Fabrication and Performance Evaluation of Cowpea Thresher for Small Scale Cowpea Farm Holders in Nigeria

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Authors’ contributions

This work was carried out in collaboration between all authors. Authors OWMB and BAO read and approved the final manuscript.

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ABSTRACT

Aims: To develop and evaluate an affordable, accessible, easy-to-operate and functional small-scale thresher machine to make cowpea farming a profitable venture.

Study Design: Fabrication and performance evaluation.


Methodology: Construction of a cowpea thresher machine was carried out by sizing and marking out the plate with the aid of scriber and cutter. The shaft was smoothened and the various components were welded and assembled with the aid of fasteners. The thresher was made-up of the feeding unit, which provided an opening through which the cowpea was introduced into the
machine for threshing. As the various components of the cowpea thresher (threshing drum, the lower concave (screen), the spikes and separating unit) were being assembled, dimension analysis was carried out on two varieties of cowpea grains. This was meant to determine the screen sieve size.

**Results**: Findings from this study indicated the mean cowpea grain threshing efficiencies of 71.40, 66.10, and 63.10% at a different speed of 472, 339, and 283 rpm respectively. The maximum throughput capacity (59.78 kg/hr) was obtained at threshing speed of 472 rpm. This revealed that as the speed decreased the threshing efficiency, the throughput capacity and grain loss also decreased, while damaged grains are negligible.

**Conclusion**: The fabricated cowpea thresher is therefore, a suitable machine with high efficiency to carry out necessary small scale post-harvest operations in cowpea production.

**Keywords**: Cowpea; thresher; construction; performance; evaluation.

1. INTRODUCTION

Cowpea (*Vigna unguiculata* L.) is the second economically important cash crop in Africa after groundnut. It is grown in Nigeria as one of the staple crops that provide much needed protein requirement in the dietary table. A lot of Nigerians earn their living directly and indirectly through the cultivation of cowpea. The crop’s value lies mainly in its high protein content as well as its ability to fix atmospheric nitrogen and improve poor soils. Cowpea can be prepared in many ways for consumption e.g. boiling, grinding and processing into “akara”, “moinmoin” etc. [1]. According to Olaoye [2], the chaff can be used as feed for livestock while the seeds are dried to moisture content of between 8 to 10% and sold.

Being a source of income for many small holder farmers in sub-Saharan Africa, cowpea contributes to the sustainability of cropping systems and soil fertility improvement in marginal lands through the provision of ground cover and plant residue, nitrogen fixation and suppressing weed. Additionally, cowpea is known as the cheapest source of protein to the poverty ridden populace of Nigeria [3]. Recently, following the interest of international bodies in reducing hunger, poverty and malnutrition in developing countries, the prospect for reducing food insecurity through increase in cowpea productivity is significant [4].

Production of cowpea is incomplete without threshing operations. Threshing involves the removal of grains from pods. It can be done either mechanically or manually. Manual system of threshing is characterized with time wastage, threshing loss and high drudgery. Mechanical threshing involves high but expensive technology which though helps to maintain the quality of the final products and eliminates drudgery associated with local threshing systems [2].

In Nigeria, threshing is done traditionally by placing the harvested crop on the muddy floor or on concrete and beating with a stick or flailed. Other methods include the use of mortar and pestle to remove the seeds. These methods of threshing however are not convenient enough; the output is low, sometimes contaminated, time consuming and require high labour [5].

Attempts have been made to solve the problems associated with cowpea threshing in Nigeria through the development of both manually and mechanically operated threshers [5]. Threshing machines for other grains such as coffee have been designed by other researchers [6]. Ajayi and Adejumo [7] and Afify et al. [8] developed okra and black seed threshers respectively, while Abdulkadir et al. [9], Nwakairea et al. [10] and Olumuyiwa et al. [11] developed maize threshers. Dauda [12] designed, constructed and evaluated the performance of a manually operated cowpea thresher for small scale farmers with threshing efficiencies of 85.96%, 84.6% and 84.1% with fan speeds of 372rpm and cleaning efficiencies of 92.75%, 92.5% and 92.35% respectively.

