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COMPARATIVE ANALYSIS OF THE THRESHING CYLINDERS PERFORMANCE ON SORGHUM

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ABSTRACT Two threshing cylinders were evaluated on sorghum in a conventional thresher. Moisture content of sorghum grain at threshing was 8 % wb while the cylinder – concave clearance was 1.5 cm at inlet, 0.3 cm inside and 0.7 cm at the outlet for the two cylinders. Threshing speed ranged between 3.6 and 6.4 m/s; fan speed 2.1 and 4.6 m/s and the sieve oscillation speed ranged between 1.47 and 2.59 m/s for cylinder I and II respectively. Feed rate ranged between 491 and 720 kg/hr for the two cylinders. Performance test results showed that threshing efficiency averaged 99.9 % for each of the two cylinders. In addition, cleaning efficiency ranged between 94.35 and 96.17 % and 98.06 and 99.8 % while cleaning loss ranged between 9.73 and 27.7 % and 6.5 and 9.91% for cylinder I and II respectively.

Keywords: Sorghum, Threshing cylinder, Threshing speed, Moisture content, Feed rate, Cleaning efficiency, Cleaning loss.

INTRODUCTION Sorghum (S*orghum bicolor*) is grown mostly in the Sudan, Northern and Southern vegetation zones of Nigeria. It is one of the crops grown in Africa as food crop with less than 5% of its annual production commercially processed by the industries (Rohrbach and Kiriwaggulu, 2001). It is a security crop used to produce such traditional fermented foods such as Ogi (Yoruba), Akamu (Ibo), Masa (Hausa), Tuwo (Hausa) among others (Obilana, 1981). There is increasing demand for sorghum as food, feed production, non – alcoholic and beverages (Rooney, 2003; Rohrbach, 2004).

Threshing is the process of separating grains from dry heads accomplished by impact of a fast moving element, rubbing, squeezing or a combination of these methods on the heads (Picket and West, 1988). Traditionally, in Nigeria, threshing is still being carried out manually involving beating the sorghum heads strenuously with sticks at different spots in or near the farm. Threshing points may be bare ground, on tarpaulin, in the field, stony or rocky areas and abandoned roads near the farm (Simonyan, 2006). Manual threshing of sorghum is labour intensive drudgery in terms of energy expenditure of 41.87 kJ/mins and heart beat rates per minutes of 150 (Ali, 1986). Losses occur during threshing due to spillage, incomplete removal of grains from heads, damage to grains and contamination with sands and stones. RUSEP (2001) reported that small-scale producers, who account for 90 % of the total agricultural production, are not using improved technology. This they opined, inhibits efficiency in terms of productivity, reduces quantity and quality of products and puts enormous strains on labour force.

Figure 1. Traditional threshing of sorghum

Mechanical threshers are usually designed using striking, squeezing and rubbing principles. There are different types of threshing cylinders - spike and loop cylinders thresh based on striking action mainly while rasp bar cylinders threshes mainly on friction and rubbing. Singh and Kumar (1976) reported that swinging hammers cylinder type consumed more power than the rasp bar and spike tooth cylinder. In addition, Singhal and Thierstein (1987) reported that the spike tooth and rasp bar cylinders are safe for use among the village farmers on manually fed stationary threshers.

Factors influencing threshing of crops can be broadly grouped into crop characteristics and machine parameters (Simonyan *et al.,* 2006). Threshing efficiency is related to the peripheral speed of cylinder. Threshing efficiency increases with increase in cylinder speed (Ige, 1978). Increasing cylinder speed means more impact between grain ear and revolving cylinder per unit time leading to grain damage (Harrison, 1975). Adjustment of concave clearance is a crucial factor for the quality of threshing. Crop feed rate is also an important factor affecting threshing efficiency (Simonyan and Oni, 2001). There is an optimum feed rate, excess of which causes blockage of threshing and separation system and a possible breakdown. A low feed rate would lead to a waste of time and money while a higher than optimal feed rate increases the total grain loss. Feed rate increases with cylinder speed and spike length (Joshi and Singh, 1980). Grain damage increases with increase in cylinder speed and decreases with increase in concave clearance, feed rate and moisture content (Ghaly, 1985). Grain loss increase with cylinder and blower speed (Kashyap and Pathak, 1976).

