Modification of Institute for Agricultural Research Multi-Crop Thresher for Improved Performances

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Abstract- In millet producing areas of Nigeria, the predominant method of threshing is traditional. It involves beating the millet panicle with a stick, over a log of wood or by pounding using mortar and pestle. This method is inefficient, time-consuming, labor intensive, prone to drudgery, uneconomical, low output and gives product contaminate with extraneous material such as stones and sand. Though imported threshers are effective in millet threshing; they are expensive, complex in design and required skillful personnel for operation. An Institute for Agricultural Research (IAR) multi-crop thresher for sorghum, millet, and wheat was modified for improved performances. The performance of the modified thresher was evaluated using Ex-borno variety of pearl millet. Two levels of moisture content; 9.21% and 10.81%, four feed rates levels; 3, 4, 5 and 6 kg/min, four levels of drum speed; 700, 800, 900 and 1000 rpm were considered during the experiment. The test results indicated as high as 98.78% threshing efficiency, a minimum of 1.02% grain damage, maximum cleaning efficiency of 97.19%, and 2.50% scatter loss and maximum throughput capacity of 194.02 kg/hr. In comparison to the previous thresher, threshing efficiency, mechanical grain damage, cleaning efficiency, scatter losses, and throughput capacity have improved by 2.01%, 330.56%, 9.79%, 10.78%, and 69.86% respectively. The developed thresher is anticipated to increase the farmer’s productivity due to improved performances.

Keywords- Millet, Threshing Efficiency, Cleaning Efficiency, Feed Rate, cylinder Speed

1 INTRODUCTION

Millet is a collective term referring to a number of small-seeded annual grasses that are cultivated as grain crops, primarily on marginal lands in dry areas of subtropical and tropical regions (FAO and ICRISAT, 1996). In terms of cropped area and contribution to food security in Africa, pearl millet is the most important species; it accounts for almost half of global millet production. According to FAO (2014). About 1.6 million hectares of land is devoted to millet production in Nigeria, and about 1.4 million tonnes are produced annually. Savannah ecological zone of Nigeria is the major production area. Millet is generally used as staple food in almost all homes across Africa. It is being used for making traditional dishes such as tuwo, waina, and ogi. It is also used in preparation of beverage and drinks. The stalk and other residues of the crops are used as animal feed and in roofing of mud houses. In comparison to other cereals, millet has equivalent or superior nutritional values (Obilana, 2005).

Threshing of millet involves the removal of grains from the stalk or panicle. It is achieved by striking, treading, squeezing, tearing, and rubbing actions or by combinations of these methods (Joshi and Singh, 1980). It is either done manually (traditional) or mechanically. In traditional method it is performed by treading the grain under the hooves of animals, striking the grains with sticks, beating them over a log of wood or bamboo grating while in mechanical method it is achieved by using different types of power threshers. In Nigeria, the predominant means of millet threshing is manual, this method has the disadvantage of high grain losses and contamination with foreign materials, and it is also slow and tedious (Silas, 1996 and Joshi, et al, 2015). To ameliorate the problems associated with manual threshing in Nigeria, different type of threshers were imported into the country.

However, these imported threshers are complex in design, expensive, and require skillful technical personnel. An alternative to importation of thresher is to develop them locally and continue to improve their performance through modifications. This study is conceived In line with that idea of local development modification. The main aim of the work is to modify IAR multi-crop thresher for improved performances and affordability to small-scale farmers. Thus, it is anticipated to improve farmer’s productivity and increase timeliness of operation.

Studies on grain threshing and mechanical thresher have been conducted by many researchers Fu, et al., (2018), and Olaoye, (2011). Threshing, and cleaning involve dependent variables, which are functions of several independent variables. Grain cleaning can be considered a stochastic process with particles changing orientation in a random manner both in time and space. The physical parameters affecting the cleaning process are broadly grouped into crop characteristics and machine parameters (Simonyan and Imokheme, 2006). Gbabo et al., (2013) reported that, millet thresher in general works more efficiently as the moisture content decreased and the threshing drum speed increases. Based on recommended design and operational parameters for pearl millet threshing, a thresher was developed by Kamble et al (2003). The performance of the thresher was affected by cylinder speed, cylinder concave clearance, grain moisture content, and feed rate.

Oseuke (2011) developed model for optimizing the performance characteristics of cereal thresher. The model was validated using previously published data and was found to fit the data well. Awdy et al (2003) reported that cleaning efficiency and total losses of grains were positively affected by airspeed, and sieve tilt angle. The author also observed that purity was negatively affected by moisture content, and feed rate.

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2 MATERIAL AND METHOD
2.1 MATERIALS
Bundles of Ex-borno variety of pearl millet were sourced from Dawakin Tofa Market in Kano state. Physical, mechanical and aerodynamic properties of the millet that are relevant in design of threshers were gotten from Dangora et al. (2010), and (Ajav and Ojediran, 2006). In selecting construction materials for the modified thresher, function, local availability, cost and strength were considered. Gauge 16 mild steel sheet was selected for the construction of the feed hopper and shaker, mild steel (C1040) was selected for the shaft design, Angle iron of size 25mm × 25mm × 3 mm was chosen for the frame while the blower was constructed using galvanized steel plate of gauge 18. Pulleys were selected based on the values of diameters obtained from the speed ratios.

