

Performance evaluation of motorized and treadle cowpea threshers

Adekanye, Adesoye Timothy^{1*}, Joshua Olanrewaju Olaoye²

(1. Department of Agricultural and Biosystems Engineering, Landmark University, P.M.B.1001, Omu - Aran, Kwara State, Nigeria;

2. Department of Agricultural and Biosystems Engineering, University of Ilorin, P. M. B. 1515, Ilorin, Nigeria)

Abstract: A motorized thresher and a treadle cowpea thresher were evaluated in terms of threshing efficiency (%), throughput capacity (kg h^{-1}), cleaning efficiency (%), mechanical damage (%) and percentage loss (%) for three commonly grown cowpea varieties in Nigeria. The three varieties were 994, IAR48 and TVX. The cylinder concave clearances were fixed at 13, 12 and 11 mm based on the major diameter of each cowpea variety. The investigation was conducted at three levels of moisture contents (12.5%, 15% and 17% wet basis). Evaluation results indicated that for motorized thresher threshing efficiency varied from 71.4 to 82.86%, 73.56 to 87.14% and 77.63 to 88.57% while for treadle thresher threshing efficiency varied from 20.50 to 24.29%, 21.50 to 25.71% and 25.05 to 28.57 for 994, IAR48 and TVX varieties respectively. The highest cleaning efficiency of 80.77% was obtained at 610 r min^{-1} for 994 cowpea variety for motorized thresher. Least damage of 6.00% and 7.5% were observed at 405 and 406 r min^{-1} for IAR48 and 994 varieties for motorized and treadle threshers respectively. A throughput capacity of 66.06 kg h^{-1} was obtained at moisture content of 12.5% wet basis and 405 r min^{-1} while throughput capacity of treadle thresher was 55.51 kg h^{-1} at moisture content of 17% wet basis and 610 r min^{-1} .

Keywords: cowpea, mechanical damage, moisture content, threshing efficiency, variety

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1 Introduction

Cowpea (*Vigna unguiculata L. Walp*) is an annual legume crop which originated from Africa and is widely grown in Africa, Latin America, South East Asia and the southern United States (Allen and Watts, 1998). The value of cowpea lies in its high protein content. Cowpea also fixes atmospheric nitrogen and improves poor soils. Cowpea is used for human consumption and animal fodder and it is rich in protein and is the second economic cash crop in Africa after groundnut (Rachie and Singh, 1985).

Cowpea is grown in Nigeria as one of the staple crops that provide much needed protein requirement in the dietary table (Olaoye, 2011). Many Nigerians earn their

living directly or indirectly through the cultivation of cowpea. Cowpea is consumed in several ways when prepared. It could be prepared in several ways for consumption (boiling, grinding, and processing into “Akara ball”, “moinmoin”, etc), (Lawrence, 2006).

Production of cowpea is incomplete without threshing operation. Threshing involves the removal of grains from the pods. Threshing can be done either mechanically or manually. Manual system of threshing is characterized with time wastage, threshing losses, and high drudgery. Mechanical threshing involves high technology which is very expensive, though it helps to maintain the quality of the final products; it eliminates drudgery associated with local threshing system and reduces threshing losses (Olaoye, 2011). About 7.56 metric tonnes of cowpea are produced worldwide annually on about 12.76 million hectares. Sub-Saharan Africa accounts for about 70% of world total production (FAO, 2004; IITA, 2007).

Improper harvesting and threshing of cowpea usually

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* Corresponding author: Adekanye, Adesoye Timothy, Department of Agricultural and Biosystems Engineering, Landmark University, P.M.B.1001, Omu - Aran, Kwara State, Nigeria. Email: adekanye.timothy@lmu.edu.ng.

results in losses of up to 5% of the crop (Allen and Watt, 1998; and Bruce et al. 2001); Olaoye (2011) asserted that better production techniques alone are not sufficient to solve the problem of field losses in production of cowpea. Attention must also be paid to the suitable method of harvesting and threshing to minimize field losses. Some factors affecting the efficiency of threshing operation include feeding method, cylinder speed, concave-to-cylinder clearance and moisture content (Kepner et al. 1978).