The relative importance of sorghum in rural food systems and to industries suggests that opportunities exist for its commercialization and mechanisation. Designing and developing an appropriate cylinder for sorghum threshers is a vital step in the mechanization of the post-harvest treatment of this important crop. The aim of this paper therefore is to report on the performance of two designed threshing cylinders on a motorized conventional sorghum thresher.

MATERIALS AND METHODS

The test rig The test rig used for the study is shown in Figure 2. It consists of frame, hopper, threshing unit, sieve, reciprocating mechanism, blower, and collection tray. The 100 cm long collection tray was divided into eight equal compartments. Each compartment is 11 cm long just as was done by Kutzbach (2003) and Rothaug *et al*., (2003). Figure 3 shows the sectional view of the sorghum thresher testing rig. A 3.75 kW (5 hp) engine was used to prime the threshing, sieving and blower units. The specifications of the sorghum thresher are listed in Table 1.

Figure 2. Sorghum thresher test rig

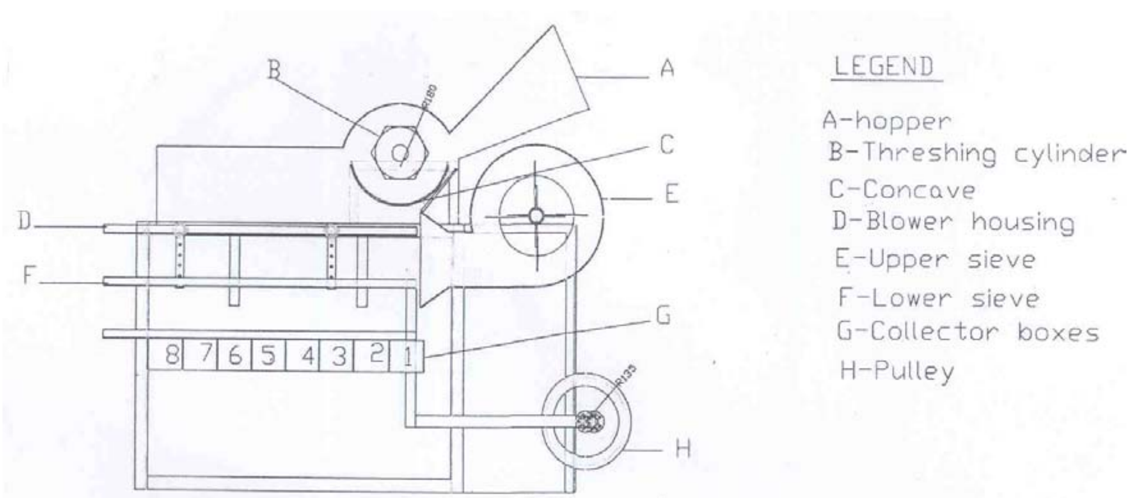

Figure 3. Sectional view of the sorghum thresher testing rig.

Table 1. Parameters of the sorghum thresher test rig**.**

Parameter	Dimension (m)
Overall length	1.474
Overall width	0.386
Overall height	1.323
Effective threshing cylinder diameter	0.140
Effective concave diameter	0.310
Sieve dimension	0.735 x 0.300
Sieve amplitude	0.05
Blower-major diameter	0.460
Blower- minor diameter	0.350
Blower- width	0.300
Blower-throat	0.150
Blower blades dimension	0.160 x 0.120
Sieve inclination	0^0(horizontal)
Air direction	0^0(horizontal)
Cylinder –concave clearance	0.015

