of coefficient of static friction between grains and other constituent material. The cleaning efficiency decreased with increased feed rate which may be due to fact that at higher feed rate the quantity of the threshed material waiting for cleaning increased thereby over burden the cleaning unit at a particular time, hence reduce the cleaning efficiency. The R2 values show a good linear relation between the moisture content and cleaning efficiency.

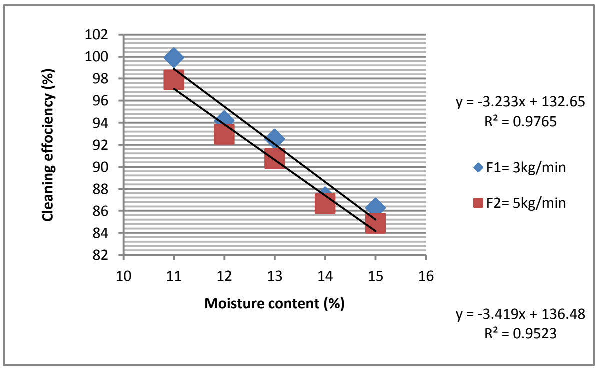

Fig 1: Effect of Moisture content on the cleaning efficiency at different feed rate

3.2 Effect of Moisture content on Scatter loss at different feed rates

The highest scatter loss of 5.25% was recorded at 11 % moisture content and 5 kg/min feed rate while the lowest value of 2.59% was obtained at 15 % moisture content and 3 kg/min feed rate. Fig 2 indicates that the scatter grain increased with decreased in moisture content and increase in feed rate. This may be link with the decreases in moisture content decrease the terminal velocity of the grains thus the fan can easily blow both grain and chaff. Similarly an increase in feed rate result of increase in scatter losses. This could be as the feed rate increases the quantity of the threshed material will also increases which lead to increase the tendency of more material to move and bounce over the sieve thereby increase the scatter losses Fig. 2 illustrate. The R2 values show strong linear relation between the moisture content and scatter losses. From the evaluation of the modified machine a decrease in scatter loses was recorded which could be due to the redesign of cleaning mechanism.

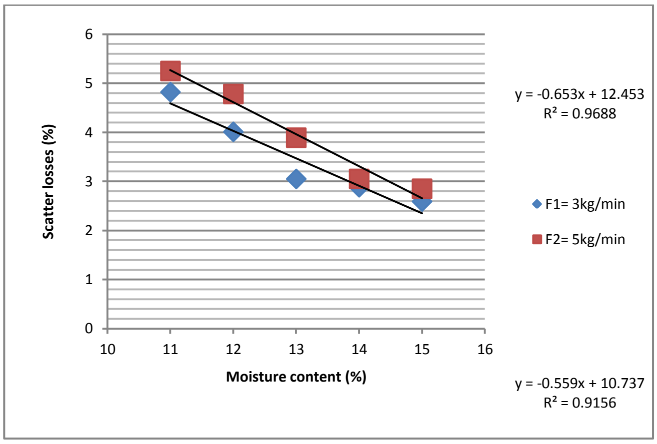

Fig 2: Effect of Moisture content on Scatter losses at different feed rate

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

Figure 3 shows the effect of moisture content and feed rate on throughput capacity. The throughput capacity increased with decrease in moisture content. The maximum throughput capacity of 250 kg/hr was recorded at 11% moisture content levels and 5 kg/min feed rate while the lowest value of 148.95 kg/hr at 3kg/min and 15% moisture content level. This show that the capacity increased with decreased in moisture content which could be due to the fact that at low moisture level sorghum ear head required less force for grain to detach. Timothy (2012) reported similar result and obtained the highest throughput capacity of 110 kg/hr at the lowest moisture content of (9 %) and the minimum throughput capacity of 43.kg/hr at the highest moisture content of (16 %), however, this research observed an increased throughput capacity from 110 kg/h to 250 Kg/hr. Figure 1.3 also illustrated that the throughput capacity increases with an increase feed rate and agreed with Abiodun (2000) the author stated that the throughput capacity decreased with decreased in feed rate and obtained the highest throughput capacity of 66 kg/h at the highest feed rate level (4kg/min). The R2 values indicate that a linear relation between the moisture content and throughput capacity exists.