2.2 DESIGN CONSIDERATIONS
The factors considered in developing the multi-crop thresher were to develop:

I. Machine that can effectively thresh and clean millet.
II. Machine that can be fabricated using locally available materials.
III. Machine with Minimum loss due to threshing, separation, and cleaning.
IV. Machine that can improve the timeliness of millet threshing operation.

2.3 MAJOR MODIFICATION IN THRESHER
The old thresher was modified by increasing the number of beaters from 32 to 46. Three rows of five sets of cutting knives were mounted on the cylinder cover of the new thresher. To improve grains separation from chaffs, the sieve size was changed from 5.0 to 4.0 mm. The shaking system was changed from a twisted belt design to an inline belt system; this has solved the problem of belt coming off especially at high speed.

2.4 COMPONENT DESIGN AND SELECTION
2.4.1 Determination of the Size of Feed Hopper
Static friction angle of the ear head was considered in the design of the hopper slope. The bottom of the hopper was designed square in shape of size 250 by 250 mm; the top is rectangular with a size of 430 by 320 mm. It has a depth of 400 mm and slanted inward at an angle of 30°.

2.4.2 Determination of Concave Sieve Radius
The radius of curvature of concave sieve \( r_c \) was determined by the following expression as used by Dangora et al. (2006):

\[
r_c = r_d + h_p + C_c
\]

Where:
- \( r_c \) = radius of concave sieve (mm)
- \( r_d \) = radius of cylinder drum (mm)
- \( h_p \) = height of peg above the drum (mm)
- \( C_c \) = cylinder concave clearance (mm)

2.4.3 Determination of Cylinder and Spike Tooth Volume
This was obtained by summing up the volume of the threshing cylinder (which is hollow cylinder) and peg teeth volume (solid cylinder)

\[
V = \pi(r_1^2 - r_2^2)L + (\pi r_3 h)n
\]

Where:
- \( V \) = Volume of the cylinder and peg tooth (m³)
- \( r_1 \) = outer radius of the cylinder (mm)
- \( r_2 \) = inner radius of the cylinder (mm)
- \( r_3 \) = radius of the peg tooth (mm)
- \( L \) = length of the cylinder (mm)
- \( h \) = height of the peg tooth (mm)
- \( n \) = Number of peg tooth

2.4.4 Selection of the Size of the Sieve Holes
Sieve size of 4.0 mm was used based on the properties of millet as reported by Ojediran et al (2010). The size of the sieve tray was 600 mm long by 450 mm wide.

2.4.5 Reciprocating Mechanisms
In accordance with Ahmed et al. (1993). A sieve oscillation frequency of 6 cycles/sec and amplitude of 7 mm was used for the thresher.

2.4.6 Determination of Other Major Component Sizes
Pulley, belt lengths, belt angle of contact, belt tensions, and shafts diameters were calculate from formula in Khurmi and Gupta (2005).

2.5 DESCRIPTION OF THE MODIFIED THRESHER
The thresher consists of the following major parts: frame, feeding unit, threshing unit, outlet, and cleaning unit. Figure 1 shows cylinder cover with knives, figure 2 is a cylinder with spike tooth, and figure 3 shows the developed thresher. Table 1, Shows specification of the major component of the thresher.
Table 1. Modified thresher specifications

<table>
<thead>
<tr>
<th>Main parts of the thresher</th>
<th>Parameters</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main frame</td>
<td>Length</td>
<td>mm</td>
<td>1000</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>mm</td>
<td>730</td>
</tr>
<tr>
<td></td>
<td>Height</td>
<td>mm</td>
<td>900</td>
</tr>
<tr>
<td>Drum</td>
<td>Length</td>
<td>mm</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>Diameter</td>
<td>mm</td>
<td>220</td>
</tr>
<tr>
<td>Spike tooth</td>
<td>Length</td>
<td>mm</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>Diameter</td>
<td>mm</td>
<td>20</td>
</tr>
<tr>
<td>Concave</td>
<td>Radius</td>
<td>mm</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>mm</td>
<td>300</td>
</tr>
<tr>
<td>Top cover</td>
<td>Diameter</td>
<td>mm</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>mm</td>
<td>250</td>
</tr>
<tr>
<td>Shaker</td>
<td>Length</td>
<td>mm</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>mm</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Stroke</td>
<td>mm</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Tilt angle</td>
<td>°</td>
<td>30</td>
</tr>
<tr>
<td>Aspirator</td>
<td>Impeller diameter</td>
<td>mm</td>
<td>520</td>
</tr>
<tr>
<td></td>
<td>Width</td>
<td>mm</td>
<td>200</td>
</tr>
<tr>
<td>Source of power</td>
<td>5.0 hp Diesel Engine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.1 Effect of Cylinder Speed on Threshing Efficiency at Different Moisture Content