There is now a general awareness in Nigeria and other developing countries that the rapid development of agriculture depend to a large extent on the successful introduction of modern agricultural machinery. Many grain threshers have been developed but reliable information and performance data on them are limited. The main objective of this study is to evaluate performance of two types of cowpea threshers: treadle and motorized. Specific objectives were to establish performance index for the threshers, identify performance indices with reference to economic viability and compare the performance of the two threshers.

2 Materials and methods

2.1 Description of motorized cowpea thresher

Hopper - the hopper is an inlet through which cowpea pods are fed into the threshing chamber. It is made up of galvanized metal of 1.5 mm thick, 300 mm high and 280 mm wide.

Threshing unit - this consists of the shaft and the perforated drum which provides support for the threshing drum. The drum is made up of a metal steel plate of 1.5 mm thickness, 500 mm by 503 mm rolled and welded to form a drum of 500 mm length. The open ends were covered with a circular sheet of diameter 160 mm. The drum obtained its threshing speed from the electric motor through pulley speed reduction system. The designed threshing speed was 550 r min^{-1} .

Blowing/Cleaning unit - the fan was made up of 6 blades of 0.5 mm thick, 100 mm length and 60 mm breadth. The blades are straight for effective cleaning of threshed cowpea (i.e. removal of chaff from the grains).

Threshed grains outlet collector:-This was made of

metal sheet of 440 mm long folded to form 120 mm from each ends. It was inclined to facilitate effective sliding of the cowpea grains.

Main frame - it is made of angle iron $40 \times 40 \text{ mm}$, the overall dimension was 800 mm length, 635 mm, 5.5 mm breadth and 450 mm width. The motor frame with 90 mm length, 5.5 mm breadth and 450 mm width was yielded to it. The frame gives support to the shaft, houses the concave, fan housing and seed outlet.

Pulley -they transmit power from the electric motor to the threshing shaft and fan shaft via the v-belt.

Transmission belts- they transit power from one pulley to another i.e. from motor pulley to main shaft pulley and lastly to the fan shaft pulley.

The motorized thresher rubs the un-threshed cowpea pods against wood concave. The threshed seeds and chaff passes down to the screen into the blowing unit where the separation of grain and chaff by fan occurred. The grain falls into the collecting tray outlet and the chaff blown off through the chaff outlet (Figure 1).

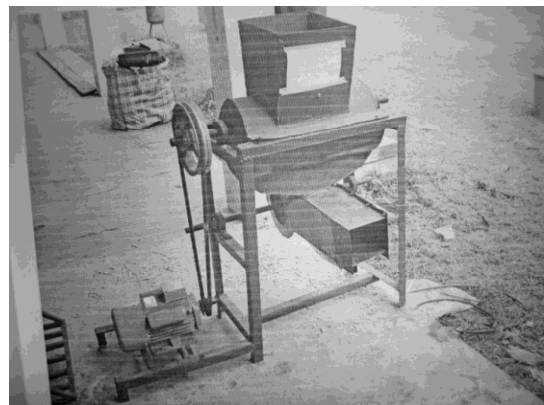


Figure 1 Motorized cowpea thresher

2.2 Description of treadle cowpea thresher

The pedal operated cowpea thresher was designed and constructed at the Department of Agricultural Engineering, University of Ilorin, Ilorin, Nigeria. It consists of the following features;

Hopper – was made of metal plate, trapezoidal in shape with an overall capacity of 80 k gh^{-1} . This is made to conform to the shape of the threshing cylinder, so that it can rotate freely without interference.

Threshing cylinder – was made of metal plate folded together. Another metal plate was perforated and wound round the drum.

Grain and chaff outlet – made of metal plate constructed in such a way to allow free drop of grains and chaff under gravity.

