IMPACT OF DRUM SPEEDS AND MOISTURE CONTENT ON THE PERFORMANCE OF A COWPEA THRESHER

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ABSTRACT
The evaluation of a previously designed and fabricated cowpea thresher was conducted at the Department of Agricultural and Bio-environmental Engineering Technology of Rufus Giwa Polytechnic in Owo, Ondo State, Nigeria. The evaluation focused on the impact of drum speed and moisture content on the performance of the machine. The experiment involved testing the thresher at different drum speeds of 250, 350, and 450 rpm and moisture content levels ranging from 8% to 20%. The evaluation considered various performance parameters, including the percentage of broken seeds, threshing efficiency, quality performance efficiency, and output capacity, which were found to be 4.5%, 97%, 88%, and 100 kg/h, respectively. The results of the Analysis of Variance (ANOVA) indicated that both drum speed and moisture content significantly influenced the machine parameters, with p-values ranging from 0.00161 to 0.00235. The interaction between drum speed and moisture content affected the threshing efficiency and quality performance efficiency of the thresher. These findings underscored the crucial roles played by drum speed and moisture content in optimizing the threshing process of the machine. The data generated from study is recommended for commercial production and use of the machine.

Keywords: Capacity, crop moisture, efficiency, machine speed, evaluation, threshing.

1. INTRODUCTION

Cowpea (*Vigna unguiculata Walp*), commonly known as beans is a protein-rich leguminous crop, widely consumed and has stable cultivation. As a leguminous plant, it plays a crucial role in soil enrichment through nitrogen fixation by bacteria in its root nodules (Komolafe and Joy, 1981). According to FAO (1981), the crop is cultivated in various regions, including India, Southeast Asia, Australia, the Caribbean, the southern United States, and the lowland tropics of Africa. Nigeria stands out as the leading producer, accounting for 61% of the world's recorded annual yield of approximately 760,000 tonnes (Leaky and Wills, 1977).

The crop is widely used in Nigerian communities. It can be prepared by soaking the seeds and removing their coat, then grinding them into a paste and mixing it with a small amount of oil before boiling them to make moi-moi or frying them to make akara cakes. In specific communities, the fresh seeds and young pods are consumed as a vegetable, while the young shoots and leaves are used as spinach. However, despite its numerous nutritional benefits, the crop is not extensively cultivated on a large scale due to the laborious harvesting and threshing processes involved (Fulani *et al.,* 2013).

Adekanye and Olaoye (2013) noted that the threshing of the crop can be carried out manually or mechanically. However, both methods are associated with a high rate of seed breakage. Manual threshing, which involves using a pestle and mortar or beating the dried crop on the floor with a stick, is a time-consuming process that leads to threshing losses and requires a lot of physical effort (Maunde, 2011; Olaoye, 2011). To reduce the risk of stones in the final product, a tarpaulin or mat can be placed on the ground before threshing and winnowing is used to separate the seeds from the chaff (Fulani *et al*., 2013).

Mechanical threshing refers to using an engine or electric motor to power a machine separating the crop from its stalk. Axial flow threshers work by spirally moving the crop between a threshing drum and concave for several turns; the repeated impact of the threshing pegs ultimately threshed the crop. This method of threshing offers numerous advantages, including producing high-quality output, reduced labour compared to traditional threshing methods, and lower rates of threshing losses (Manes *et al.*, 2015; Olaoye, 2011).