Principle of operation Sorghum heads flowed under gravity to the threshing chamber where the impact of the revolving threshing cylinder threshed the grain. After contacting the threshing cylinder, the straw and loose kernels accelerate round the concave at different rates due to the difference in the coefficient of restitution of straw and grains. Grain that was freed falls through the concave on the reciprocating upper sieve. Threshed, unthreshed, partially threshed and some grains fell on the upper sieve. The conventional thresher does not have straw walker and grain pan. Everything coming from the threshing chamber is discharged on the upper sieve. As the sieves reciprocated there is horizontal and vertical displacement which moves straw to the end of the cleaning unit to be discharged. Air stream from the blower helped to disperse grain and straw which allowed grain to pass through upper sieve hole to lower sieve. As grain and chaff passed across air stream, the lighter materials are blown off, while clean grain was collected in collector compartments. The two threshing cylinders I and II were used alternately with the threshed products collected for analysis. Figure 4 shows the threshing cylinders used on the conventional sorghum thresher. Concave was formed into a basket by using 4 mm thick flat bars and 10mm diameter iron rods. The concave has a semicircular diameter of 310 mm.

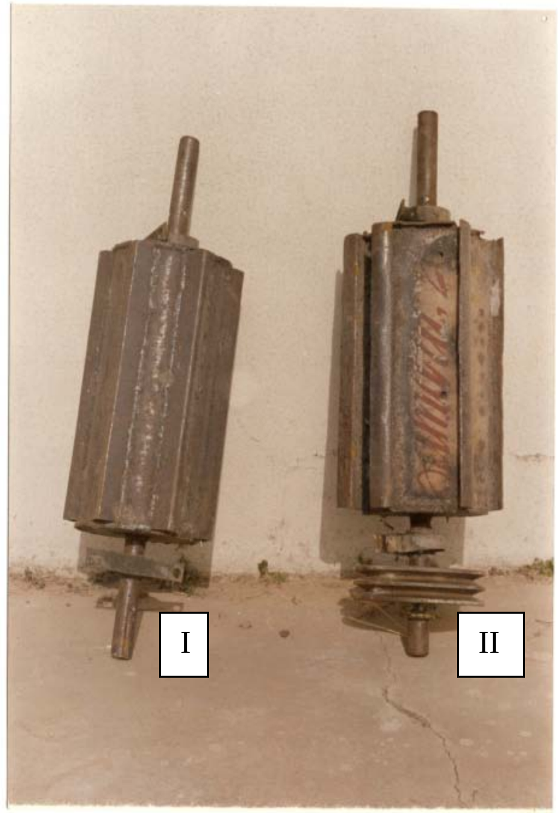

Figure 3. Threshing cylinders used on the sorghum test rig

Test procedure One kilogram of sorghum (SAMSORG 17) was taken randomly from a heap of harvested crop heads and fed into the hopper manually. Feeding time, cylinder speed, blower speed and sieve reciprocation speed and frequency were recorded. The feed rate was calculated in kg/hr. Grain output was expressed in kg/hr by recording the time taken in the threshing operation and weight of grain recovered. Moisture of sorghum at threshing was 8 % wb and the cylinders – concave clearance for the two cylinders were 1.5 cm at inlet, 0.3 cm inside and 0.7 cm at the outlet. Threshing speed ranged between 3.6 – 6.4 m/s; fan speed 2.1 - 4.6 m/s and sieve oscillation speed ranged between 1.47 and 2.59 m/s for cylinder I and II respectively. Feed rate ranged between 491 - 720 kg/hr for the two cylinders. Unthreshed tailings were manually separated from the straw to determine the threshing efficiency (TE).