Mainframe –was made of angle iron. It houses the main shaft and provides support for the thresher.

Main shaft – was made of angle irons welded together. It passes through the center of threshing cylinder and the end plate.

The pedal – was made of angle irons welded together. The linkage bar connects the pedal to the crank mechanism which initiates the motion of the threshing unit.

It is powered manually using human energy. Motion is initiated by depressing the pedal which moves up and down and causes the linkage bar to move. This causes the threshing cylinder to move (Figure 2).

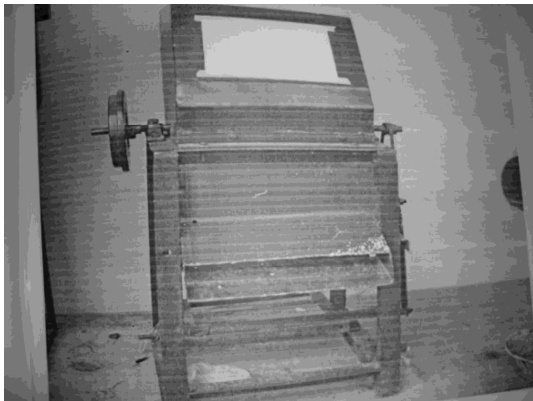


Figure 2 Treadle cowpea thresher

2.3 Materials for evaluation

2.3.1 Crop parameters

Moisture content – this was determined using oven dry method. The cowpea pods to be threshed were initially weighed and placed in the oven. The cowpea samples were removed and allowed to cool before reweighing. Their respective moisture content was determined using the relation:

$$\text{Moisture content (\%)} = \frac{w_1 - w_2}{w_1} \times 100 \quad (1)$$

where, w_1 = initial weight; w_2 = final weight.

2.3.2 Feed rate

This is the total mass of cowpea pod including grain, straw and chaff introduced into the threshing unit in batches of 10 kg. It was measured using an automatic stop watch. The timer monitors the threshing event from the loading point to the time taken for the first and

last grain crop to be discharged.

2.4 Experimental design

The performance evaluation of the machines was carried out at the Department of Agricultural and Biosystems Engineering, University of Ilorin, Nigeria. The distance between the threshing drum and the concave was set at 13 mm, 12 mm, and 12 mm based on the major diameter of each cowpea variety. The motorized thresher was evaluated first. It was operated by electric motor (rated power 2 hp, 1410 r min⁻¹). Four speeds i.e. 610 r min⁻¹, 504 r min⁻¹, 456 r min⁻¹ and 405 r min⁻¹ were used during the testing. These speeds were obtained by changing the pulley diameters and measured with the aid of tachometer.

The fan was driven from the same power drive shaft as that of the threshing drum with respective speed of 1,102, 968, 868 and 787 r min⁻¹. For each test, a combination of feed at 3 levels (169, 120 and 105 kg h⁻¹), 3 cowpea varieties (TVX, 994 and IAR 48), 4 cylinder speed (610, 504, 456 and 405 r min⁻¹) and three moisture content (12.5%, 15% and 17%) levels were adopted. The threshing time for each test was recorded by a stop watch. The threshed grain was collected at the outlet, the percentage grain damage and shattering loss during the testing was determined. The process was replicated twice for the combinations.

For the treadle thresher, the same procedure was adopted. Meanwhile, the speeds were obtained and made constant by pedaling with four different 500 level students of the Department. The threshed grains and the un-threshed materials were collected from the chaff manually and weigh after threshing. The damaged seed were also separated from the threshed grains and weighed.

3 Results and discussion

3.1 Throughput capacity

Figure 3, Figure 4 and Figure 5 show the effect of drum speed on throughput capacity at different pod moisture contents and feed rates of 105, 120 and 160 kg h⁻¹ for the motorized thresher. Throughput capacity for the motorized thresher increased from 45.82 to 60.04, 42.71 to 45.78 and 36.42 to 49.41; from 51.43 to

72, 42.00 to 58.60 and 37.61 to 48.46: from 58.61 to 84.00, 54.78 to 74.12 and 25.82 to 63 for 994, IAR48 and TVX respectively at feed rate of 105 kg h⁻¹.