There are a lot of problems facing Nigerian farmers on the issue of threshing. Traditional or manual methods of threshing cowpea especially for commercial purpose do not support large scale threshing. Much time is required to thresh cowpea with relatively low work done. Mostly, women and children are predominantly engaged in the highly laborious task of threshing the beans. Huge losses and breakages of grain due to the impact of pressure applied when beating grains in traditional threshing are also
experienced. The quality of cowpea threshed is also low. This in turn affects the beans shelf life and viability. The cost of multi-mechanical thresher which could have served as a better alternative has over time proved to be too high for the poor rural farmers to afford. All these would expectedly impact negatively on the farmers' profits and consumers' well being.

In order to ameliorate the highlighted problems, it is necessary to design, fabricate and evaluate the performance of a locally sourced, affordable but effective cowpea thresher for a significantly enhanced cowpea production in the country.

2. MATERIALS AND METHODS

2.1 Material Selection

Materials used for the fabrication of the cowpea thresher were obtained locally from Surulere Market, Ilorin, Nigeria and selected based on strength, availability, durability and cost (affordability). Scrap mild steel angle iron were used for the frame, mild steel sheet for the threshing chamber and steel rod was used for the shaft. Construction of the machine was carried out by sizing and marking out the plate using scribe and cutter. The shaft was smoothened with sand paper and various component parts were welded. Assembling of parts was done using fasteners (bolts and nuts).

2.2 Design Considerations and Analysis

The design stage included measurement of the physical parameters of the crop (cowpea) to determine appropriate design variables for the threshing operation. The threshing components were designed using relevant engineering principles and theories. The design concept involved the use of impact forces of mild steel rod beaters against steel plate with sufficient power requirement. The design considerations included economy, ergonomics, strength, machine efficiency and product quality, simple operation and maintenance requirement to meet the needs of local farmers, detachability for easy transportation and economical consumption of power.

2.3 Description of Cowpea Thresher Component Parts

The cowpea thresher is made up of the following components: The frame, threshing drum, concave, shaft, threshing chamber housing, hopper, seed outlet, fan (blower), fan housing, pulley, bearings, and prime mover (electric motor).

2.3.1 The frame

The frame is a support for other component parts that make-up the machine. It is a rigid structure capable of withstanding both static and dynamic stresses generated from the machine while in use. It was made from (50 mm x 50 mm x 2 mm) angle iron. The length, width and height were 600 mm, 400 mm, and 800 mm respectively. The frame components were held together with 17 mm width bolt and nut. The prime mover frame was 265 mm long, 240 mm wide and 200 mm high. It was attached to the frame.

2.3.2 The hopper

The hopper is the component part that serves as a feeding unit for the harvested cowpea into the threshing chamber of the machine. Available information [13] on the pod length, width, thickness and angle of repose was used to design the hopper. The cowpea pods were poured into the threshing chamber. It was shaped as a frustum and has a height of 200mm.

2.3.3 The screen

A 2 mm mild steel metal sheet was used to fabricate the screen, dimensioned 500 mm by 470 mm. It was marked and drilled at regular intervals of holes- 12 mm diameter, and 50 mm length from one hole to another. The holes were made along the length of the screen. The screen was rolled to a concave shape with flange at the two sides, and bolted to the frame.

2.3.4 The threshing chamber

Threshing and pre–cleaning of the crop (cowpea grain and chaff separation) takes place in the threshing chamber. The unit consists of threshing drum, the lower concave screens and the side plate cover. Threshing drum was made from 2 mm mild steel sheet rolled into a perfect cylinder of 200 mm diameter and 380 mm length. The spikes were welded in a spirally arranged form along the length of the drum. The drum was welded on the main shaft which supported, carried and transmitted torque to it.

2.3.5 The spikes

These are threshing mechanisms which perform threshing operations. Spikes were welded to the
threshing drum and all were of equal length 100 mm and 10 mm diameter weld spirally on the threshing drum. This arrangement allows the spikes to carry the straw from the feeding end to the outlet.