The threshed product became the input in the cleaning process. Cleaned grains in each collector compartment were collected in a transparent polyethylene bag and labeled to be analyzed. Sample collected in each compartment was weighed with electronic weighing balance and cleaned manually to quantify the grain and non-grain material. The mass of the cleaned grain was recorded for each compartment. The difference gave the mass of impurities. This was used to calculate the cleaning efficiency (CE). Chaff blown out of the machine was collected in a black polyethylene bag and labeled accordingly. The waste collected was weighed using electronic weighing balance and manually cleaned to separate the grains. The cleaned grain separated from the waste was used to calculate the cleaning loss (C_L).

$$TE = 100 - \frac{D}{A} \tag{1}$$

Where:

TE = threshing efficiency, %

D = mass of unthreshed grain at the outlet per unit time, kg

A = total grain input per unit time (A= B + C + D)

B = mass of threshed grains at the main outlet per unit time, kg

C = mass of threshed grain at all other outlet per unit time, kg.

$$CE = \frac{G_0}{G_0 + C_{cg}} \times 100 \tag{2}$$

Where:

CE = cleaning efficiency, %

G_o = mass of pure grain at the outlet, kg

C_{cg} = mass of contaminant in cleaned grain, kg

$$C_L = \frac{G_w}{G_i} \times 100 \tag{3}$$

where:

G_o = mass of grain at the waste outlets, kg

G_i = mass of grain at input, kg.

Paired t test was used to test if there is any significant difference between the two threshing cylinders.

RESULTS AND DISCUSSION

Threshing efficiency The threshing efficiency for the two cylinders is shown in figure 5. The figure shows that the highest threshing efficiency from the two cylinders are 99.96 % and 99.89 % while the minimum threshing efficiency was 99.94 % and 99.89 % for cylinders I and II respectively. The t test gives no significant difference between the threshing efficiency obtained from the cylinders. The implication of this is that any of the two cylinders could be used to thresh sorghum.

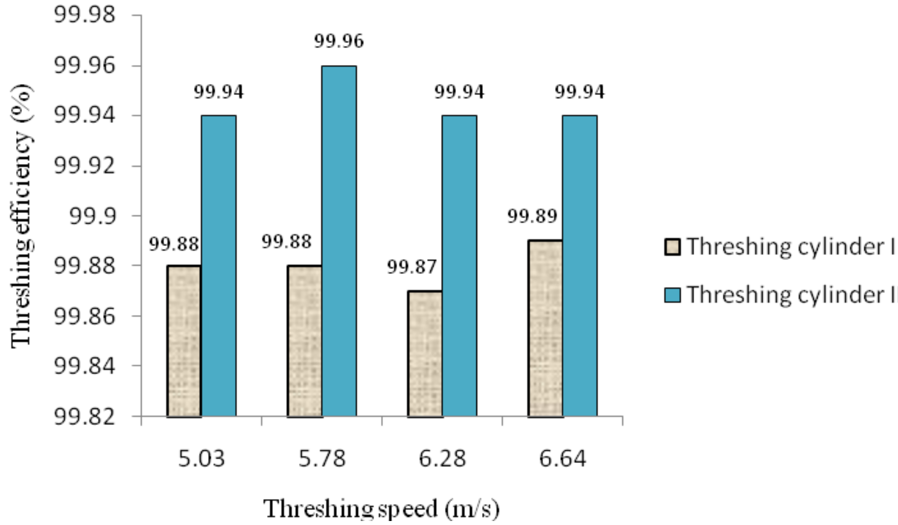

Figure 5. Threshing efficiency of the two threshing cylinders

Cleaning efficiency The cleaning efficiency obtained when using cylinders I and II is shown in figure 6. There are consistently higher values for cleaning efficiency for cylinder II than I for all the results obtained. The highest obtained cleaning efficiency was 99.8 % and 96.17 % while the minimum was 98.06 % and 94.35 % for cylinders II and I respectively. We observed that non-grain materials were chopped into fine particles. This accounted for increased particle size range. The formation of minute particles may also be the reason for the lower cleaning efficiency for cylinder I.