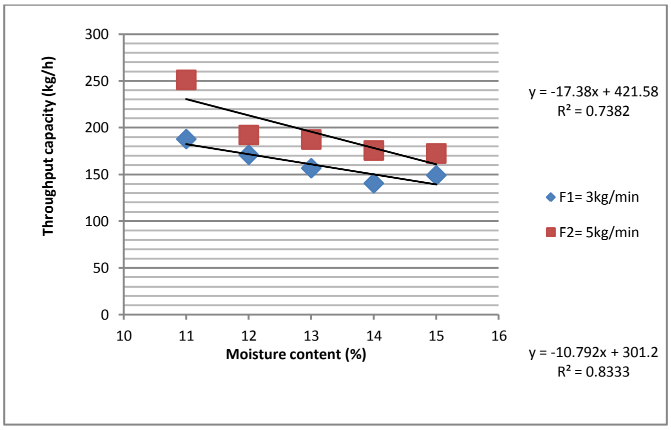

Fig. 3 Effect of moisture content on Throughput capacity at different feed rate

3.4 Effect of speed on cleaning efficiency at different feed rate

Figure 4 shows the effect of fan speed on cleaning efficiency at different feed rate. The maximum cleaning efficiency of 99.83 % was obtained at 1100 rpm fan speed and 3 kg/min feed rate while the lowest cleaning efficiency of 91.53 % was recorded at the lower speed level of 700 rpm and second feed rate 5kg/min. The results obtained is higher than that of Timothy (2012) the author obtained a maximum cleaning efficiency of 70.3 % at 700 rpm and 9 % moisture content level and 1 kg/min feed rate. This could be associated with the increase in the number of sieves from one sieve to three different sizes of sieves. However, this is similar to the Abiodun, (2000) results and obtained the maximum cleaning efficiency of 72.77 % at the highest speed level of 800 rpm. The R2 values show a strong linear relation between cleaning efficiency and fan speed.

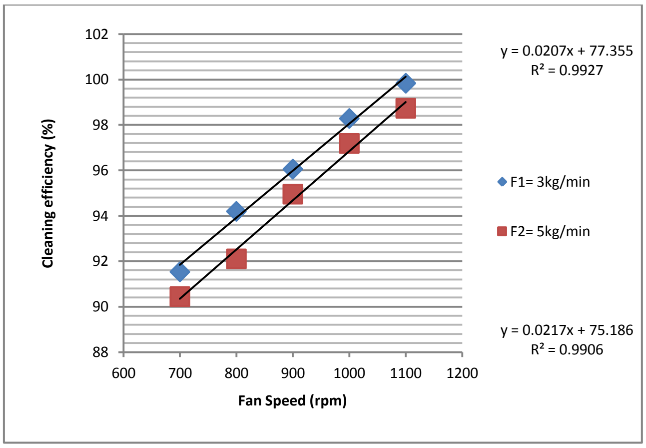

Fig 4 Effect of Fan speed on cleaning efficiency at different feed rate

3.5 Effect of Fan speed on scatter losses at different feed rate

Fig 5 shows the effect of fan speed on scatter losses at different feed rate. The highest scatter grain of 5.38% was recorded at 1100 rpm fan speed and 5 kg/min feed rate while the lower value of 2.02% was obtained at 700 rpm fan speed and 3 kg/min feed rate. A decrease of scatter grain was record as compared with the Timothy (2012) result. The author recorded the maximum of 11.8 % scatter losses at fan speed of 700 rpm. These decreased scatter grains may be due to redesigning shaking mechanism. Fig 5 shows that an increase of fan speed and feed rate results to an increase of scatter grain. These may be connected to the fact that at higher speed large percentage of the grains are carry away by the fan while some are waiting on the sieve and pile up thereby causing grain losses. R2 values show a close linear relation between the scatter grain and cylinder speed.

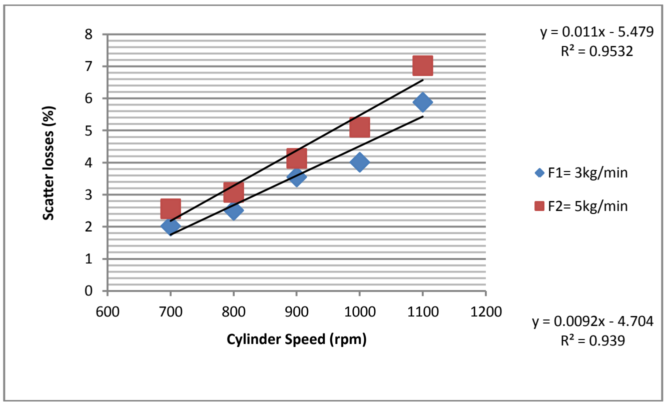

Fig 5: Effect of fan Speed on Scatter losses at different feed rate

3.6 Effect of Fan speed on throughput capacity at different feed rate

Fig 6 presented the effect of fan speed on throughput capacity. The maximum of 235.96 kg/hr was obtained at the fan speed 1100 rpm and feed rate of 5 kg/min while the minimum throughput capacity of 96.50 kg/hr was observed at the speed level of 700 rpm and feed rate of 3kg/min. The results show an increase of throughput capacity from 110 kg/hr to 235.96 kg/hr when compared with the previous IAR sorghum thresher. The R2 values show a strong correlation between throughput capacity and fan speed.