2.3.6 The shaft

The shaft is an important machine element which transmits power (torque) from the prime mover to the threshing drum. The shaft was made from high-speed steel (HSS) to resist the bending and twisting action while in use. It is 700 mm in length and 35 mm in diameter.

2.3.7 Threshing chamber housing

Threshing chamber housing was fabricated with 1 mm mild steel metal which was bent to form a concave of diameter 190 mm and 500 mm length, sealed at the two ends. Both sides were flanged to form an attachment to the frame.

2.3.8 The fan

This was included to perform winnowing operations. It was constructed from 1mm sheet metal as blades. The blades were six in number, arranged at an angle of degree to each other, length 420 mm and 100 mm width welded to the shaft of 25 mm diameter and 700 mm length.

2.3.9 The fan housing

The fan housing provides covering for the fan and as well directs the air current to the direction of chaff outlet. Fan housing was made with 1 mm metal sheet. It was located beneath the hopper, sealed at both ends with one end removed, and with a 220 mm diameter and 420 mm length.

2.3.10 The outlets

These are channels for ejection of the straw and collection of grains and chaff. Each outlet was made with 1 mm mild steel metal with open end so that escaped threshed grains dropping at seed outlet was recovered. Seed outlet was fabricated by 1 mm mild steel metal sheet. It was attached to the machine under the threshing unit. Chaff outlet forms an extension of the seed collection chamber. It was made with 1 mm mild steel metal sheet and tapered outward. It extended out by 180mm and the width 400 mm.

2.3.11 The pulley

Pulleys are grooved circular discs with a hole to intersect the shaft at the centre. They were coupled to the shaft end to accommodate v- belt, which transmitted power from prime mover to the shaft .The diameter of the two pulleys on the threshing drum and fan housing were 178 mm and 67 mm.

2.3.12 The bearings

Bearings are the machine elements which carry shaft and permit them to rotate with minimum friction. The size of the bearings used was 6207 (35 mm diameter), while 6250 (25 mm inner diameter) was on the fan shaft.

2.3.13 The prime mover

A prime mover (electric motor) with 1440 rpm, 2hp motor was used to test the cowpea thresher.

2.4 Test Methodology

The cowpea thresher was allowed to run empty for five minutes when a steady momentum was achieved. It was tested for threshing efficiency, cleaning efficiency, percentage grain loss at waste outlet, the throughput capacity and broken seeds. Power consumption of the machine was taken into consideration and the speed was determined by using tachometer and manual calculations with thresher pulley diameters of 178 mm, 270 mm and 300 mm.

Fabrication and testing of the machine were carried out based on the data collected on cowpea and other information from literatures [13]. The thresher components were fabricated and assembled as shown in Figs. 1 - 7. Local cowpea grains (big Oloyin) were used in testing the performance of the machine. Bulk sample (18.64 kg) of the grains was used for testing the machine. Pre-dried, weighed sub-samples (1.5 kg) were fed through the hopper, using different speeds: 472, 339 and 283 rpm for the period of 90, 112 and 125 seconds respectively. Time taken for each sample to thresh was recorded. Samples of threshed cowpea were collected and weighed after removal of contaminants (chaff). They were then separated into “threshed but damaged” and “threshed but undamaged” (sound) beans. Pictorial view of the developed cowpea thresher is shown in Plate 1.
Fig. 1. Orthographic view of the cowpea thresher

Fig. 2. Orthographic view of the Hopper
Fig. 3. Orthographic view of the Screen

Fig. 4. Orthographic view of the lower shelling chamber of the cowpea thresher
Fig. 5. Orthographic view of the Threshing Drum

Fig. 6. Orthographic view of the Blower
Fig. 7. Orthographic view of the Support Frame

Plate 1. Pictorial view of the fabricated cowpea thresher
3. RESULTS AND DISCUSSION

Table 1 shows the physical dimensions/properties of cowpea grains used in this study in order to give an idea of the size of holes to drill on the screen for easy passage of beans during threshing operations. Beans length and width ranged between 8.95–9.945 mm and 6.32–6.94 mm respectively. Maximum values of their thickness and diameters were 5.00 mm and 7.30 mm respectively, while their sphericity ranged between 0.692 and 0.704 mm (Table 1).