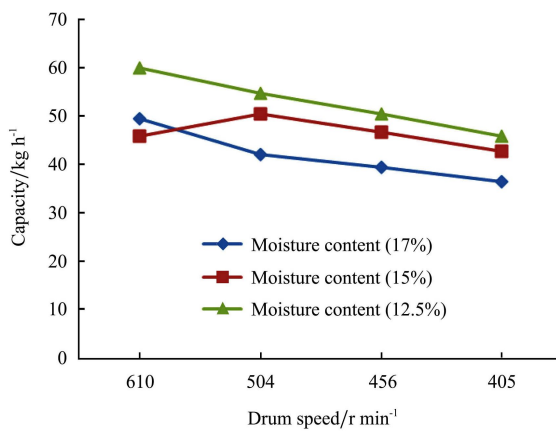


Figure 3 Effect of drum speed on capacity at different grain moisture content and feed rate of 105 kg h⁻¹ for 994 using motorized cowpea thresher

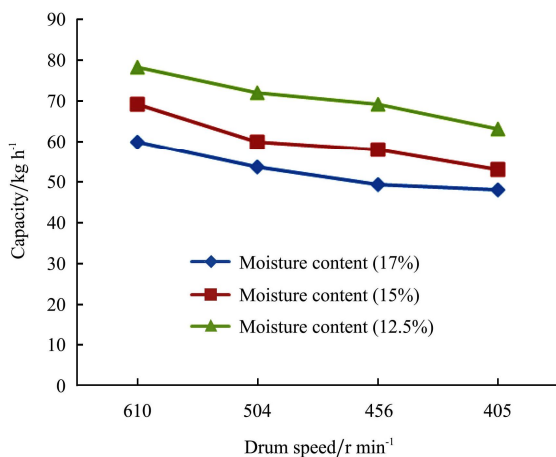


Figure 4 Effect of drum speed on throughput capacity at different grain moisture content and feed rate of 120 kg h⁻¹ for IAR 48 using motorized cowpea

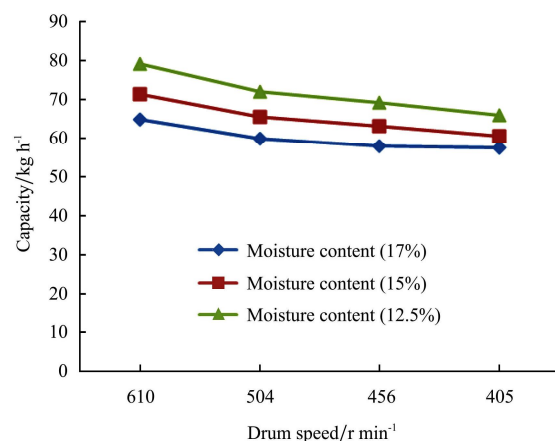


Figure 5 Effect of drum speed on capacity at different grain moisture content and feed rate of 160 kg h⁻¹ for 994 using motorized cowpea thresher

At feed rate of 120 kg h⁻¹, throughput capacity of the motorized thresher increased from 57.14 to 72, 53.73 to 66.67 and 46.75 to 61.01 kg h⁻¹ for 994 varieties; for IAR48 it increased from 63.16 to 78.26, 52.94 to 69.23 and 48.04 to 60 kg h⁻¹ (Figure 4) while throughput capacity of TVX was observed to increase from 65.45 to 85.71, 63.16 to 76.59 and 57.14 to 70.59. It was observed that the throughput capacity is proportional to feed rate.