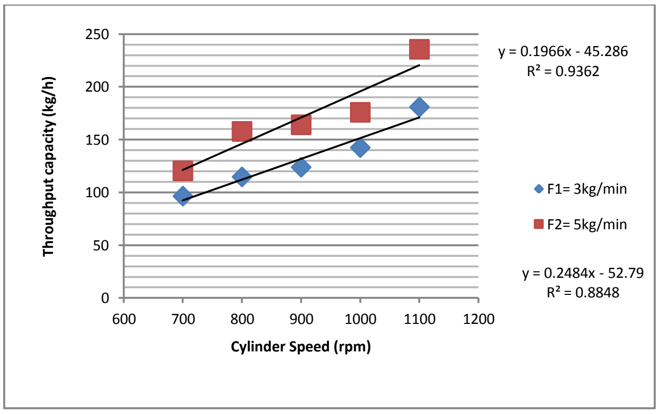

Fig 6: Effect of fan speed on throughput capacity at different feed

4 Conclusion

The modification and performance evaluation of the cleaning system of IAR sorghum thresher was conducted and cleaning efficiency was observed to increase with a decreasing feed rate and moisture content and increase in the fan speed. Scatter loss increased with an increase in cylinder speed and feed rate and lower moisture content. Throughput capacity also increased with an increase in cylinder speed and feed rate and lower moisture content. The performances achieved of the machine were 99.95%, 5.45%, and 250 kg/h for cleaning efficiency, scatter loss and throughput capacity respectively. However, when the results were compared with that of Timothy (2012) a decrease in scatter losses from 11.6 % to 5.45 % was obtained. Similarly the throughput capacity increased from 110 kg/h to 250 kg/h. An increase of cleaning efficiency was achieved from 70.3 to 99.95 %.

REFERENCE

Abdulsalam, M. (2011). Performance Evaluation of a shaker mechanism of an axial flow maize sheller.11th international conference and 32nd annual general meeting of Nigerian institute of agricultural engineers 11th – 20th October,2011 Ilorin Oyo state Nigeria.

Abiodun, A. (2000). Design and Construction of Manually operated sorghum thresher. Unpublished HND.project. Department of Agricultural Engineering Samaru, College of Agriculture, Zaria, Nigeria

Ali, M. A. (1986) Comparative Ergonomics Studies of Male and Female Operations on Selected Farm Task. Unpublished M.Sc. Thesis.Ahmadu Bello University, Zaria, Nigeria.

ASAE. (1972). American Society of Agricultural Engineers; ASAE Standard S.352-1 and S 401-1. Yearbook, 2950 n Taylor, Niles Road, St Joseph, Michigan 49085.Pp 25

Hall, A.S., Halloenko, A. R and Laughin, H. G (1982). Theory and problems of machine design schaums book line series Mc grave hill book company Pp:112

Jain, S. C and Grace P.(2003). Farm machinery an approach. Centre for farm machinery training & testing institute of Tractor Nager, BUDN. Published Standard publishers Distributors. 1st edition

Khumir, R.S and Gupta, J.K (2007).A textbook of machine design. 14 Edition, Eurasian Ltd. Ran Nagar New Delhi, pp.1230

Rohrbach, D. D, 2004. Improving the commercialization of sorghum and pearl millet in Africa.http.www.afripo.org.uk/peper22.rohrbach.pdf.30/12/14.

Rooney, L. W, 2003. Overview of sorghum and millet research failures and successes.Faculty of food science, cereal quality laboratory, soil and crop science department, Taxas A & M University USA.http://www.afripo.org.uk/paper.rooney.pdf.15/10/03

Rural sector enhancement programme (RUSEP), 2001. Need assessment study for market-driven agricultural technology transfer and commercialization in KatsinaState. USAID/IITA.Pp51

Simonyan, K. J., Yiljep Y D. and O.J Mudiare 2006. Modeling cleaning Process of a stationary sorghum thresher. "Proceeding of the Seven International Conference of Institute For Agricultural Engineers" Vol. 28:Pp106-109

Timothy, Y. J, (2012). Design, Construction and Performance Evaluation of an improve Sorghum thresher. Unpublished MSc. thesis. Department of Agricultural Engineering Ahmadu Bello University, Zaria, Nigeria

Wimberly J. E. (1983). A technical handbook for the paddy rice postharvest industry in develoing countries. International Rice Research Institute, Manila, Philippines.

Yavini, S., 2002. Development of improved IAR multi-crop thresher.Unpublished B. Eng. Project Department of Agricultural Engineering Ahmadu Bello University, Zaria. Pp:45

Rear view

Side view