The efficiency of the threshing process is influenced by several factors, including the method of feeding, cylinder speed, concave-to-cylinder clearance, and moisture content (Olajide *et al*., 2022; Abulasan and Ashebir, 2021). The study by Muhammed-Bashir *et al*. (2018) reported mean threshing efficiencies of 71.40, 66.10, and 63.10% at a different respective speed of 472, 339, and 283 rpm. The maximum throughput capacity of 59.78 kg/h was obtained at threshing speed of 472 rpm in the same study. It was concluded that a decrease in the speed values resulted to a decreased in the value of the threshing efficiency, the throughput capacity and grain loss. However, Eric *et al.* (2017) reported that the efficiency of the threshing process decreased with an increase in feed rate and concave clearance. Herbek and Bitzer (2004) conducted a study that found cylinder speeds between 400 to 800 rpm were adequate, as higher speeds of 800 to 900 rpm caused more damage to the seeds. Ajav and Adejumo (2005) evaluated an okra thresher using various parameters. The speed of the drum significantly impacts the performance of cowpea threshing machines. Various investigations have been conducted to analyze the effects of drum speed on the threshing efficiency and seed damage in cowpea threshing machines. According to Madukwe *et al.* (2019), the threshing efficiency of a cowpea threshing machine increased with the increasing speed of the drum, up to a certain point beyond which the further increase in drum speed did not yield a significant improvement in threshing efficiency.

Several studies have explored the impact of moisture content on the performance of cowpea threshing machines. The moisture content of cowpea pods is a crucial factor influencing threshing efficiency and seed damage (Adekunle et al., 2017). Ezeilo *et al.* (2018) found that increasing moisture content from 8% to 18% decreased threshing efficiency and increased seed damaged. Several studies have investigated the impact of drum speed and moisture content on the performance of cowpea threshing machines. Madukwe *et al.* (2019) discovered that the best drum speed for a cowpea threshing machine depended on the moisture content of the cowpea pods. Higher drum speeds were more effective at higher moisture content. Similarly, Adekunle *et al*. (2017) found that the optimal drum speed for a cowpea threshing machine varied depending on the moisture content of the pods.

Therefore, the objective of this work is to: Investigate a previously developed Cowpea thresher about the impact of drum speed and moisture content on the machine's performance.

2. RESEARCH METHODOLOGY

2.1 Description of the Cowpea Thresher

The cowpea thresher used for the investigation is the modified version of the existing cowpea thresher previously designed and fabricated at the Department of Agricultural and Bio Environmental Engineering of Rufus Giwa Polytechnic Owo, Ondo State, Nigeria. The thresher consists of a frame, hopper, feed control gate, thresher shaft with bearing, concave sieve, blower shaft with bearing, blower cover, belts and pulleys and two chutes. (One for the shaft and the other for the seeds discharged). The hopper is connected to the threshing drum. The feed control gate regulates the amount of cowpea entering the threshing chamber between the threshing drum cover and the hopper; this prevents the threshing unit from overloading.

The sizes of the cowpea seeds determined the concave sieve dimension. The threshing unit and all the other components are mounted on the frame; the blower is attached to one end of the frame. The chute is located at the other end of the sieve for discharging clean grain. The thresher is powered by an electric motor via a belt and pulley transmission system. The feed control gate regulates the flow of cowpea pods from the hopper to the threshing unit. The threshed cowpea seeds pass through the sieve and are cleaned by an air stream from the blower. The cowpea thresher and the cowpea beans before threshing are presented in Figures 1 and 2.

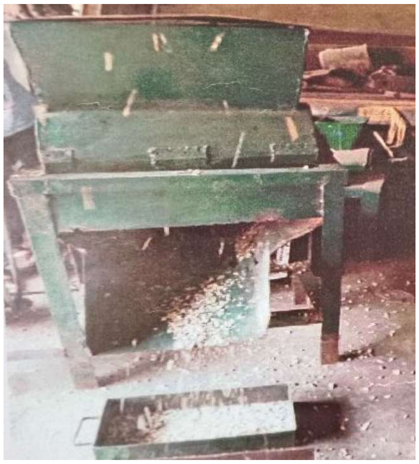

Figure 1. Cowpea thresher

Figure 2. Cowpea before threshing

2.2 Evaluation Test and Procedure

The initial moisture content of the cowpea pods was determined using a grain moisture meter. The moisture content readings were carried out in three replicates for each sample. 50 kg of cowpea pods was collected from the Teaching and Research farm of Rufus Giwa Polytechnic Owo, Nigeria. The cowpea pods were divided into 20 samples, each weighing 2kg were tested at the inner drum speed of 250, 450, and 650 rpm respectively; seven levels of cowpea moisture contents 8, 10, 12, 14, 16, 18 and 20% and the variable speeds of machine were achieved using a combined pulley of three varying sizes. Varying volumes of water were added to the same of quantity of beans and sun-dried for 30 minutes. The moisture content was later determined using a grain moisture meter.