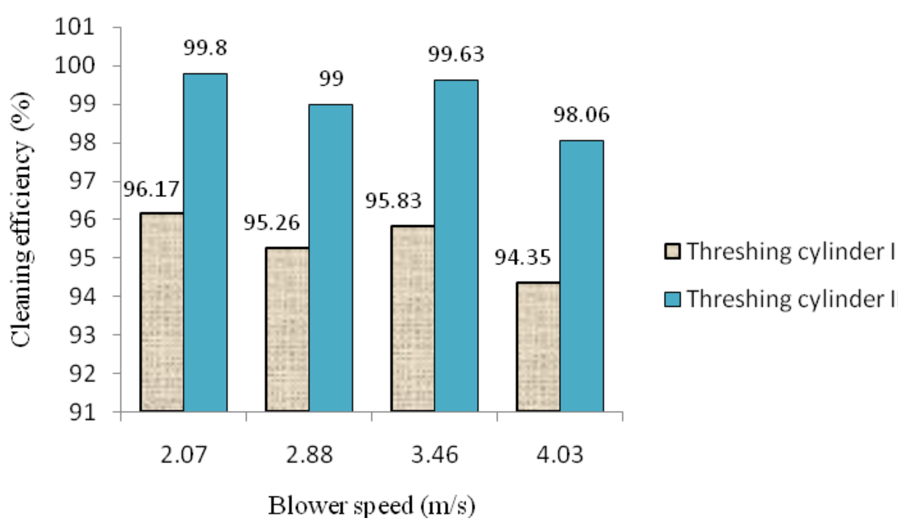

Figure 6. Cleaning efficiency of the two threshing cylinders

Cleaning loss The cleaning loss from the two cylinders is shown in figure 7. The result showed a consistently high cleaning loss for cylinder I than cylinder II. The highest cleaning loss of 27.73 % and 9.91 % was obtained while the minimum of 9.73 % and 6.5 % was obtained for cylinders I and II respectively. Desirable index of performance of the thresher is loss minimization.

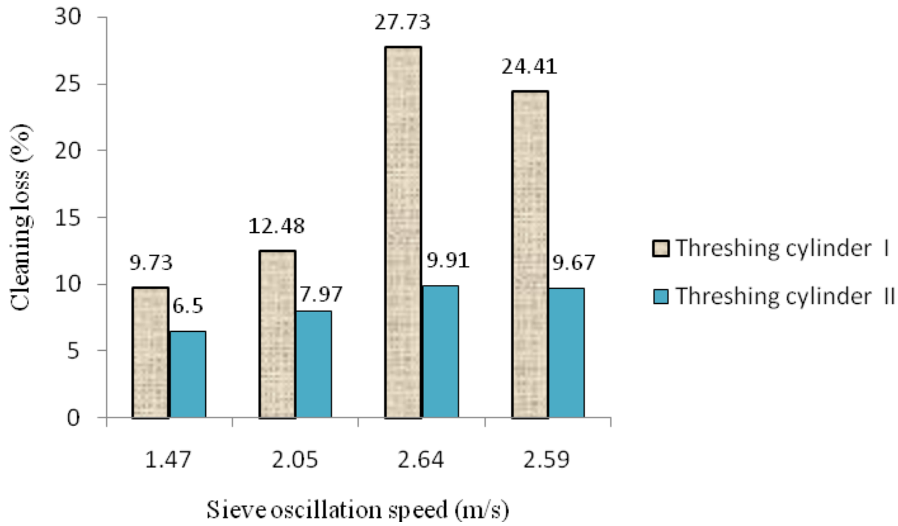

Figure 7 Cleaning loss from the threshing cylinders

CONCLUSION The performance of two threshing cylinders was evaluated on sorghum in a conventional thresher. The results showed that:

i. The two cylinders could be used to thresh sorghum.
ii. The cleaning efficiency obtained for cylinder II is consistently higher than that of cylinder I.
iii. The cleaning loss from cylinder I was higher than that of cylinder II throughout the test.

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