Table 2 shows the results of tests carried out on the fabricated cowpea thresher. The table shows that as the threshing speed was reduced from 472 rpm to 339 rpm and then to 283 rpm, threshing time increased from 91 to 111 seconds and 125 seconds respectively.

3.1 Effect of Rate of Loading on Performance Parameters

Table 3 shows how the loading rate affects threshing and cleaning efficiencies using different threshing speeds. The results reveal that as the sample weight increased (from 1.0 to 2.0 kg) at each of the threshing speeds 472, 339 and 283 rpm, the threshing efficiency decreased from 72.10 to 70.80%, 69.00 to 63.50% and 66.60 to 60.50% respectively. The cleaning efficiency also decreased from 88.90 to 73.40%, 91.4 to 76.03% and 91.70 to 76.70% respectively.

3.2 Relationship between Speed and Parameters Considered on the Cowpea Thresher

Table 4 indicates that there was direct relationship between the speed, threshing efficiency, throughput capacity and grain loss. However, there was an inverse relationship between the speed of the machine and cleaning efficiency of the grains. The machine attained maximum cleaning efficiency of 81.83% at threshing speed 283 rpm, implying that the best speed for the machine was 283 rpm based on cleaning efficiency.

At threshing speed 472 rpm, threshing efficiency, throughput capacity and grain loss were 71.40%, 59.78 kg/h and 22.26% respectively, and at threshing speed 339 rpm, the threshing efficiency, throughput capacity and grain loss were 66.10%, 48.36 kg/h and 20.26% respectively, while at 283 rpm speed, the three main parameters decreased to 63.90%, 43.27 kg/h and 20.16%. Contrary to the case with the other parameters, the cleaning efficiency decreased with increase in threshing speed (Table 4). The highest values of throughput capacity (59.78 kg/h) and threshing efficiency (71.40%) obtained at a threshing speed of 472 rpm and the maximum cleaning efficiency of the machine obtained at threshing speed 339 rpm agree with the findings of Singh et al. [14] who fabricated a power paddy thresher in India against a local cowpea variety known as “Thapa Chini”.

Table 1. Physical dimension analysis on cowpea grains

<table>
<thead>
<tr>
<th>Grain dimensions (mm)</th>
<th>Variety</th>
<th>Standard deviation (mm)</th>
<th>Variety</th>
<th>Standard deviation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Big Oloyin</td>
<td></td>
<td>Flat Oloyin</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>9.95</td>
<td>1.06</td>
<td>8.95</td>
<td>0.74</td>
</tr>
<tr>
<td>Width</td>
<td>6.94</td>
<td>0.65</td>
<td>6.32</td>
<td>0.51</td>
</tr>
<tr>
<td>Thickness</td>
<td>5.00</td>
<td>0.58</td>
<td>4.29</td>
<td>0.38</td>
</tr>
<tr>
<td>Equivalent Diameter</td>
<td>7.30</td>
<td>0.66</td>
<td>5.36</td>
<td>0.32</td>
</tr>
<tr>
<td>Sphericity</td>
<td>0.70</td>
<td>0.06</td>
<td>0.69</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 2. Performance evaluation of the fabricated cowpea thresher

<table>
<thead>
<tr>
<th>Threshing Speed (rpm)</th>
<th>Weight of Sample (kg)</th>
<th>Time (s)</th>
<th>Threshed cowpea $W_1$ (kg)</th>
<th>Damaged $W_2$ (kg)</th>
<th>Undamaged $W_3$ (kg)</th>
<th>Chaff $W_4$ (kg)</th>
<th>Grain in waist outlet (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>472</td>
<td>1.5</td>
<td>91</td>
<td>0.831</td>
<td>0.082</td>
<td>0.784</td>
<td>0.0026</td>
<td>0.0140</td>
</tr>
<tr>
<td>339</td>
<td>1.5</td>
<td>111</td>
<td>0.784</td>
<td>0.073</td>
<td>0.711</td>
<td>0.0056</td>
<td>0.0124</td>
</tr>
<tr>
<td>283</td>
<td>1.5</td>
<td>125</td>
<td>0.760</td>
<td>0.066</td>
<td>0.694</td>
<td>0.0068</td>
<td>0.0100</td>
</tr>
</tbody>
</table>
Table 3. Performance of parameters on rate of loading