For the treadle thresher, throughput capacity at 12.5%, 15% and 17% moisture content increased from 59.50 to 70.59, 56.69 to 60.50 and 55.38 to 59.50 kg h⁻¹ for 994; 60.05 to 69.90, 56.25 to 61.02 and 54.55 to 60.00 kg h⁻¹ for IAR48 while it increased from 64.29 to 75.00, 56.69 to 69.23 and 54.96 to 66.06 kg h⁻¹ for TVX. This shows that the motorized thresher has the highest throughout capacity. The maximum throughput capacity was obtained at the highest feed rate of 160 kg h⁻¹, 12.5% grain moisture content and at a drum speed of 610 r min⁻¹ for all the varieties investigated. The throughput capacity increased from 66.06 to 79.12, 60.50 to 71.29 and 57.60 to 64.86 kg h⁻¹; 66.06 to 80.00, 60.00 to 69.00 and 56.69 to 64.29 kg h⁻¹ and from 74.23 to 87.81, 67.92 to 79.12 and 62.61 to 72.00 kg h⁻¹ respectively with increase in drum speed from 405 r min⁻¹ to 610 r min⁻¹ at feed rate of 160 kg h⁻¹ for respective varieties 994, IAR48 and TVX using motorized thresher.

By comparing the results, it can be concluded that the motorized thresher has the highest throughput capacity of 79.12 kg h⁻¹ with TVX variety. Dauda (2001) reported throughput capacity for a manually operated cowpea thresher of 95.4, 93.5 and 92.8 kg h⁻¹ for Kanannado, Borno Brown and Aloka Local, respectively and Olaoye (2011) reported a threshing efficiency of 97% for variety IT84^s-2246 – 4 at moisture content 11% and cylinder speed of 100 r min⁻¹.

3.2 Threshing efficiency

Figure 6, Figure 7 and Figure 8 show the effectiveness of threshing for motorized and treadle threshers respectively at different moisture content level and speed with respect to 994, IAR48 and TVX varieties. Motorized thresher has the highest threshing efficiency of 88.57% with TVX variety at speed capacity of 610 r min⁻¹, moisture content of 12.5% and feed rate of 105 kg h⁻¹.

Low threshing efficiency for treadle thresher was as a result of no concave which aid the adjustment of the clearance at a suitable allowable level. The feed rate influenced the threshing efficiency. Also, moisture content has a significant effect on the threshing efficiency, as moisture content decreases the threshing efficiency increases and vice versa.

From the results obtained, it could be observed that TVX cowpea variety is the easiest to thresh since the varieties were all at the same conditions. Dauda (2001) presented a threshing efficiency between 84.1% to 85.9% for a manually operated cowpea thresher while Adewumi *et al.* (2007) reported a threshing efficiency in the range of 67.5% - 97.7% for a motorized medium scale thresher-cleaner. Vejasit and Salokhe (2004) reported 98% to 100% for axial flow soybean thresher.

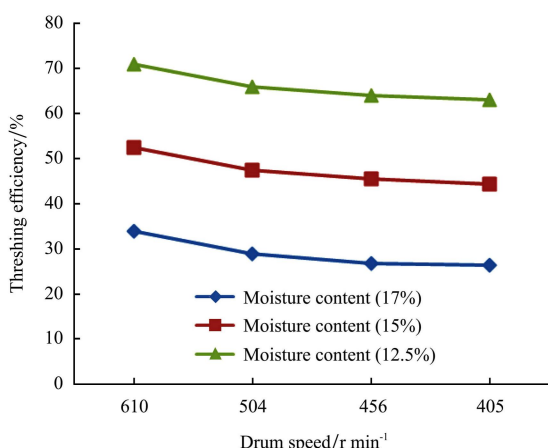


Figure 6 Effect of drum speed on threshing efficiency at different grain moisture content and feed rate of 160 kg h⁻¹ for 994 using motorized cowpea