Freshly conditioned cowpea pods were stored in polythene bags for about 12 hours to equilibrate. After each operation, the weight of fully threshed (W_{ft}), weight of partially threshed (W_{pt}), weight of unthreshed cowpea (W_{uc}), the weight of threshed but broken (W_{tub}) and weight of broken but not threshed (W_{bnt}) respectively were recorded.

Each experiment was carried out in three replicates and the data generated were subjected statistical analysis using Microsoft Excel 2016 and ANOVA. In order to evaluate the effect of machine parameters on threshing efficiency, quality performance efficiency, percentage broken and output capacity were determined using Equations 1, 2, 3, 4 and 6 as expressed by Alsharifi *et al*. (2017) and Adekanye and Olaoye (2013).

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100 \quad (1)$$

$$\text{Quality performance efficiency} = \frac{\text{weight of unbroken}}{\text{input}} \times 100 \quad (2)$$

$$\text{Percentage of broken} = \frac{\text{broken}}{\text{input}} \times 100 \quad (3)$$

$$\text{Feed rate} = \frac{\text{mass of input}}{\text{timetaken}} \quad (4)$$

$$\text{Throughput capacity} = \frac{\text{mass of output}}{\text{timetaken}} \quad (5)$$

3. RESULTS AND DISCUSSION

3.1. The Threshed Cowpea Beans and the Chaffs

The clean beans and the chaffs are presented in Figures 3 and 4.

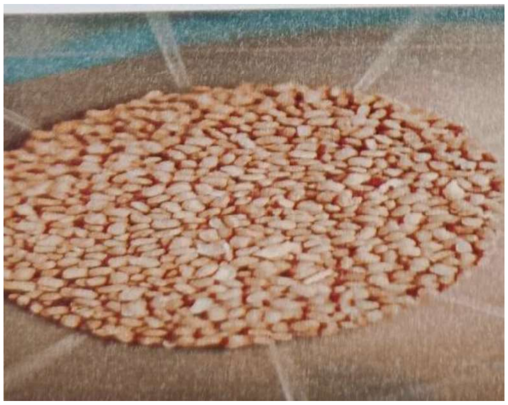

Figure 3. Cowpea beans after threshing

Figure 4. Cowpea chaffs after threshing

3.2 Impact of Moisture Content on Broken Seeds at different Drum Speed

The results of the cowpea thresher performance test as presented in Figure 5 revealed that an increase in moisture content led to an increase in unbroken seeds. Similarly, higher drum speeds resulted in reduced broken seeds. However, for moisture content above 14%, the percentage of broken seeds increased with higher moisture content and drum speeds. The lowest rate of broken seeds (4.5%) was observed at a moisture content of 14% and a drum speed of 650 rpm. According to the studies conducted by Fulani *et al.* (2013), there is consistent evidence supporting the fact that higher drum speed leads to an increase in grain damage, while an increase in feed rate corresponds to a decrease in grain damage. The grain damage is due to high striking force of the beaters at higher operating speeds and the large volume of the cowpea at the threshing cylinder surely reduced the impact of the striking force at higher speeds.

Drum speed significantly affected the percentage of broken seeds ($p = 0.00807$), indicating varying levels of broken seeds with different drum speeds. Moisture content also considerably influenced the percentage of broken seeds ($p < 0.001$), demonstrating the notable impact of moisture content on broken seeds. The interaction between drum speed and moisture content was marginally significant ($p = 0.03696$), implying that the effect of drum speed on broken seeds depends on the moisture content level and vice versa. This is in conformity with Olajide *et al.* (2022). Both drum speed and moisture content play significant roles in determining the percentage of broken seeds, and considering the interaction effect is crucial for optimizing seed threshing processes.