Data illustrated in Figure 4, present the effect of speed on millet threshing efficiency. It shows that threshing millet at 9.21% moisture content with a speed of 1000 rpm produced the highest efficiency of 97.35% while threshing of the grain at 10.81% moisture content and speed of 700 rpm produced the lowest threshing efficiency of 92.74%. This could be as a result of the lower moisture content of the millet stalk which allowed easier dislodging of the grains from the stalk and high speed of rotation of the threshing drum resulted in more impact of beaters on the millet stalks. This agreed with the result of an earlier study by Simonyan and Oni (2001), where decrease in moisture content of unthreshed grains increased threshing efficiency. It was also reported by Helmy et al. (2000) that threshing effectiveness was found to be favorably affected by increase in cylinder speed.

3.2 Effect of Cylinder Speed on Grain Damage at Different Moisture Content

From figure 5, millet grain damage varied from 0.39 to 1.02 when the thresher was run at a speed range of 700 to 1000. At any given moisture content the grain breakage increased with increase in speed. It was observed that the damage to the grain was higher at higher grain moisture content. This may be attributed to the fact that lower moisture content increases the hardness of the millet grain causing lower breakage. At higher speed, imparted energy is more causing more...
grain damage. Also, the R2 values for the relationship between the speed and the mechanical damage are 0.987 and 0.975 for the moisture content of 9.21 and 10.81% respectively. This showed a strong correlation coefficient between the variables.

3.4 EFFECT OF CYLINDER SPEED ON SCATTER LOSSES AT DIFFERENT MOISTURE CONTENT

Data illustrated in Figure 7 showed that threshing millet at lower moisture content of 9.21% and speed of 1000 rpm produced a high value of scatter loss of 2.54% while threshing at 10.38% moisture content and speed of 700 rpm produce a low value of scatter loss of 1.79%; this showed that, scatter loss increased with increase in speed and decreased with increase in moisture content. This could be as a result of the fact that higher speed gives more impact force to the seeds which in turns increased the momentum of the seeds while higher moisture content increases the cohesive forces between the seeds thereby reduced the scattering action. Gbabo et al. (2013) and Kamble et al., (2003) found similar incidence of increased scatter losses with increasing speed and decreasing moisture content.

3.5 EFFECT OF CYLINDER SPEED ON THROUGHPUT CAPACITY AT DIFFERENT MOISTURE CONTENT

The performance of the threshing cylinder speed on millet grain throughput capacity at two different levels of moisture content is shown in Figure 8. The throughput capacity of the machine increased with speed and decreased with increase in moisture content. The highest throughput capacity of 130.52 kg/hr was obtained at the highest speed of 1000 rpm, and 9.21% moisture content and the lowest value of 99 kg/hr was obtained at the lowest cylinder speed of 700 rpm and moisture content of 10.81%. The coefficient of determination values of 0.985 and 0.9665 indicates that there is a close relationship between the cylinder speed and the millet grain throughput capacity.
3.6 Comparative Performance Evaluation of the Old and the Modified Thresher

Table 3 shows comparison between the old and modified threshers using student t-test. From the table, it is only scatter loss that is statistically not significant at 1% and 5% levels respectively. The means of the other parameters were statistically significant at 5% and 1% levels.

Table 3: Comparative Evaluation of Performance between Old and modified thresher

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Old</th>
<th>Modified</th>
<th>Alpha</th>
<th>P(T=0) one-tail</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Te</td>
<td>98.05</td>
<td>94.54</td>
<td>0.05</td>
<td>0.009989</td>
<td>**</td>
</tr>
<tr>
<td>Md</td>
<td>3.975</td>
<td>0.7</td>
<td>0.05</td>
<td>0.000134</td>
<td>**</td>
</tr>
<tr>
<td>Ce</td>
<td>84.28</td>
<td>94.39</td>
<td>0.05</td>
<td>0.024549</td>
<td>*</td>
</tr>
<tr>
<td>SL</td>
<td>3.15</td>
<td>2.11</td>
<td>0.05</td>
<td>0.122078</td>
<td>NS</td>
</tr>
<tr>
<td>Tc</td>
<td>63.97</td>
<td>131.67</td>
<td>0.05</td>
<td>1.06E-06</td>
<td>**</td>
</tr>
</tbody>
</table>

NS - Not significant. (**) - Highly Significant. (*) - Significant

4 Conclusion

Multi-crop thresher has been developed using locally available materials. Performance of the thresher was tested under four cylinder speed (700, 800, 900 and 1000 rpm), four feed rate (3.0, 4.0, 5.0 and 6.0 kg/min) and two moisture content (9.21 and 10.81%). The modified thresher have a maximum threshing efficiency, minimum mechanical grain damage, maximum cleaning efficiency, minimum scatter losses and maximum output capacity of 98.78%, 1.02%, 97.19%, 2.50% and 194.02 kg/hr, this is in comparison to 97.00%, 89.56% and 71.60 kg/hr obtained in the old machine.

REFERENCE