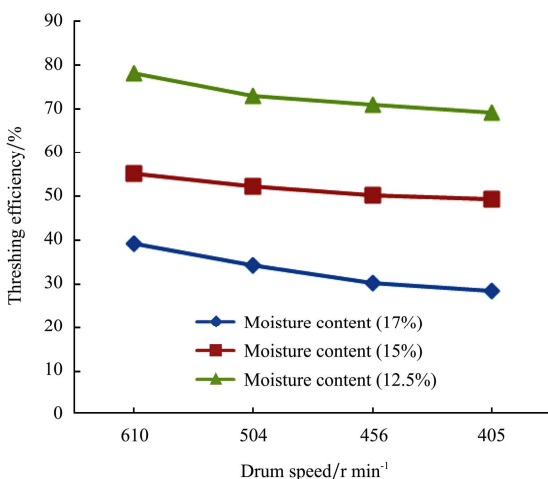


Figure 7 Effect of drum speed on threshing efficiency at different grain moisture content and feed rate of 120 kg h⁻¹ for IAR 48 using motorized cowpea

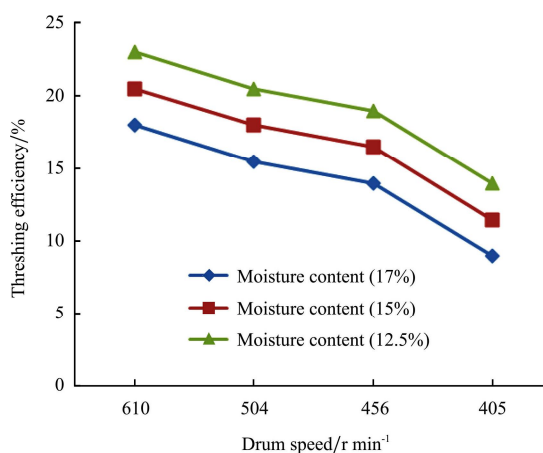


Figure 8 Effect of drum speed on threshing efficiency at different grain moisture content and feed rate of 160 kg h⁻¹ for TVX using treadle cowpea thresher

3.3 Grain damage

Figure 9, Figure 10 and Figure 11 show the effect of drum speed on the grain damage at different pod moisture contents and feed rate of 105, 120 and 160 kg h⁻¹. The results indicated that the percentage of grain damage increased slightly with an increased in drum speed and decrease in pod moisture content. This is because increasing the speed increased frequency of impact between the crop and the threshing members and hence, rubbing of the pods were more severe.

However, it was observed that grain damage decreased slightly with an increase in feed rate. For all the varieties investigated. The lowest percent seed damaged 6.00 and 2.5% for TVX followed by 994 (1 and 2.5%) and then IAR48 (1.5 and 1.5%). At moisture content level of 17% speed 405 r min⁻¹ and feed rate of 160 kg h⁻¹ for motorized and treadle thresher respectively. The reduced damage observed for motorized thresher is due to the presence of concave. At low moisture content, the grains became hard and brittle. As soon as a force is applied through the speed rotation, it splits into pieces. At high moisture content, the grains are easily compressed with lower force.

The 6% seed damage of the TVX compares favourably with the postulation by Allen and Watts (1998), that depending on the amount of cowpea threshed, the amount of broken cowpea should not exceed 15% of the total weight of threshed cowpea. However, moisture content state and impact on the cowpea pods during

threshing are paramount in determining crop mechanical damage (Allen and Watts, 1997; Dauda, 2001).

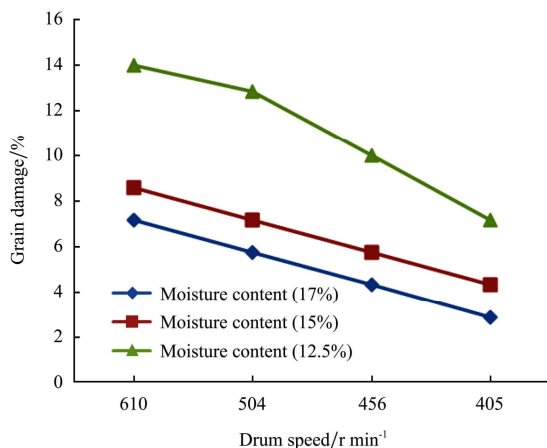


Figure 9 Effect of drum speed on percentage grain damage at different grain moisture content and feed rate of 105 kg h⁻¹ for IAR 48 using motorized cowpea thresher