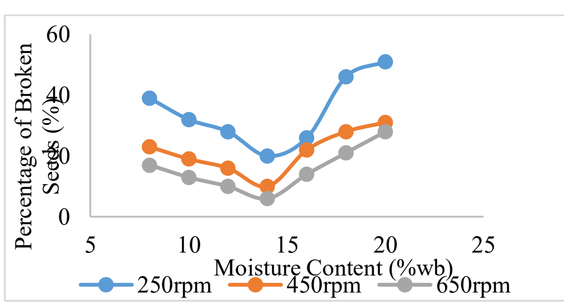

Figure 5. Moisture content versus percentage of broken seeds at 250 rpm, 450 rpm and 650 rpm drum speed

3.3 Impact of Moisture Content on Threshing Efficiency at Different Drum Speed

A threshing efficiency of 97% was observed when the machine was operated at a moisture content of 14% and a drum speed of 650 rpm. This finding aligns with previous studies by Muhammed - Bashir *et al.* (2018), which reported high threshing efficiencies ranging from 97% to 99% at moisture content levels of 11.5% to 13.5% for cowpea threshing. Figure 6 illustrates the relationship between moisture content and threshing efficiency at various drum speed levels. The results indicated that both moisture content and drum speed positively impacted threshing efficiency. Fulani *et al.* (2013) corroborated these findings by reporting that the threshing efficiency of cowpea threshers increased with higher drum speeds.

The 2-way ANOVA with interactions revealed significant effects of drum speed, moisture content, and their interaction on threshing efficiency ($p < 0.001$ for all). Drum speed was found to significantly influence threshing efficiency, indicating that different drum speeds affect the efficiency of the threshing process. Moisture content also greatly affected threshing efficiency, suggesting that varying moisture levels impact the effectiveness of grain threshing. Moreover, the interaction between drum speed and moisture content was found to be significant, indicating that the effect of drum speed on threshing efficiency depends on the moisture content level and vice versa. These findings underscore the importance of considering drum speed and moisture content when optimizing threshing efficiency, as their combined effects play a significant role in the overall performance of the threshing process. Adjusting drum speed and controlling moisture content can enhance the efficiency of the threshing operation and achieve optimal results.

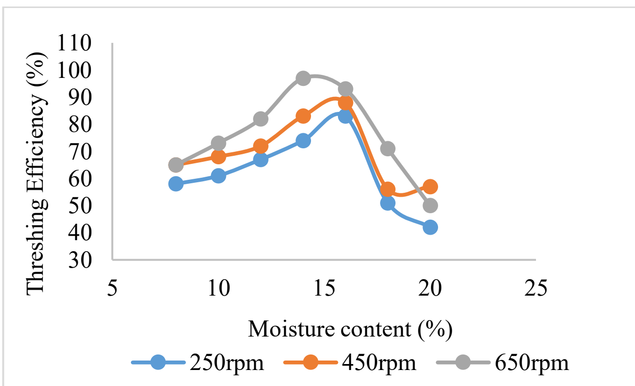

Figure 6. Moisture content versus threshing efficiency at 250 rpm, 450 rpm and 650 rpm drum speed

3.4 Impact of Moisture Content on Quality Performance Efficiency at Different Drum Speed

The quality performance efficiency indicates the quality of the threshed seeds and follows the trend of the threshing efficiency of the machine. Figure 7 revealed that an increase in the moisture content increased the quality performance efficiency of the machine. A quality performance efficiency of 88% was achieved at a drum speed of 650 rpm and a moisture content of 14%.