<table>
<thead>
<tr>
<th>Sample weight (kg)</th>
<th>Threshing speed (rpm)</th>
<th>Threshing efficiency (%)</th>
<th>Cleaning efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>472</td>
<td>72.10</td>
<td>88.90</td>
</tr>
<tr>
<td>1.5</td>
<td>71.30</td>
<td>75.80</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>70.80</td>
<td>73.40</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>69.00</td>
<td>91.40</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>339</td>
<td>75.80</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td>63.50</td>
<td>76.03</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>66.60</td>
<td>91.70</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>283</td>
<td>62.60</td>
<td>77.70</td>
</tr>
<tr>
<td>2.0</td>
<td>60.50</td>
<td>76.70</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Relationship of speed with parameters considered on the cowpea thresher

<table>
<thead>
<tr>
<th>Threshing speed (rpm)</th>
<th>Threshing efficiency (%)</th>
<th>Cleaning efficiency (%)</th>
<th>Grain loss (%)</th>
<th>*TCP (Kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>472</td>
<td>71.40</td>
<td>77.70</td>
<td>22.28</td>
<td>59.78</td>
</tr>
<tr>
<td>339</td>
<td>66.10</td>
<td>81.30</td>
<td>20.26</td>
<td>48.36</td>
</tr>
<tr>
<td>283</td>
<td>63.90</td>
<td>81.80</td>
<td>20.16</td>
<td>43.27</td>
</tr>
</tbody>
</table>

* TCP: Through-put capacity

Table 5. Relationship between threshing speed and some other performance related parameters

<table>
<thead>
<tr>
<th>Speed (rpm)</th>
<th>Threshing efficiency</th>
<th>Cleaning efficiency</th>
<th>*TCP</th>
<th>Grain loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0000</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threshing</td>
<td>1.0000</td>
<td>0.9205</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td>-0.9193</td>
<td>-0.9129</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throughput</td>
<td>0.9999</td>
<td>0.9645</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Grain loss</td>
<td>0.9686</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* TCP: Through-put capacity

3.3 Correlation Analysis

Table 5 shows the correlation analysis of threshing speed with threshing efficiency, throughput capacity, cleaning efficiency and grain loss. The results show a high positive correlation between the threshing speed, threshing efficiency (1.000) and throughput capacity (0.999). The threshing speed was also positively correlated (0.968) with grain loss. This implies high grain loss. A negative (inverse) relationship between speed and cleaning efficiency (-0.919) was however observed. This means that the higher the threshing speed, the lesser the cleaning efficiency.

4. CONCLUSION AND RECOMMENDATION

The developed cowpea thresher gave maximum capacity of 59.78kg/h. Maximum threshing efficiency of 71.4% was obtained at a threshing speed of 472 rpm; the maximum cleaning efficiency of the machine was 81.8% at the threshing speed of 339 rpm. Optimal performance parameters (efficiency and capacity) were established to be 64.60 kg/h. The machine attained maximum cleaning efficiency of 81.83% at threshing speed 283 rpm, implying that the cleaning efficiency is best at the threshing speed of 339 rpm, while threshing efficiency and throughput capacity are best at threshing speed of 472 rpm and percentage grain loss, at the least threshing speed of 283 rpm.

The fabricated cowpea thresher is therefore a good machine that has high efficiency to carry out post-harvest operations in cowpea production. Its simplicity in construction, maintenance, portability, ease of operation and repair as well as cost effectiveness make it a
suitable tool for small-scale/subsistence cowpea producers/farmers in Nigeria and across the West African sub-region. The machine can however be improved upon to accommodate more cowpea loads and provide much better results.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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