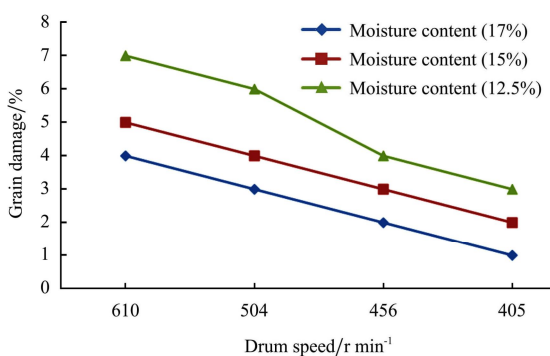


Figure 10 Effect of drum speed on percentage grain damage at different grain moisture content and feed rate of 120 kg h⁻¹ for 994 using motorized cowpea thresher

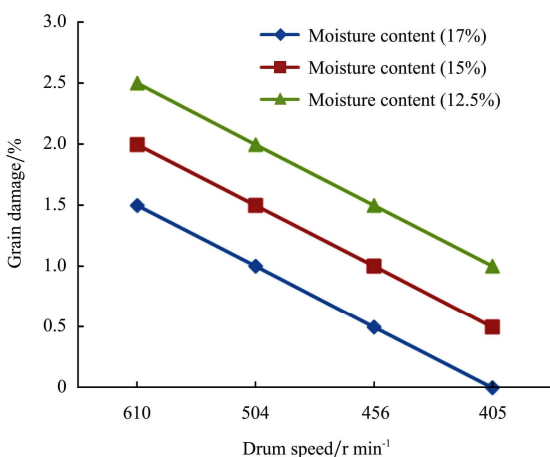


Figure 11 Effect of drum speed on percentage grain damage at different grain moisture content and feed rate of 160 kg h⁻¹ for TVX using motorized cowpea thresher

3.4 Cleaning efficiency

Figures 12, Figure 13 and Figure 14 show the effect of

machine speed on the cleaning efficiency. At the threshing cylinder speed of 405 r min⁻¹ (fan speed of 487 r min⁻¹) cleaning efficiency was 80.77%, 75.58%, and 72.46% for 994, IAR48 and TVX respectively at moisture level of 12.5% and feed rate of 160 kg h⁻¹ using motorized thresher. While at threshing speed of 610 r min⁻¹ (fan speed of 1,102 r min⁻¹) the cleaning efficiency was 73.35%, 73.00%, and 70.97%.

At feed rate 105 kg h⁻¹, highest cleaning efficiency of variety IAR48 was 74.32% at 405 r min⁻¹ and 12.5% moisture content while lowest value was 66.87% at 456 r min⁻¹ and 17% moisture content. Similar trend was observed at feed rate 120 kg h⁻¹; highest cleaning efficiency (75%) was obtained at 12.5% moisture content

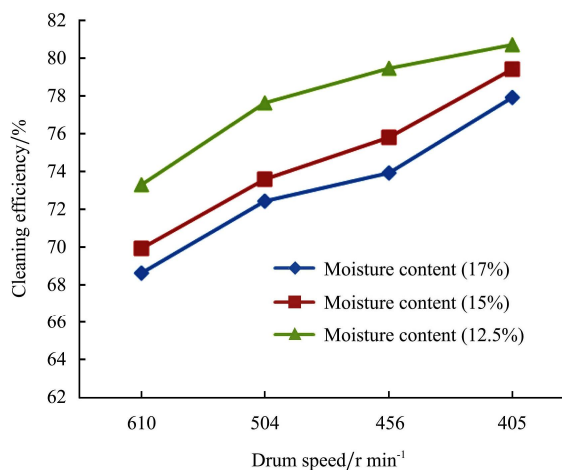


Figure 12 Effect of drum speed on cleaning efficiency at different grain moisture content and feed rate of 160 kg h⁻¹ for 994 using motorized cowpea thresher