ANOVA analysis revealed that the drum speed variable significantly affected the quality performance efficiency ($p = 0.00107$). This indicates that different drum speeds lead to varying levels of efficiency in the threshing process. This is similar to the study by Abulasan and Ashebir (2021) in their study on the performance of a thresher for soybeans. Similarly, the moisture content variable significantly influenced the quality performance efficiency ($p = 0.00235$). Different moisture content levels had a notable impact on the efficiency of the process. However, the interaction between drum speed and moisture content was not found to be significant ($p = 0.00282$). This implies that the effect of drum speed on efficiency depend on the moisture content level and vice versa.

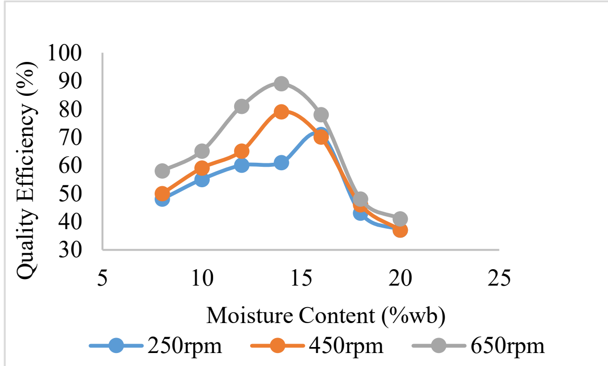

Figure 7. Moisture content versus quality efficiency at 250 rpm, 450 rpm and 650 rpm drum speed

3.5 Impact of Moisture Content on Machine Capacity at Different Drum Speed

The study found that the highest grain output capacity of 100 kg/h was achieved at a moisture content of 650 rpm. The results from Figure 8 illustrates that the machine capacity increased as both the grain's moisture content and the machine's drum speed increased. This finding is consistent with a study by Fulani *et al.* (2013) who reported higher output capacities for threshing soybeans and cowpea.

The ANOVA results indicate that the drum speed variable significantly affected the cowpea thresher's output capacity ($p = 0.00161$). This implies that different drum speeds result in varying levels of output capacity. Additionally, the moisture content variable significantly influenced the machine capacity ($p = 0.00143$), suggesting that different moisture content levels notably influence the machine capacity. It should be noted that the performance of machines depends on both the crop and machine parameter. This the reason a machine is usually subjected to an evaluation test to determine the optimum operating parameters required for its optimum performance.

The findings have emphasized the significant roles played by drum speed and moisture content in determining the output capacity of the cowpea thresher. The ANOVA results showed that adjusting drum speed and moisture content can optimize the threshing process, enhancing output capacity. This information is valuable for improving efficiency and productivity in cowpea threshing operations.

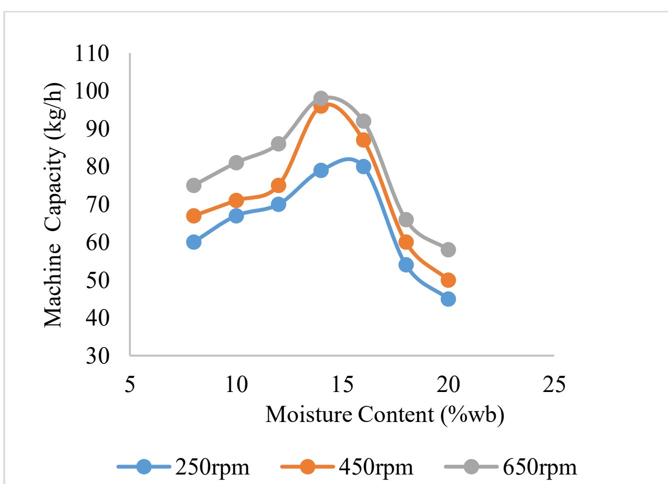

Figure 8. Moisture content versus machine capacity at 250 rpm, 450 rpm and 650 rpm drum speed

4. CONCLUSIONS

The following conclusions were drawn from this study

1. The evaluated cowpea thresher demonstrated low broken seed percentage, high threshing efficiency, good quality performance efficiency, and reasonable output capacity.
2. Both drum speed and moisture content significantly influenced the performance of the machine indicating their importance in optimizing the threshing process. The interaction between drum speed and moisture content influenced the threshing efficiency and quality performance efficiency of the machine.
3. The findings highlight the need for farmers and operators to consider drum speed and moisture content during the operation of the thresher and other similar machines to achieve optimal results.