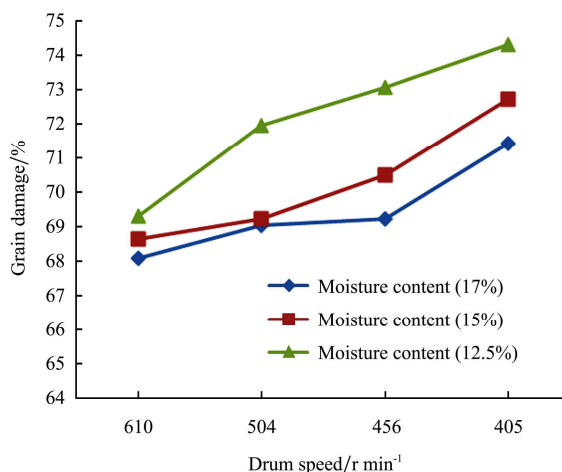


Figure 13 Effect of drum speed on cleaning efficiency at different grain moisture content and feed rate of 105 kg h⁻¹ for IAR 48 using motorized cowpea thresher

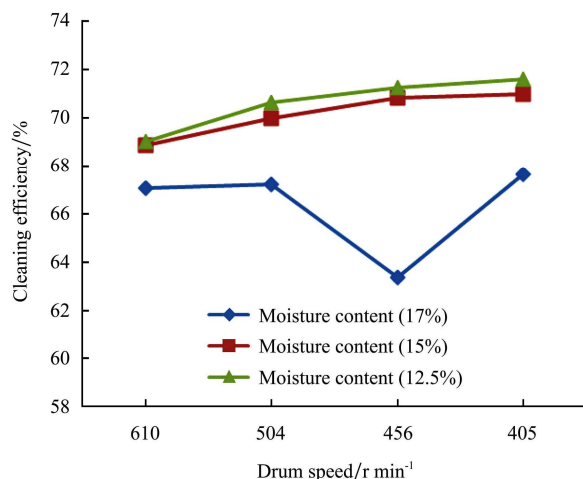


Figure 14 Effect of drum speed on cleaning efficiency at different grain moisture content and feed rate of 120 kg h⁻¹ for TVX using motorized cowpea thresher

whereas at 17% moisture content cleaning efficiency was 61.45%. These results indicate that cleaning efficiency of the motorized thresher increased as the cylinder speed and moisture content decreases. It was also observed that the feed rate had significant effect on cleaning efficiency of the thresher. Cleaning efficiency of the treadle thresher was observed to be significantly low at three levels of moisture contents and all feed rates.

4 Conclusions

Performance evaluation of motorized and treadle cowpea threshers revealed the following:

1) The throughput capacity of the two tested cowpea threshers was between 66.06, 59.50 kg h⁻¹ to 79.12, 70.59 kg h⁻¹; 60.06, 60.00 kg h⁻¹ to 80.00, 69.90 and 74.23, 64.29 kg h⁻¹ to 87.81, 75.00 kg h⁻¹ for 994, IAR48 and TVX at all drum speeds, moisture content and feed rates. By comparing the results, it can be concluded that the motorized thresher has the highest capacity of 87.83 kg h⁻¹ with TVX variety.

2) High moisture content tend to reduce the mechanical damage for the three varieties of cowpea investigated while low moisture content tend to increase mechanical damage. Based on the machine, treadle thresher has the highest grain damage. This may be due to no concave to aid rubbing action.

3) The cleaning efficiency for the motorized thresher increased as the cylinder speed decreases. Also as the feed rate increased the cleaning efficiency increases. Decreasing them moisture content increased cleaning efficiency.

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