REFERENCES

Abulasan, Q and Ashebir T. (2021) A Evaluation of soybean thresher for Chickpea Crop. Irish *Interdisciplinary Journal of Science and Research (IIJSR*), 5(2):101-108.

Adekanye A. T and Olaoye J. O. (2013). Performance Evaluation of a Motorised and Treadle Cowpea Threshers. Agric. Eng Int: *CIGR Journal.* Vol. 15, No 4.

Adekunle, A. A., Ogunsanmi, O. S. and Abegunde, O. O. (2017). Effects of drum speed and moisture content on the performance of cowpea threshing machine. *International Journal of Engineering Research in Africa*, 31, 47-54.

Ajav, E. A. and Adejumo, B. A. (2005). PerformanceEvaluation of an Okra Thresher. Agric. Eng. Int.,Vol. 7, pp 1 – 8.

Alsharifi, S. K. A., Arabhosseini, A., Kianmeher, M. H. and Kermani, A. M.. 2017. Effect of moisture content, clearance, and machine type on some qualitative characterstics of rice on (TarmHashemi) cultivar. *Bulgarian Journal of Agricultural Science*, 23(2): 348–355.

Ezeilo, E. C., Njoku, C. I., Nwambeke, C. O. and Abam, H. C. (2018). Effect of moisture content on the performance of a cowpea threshing machine. *International Journal of Engineering Research and General Science*, 6(6), 12-18.

FAO (1981). Food and Agricultural Organization Yearbook. Vol. 35. FAO. Rome, Italy.

Fulani A. U. Kuje J. Y and Mohammed B. V. (2013). Effect of Moisture Content on Performance of a Locally Fabricated Cowpea Thresher. *Journal of Engineering and Applied Sciences*, Volume 5, Number 2,

Herbek, J. H. and Bitzer, M. J. (2004). Soybean production in Kentucky: part V- Harvesting, drying, storage, and marketing. Lexington, Ky: Cooperative Extension Service Bulletin AGR132

Komolafe, M.F. and Joy D.C. (1981). Tropical Agricultural Science for West African Schools and Colleges. University Press Limited, Ibadan, Nigeria PP103 – 104.

Leakey C. L. A and Wills J. B. (1977). Food Crop of the Low Land tropics. Oxford University Press London.

Madukwe, U. E., Okoli, O. E. and Aghara, A. E. (2019). Effect of drum speed on the performance of cowpea threshing machine. International Journal of Engineering and Applied Sciences, 6(3):27-34.

Manes G. S., Dixit A., Singh A., Singh M. and Singh B. P.(2015). Comparative Performance Evaluation ofAxial Flow and Tangential Axial Flow Threshing System for Basmati Rice (Oryza sativa),Agricultural Research, Vol. 4, No 3, pp 303–308.DOI 10.1007/s40003-015-0169-3.

Maunde, F. A. (2011). Performance Evaluation ofManual Cowpea Thresher, African Journal ofAgricultural Research, Vol. 6, No 30, pp 6412.

Muhammed-Bashir O. W., Oriola K. O., Ogundeji B. A. and Adesokan, M. A. (2018). Fabrication and Performance Evaluatio of Cowpea Thresher for small Scale Cowpea Farm Holders in Nigeria. *Current Journal of Applied science and Technology*, 31(6): 1-11.

Olajide, O. G., Oladimeji, A. O. and Ale, M. O. (2022). Design, Fabrication and Performance Evaluation of a Cowpea Threshing Machine. *Global Journal of Engineering and Technology Advances*, 13(02):12-18

Olaoye, J. O. (2011). Development of a Treadle Operated Abrasive-Cylinder for Threshing Cowpea, *International Journal of Engineering Science and Technology (IJEST)*, 3(12):8548–8549.