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Effect of Operating Parameters on Decortication of *Jatropha Curcas* Fruits

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ABSTRACT: A Jatropha decorticator was designed, fabricated and its performance evaluation was carried out. Measured performance parameters included Decorticating efficiency, Cleaning efficiency, Percentage seed loss, Mechanical damaged index, and Decorticating performance index. A 5 × 2 × 2 factorial experiment in Completely Randomized Design was used to investigate the performance of the machine. The highest Decorticating efficiency, Cleaning efficiency and Decorticating performance index were 93.25%, 93% and 91.28% respectively. The lowest Percentage seed loss and Mechanical damage index were 1.49% and 1.19% respectively. More seed loss was experienced as the machine speed increased. Also, seed breakage was recorded at higher machine speed. Hence, biodiesel production from Jatropha would be highly productive and sustainable with this decorticating machine.

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Jatropha curcas. L is a shrub from the family *Euphorbiaceae*. It can survive in harsh weather conditions. All its parts are immensely beneficial for both domestic and industrial purposes (Prasad and Khan, 2012). The seed contains oil which is useful for soap, lubricant, insecticide, and biodiesel production (Lubis *et al*., 2011; Lubis *et al.,* 2012; Ong *et al.,* 2012). The rising needs for energy necessitate the exploitation of energy crops like Jatropha. The biodiesel from Jatropha is renewable, sustainable, and not harmful to the environment. It could become surrogate source energy if it is aggressively cultivated and processed into biodisesel (Yahya *et al.,* 2013). After harvesting Jatropha fruits, it is sun-dried, decorticated and oil expressed from its seeds (Jain and Sivala, 1997). Jatropha fruits is decorticated by getting rid of the outer cover that enclose the seeds and taking out the seed unharmed for oil to be expressed from it. The manual decorticating of Jatropha fruits process is quite demanding in terms of time and labour. Also, the output is dependent on the skill-sets of the operator (Jain and Sivala, 1997). Mechanical means of decorticating Jatropha fruits for biodiesel production are important to enhance mass production of the oil at a faster and easier rate with a higher recovery percentage (Amoah, 2012). Ting *et al*. (2012) designed and fabricated Jatropha decorticator that consisted of mainframe, stationary cylinder, rotary cylinder, and fan and transmission system. It was powered by 1 kW variable speed electric motor with a provision for manual operation. The developed machine was tested. The optimized operating conditions of the machine were moisture level of 9.5% (w.b), 6 mm concave clearance and 750 rpm drum speed. However, the speed of the fan which is important in the overall performance of the machine was not varied during the performance evaluation. Pradhan *et al*. (2010) developed and evaluated decorticator for jatropha fruits. The decorticator was tested at 7.97%, 10.53%, 13.09% and 15.65% moisture content (d.b), 18, 21, 24 and 27 mm concave clearance. The optimum decortication was achieved at 7.97% moisture content (d.b), 21 mm concave clearance and machine efficiency of 90.96% was obtained. However, for high level production of biodiesel from Jatropha seeds, the decorticator must be motorized in order to meet up with global energy demand. Also, going by all the economic importance

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of Jatropha seeds, motorized processing is imperative and best decorticating performance indices established. Therefore, this research work was aimed at investigating the effects of operating parameters on decortication process of the *Jatropha Curcas* fruits by a motorized decorticator.

MATERIALS AND METHODS

Sample Preparation: The *Jatropha Curcas* fruits were obtained from the University of Ilorin *Jatropha* farm, permanent Site, Ilorin. Samples of *Jatropha Curcas* fruits were dried in an oven at 130 °C for six hours. Then, the fruits were allowed to cool for an hour in a desiccator after which their weights were obtained by using a weighing scale (Model KL30l with 0.001g sensitivity). The moisture content (wet basis) of the *Jatropha Curcas* fruits was then calculated. For the evaluation of the machine performance, a portion of the *Jatropha Curcas* fruits at 14% moisture level was utilized for a part of the test. Another portion of the *Jatropha Curcas* fruits were dried until they attained 10% moisture level and were utilized for the second part of the test. 0.07 kg of *Jatropha Curcas* fruits was decorticated manually in five equal portions to establish mean seed to chaff ratio.

Experimental Procedure: The selected factors for the performance evaluation experiment were: Machine Speed which represented both the decorticating shaft speed and Fan speed, Moisture Content and Feed rate. The selected Machine speeds were 1100, 1200, 1300, 1400 and 1500 rpm. Two levels of Moisture Content used were 10% (wb) and 14% (wb). Two levels of feed rates, 30 kg/h and 40 kg/h were used for the test. The *Jatropha Curcas* decorticator was run by a 3-phase 5 hp electric motor that had a double-grooved pulley on it. The same electric motor was used to run the decorticating drums and the fan simultaneously. Hence, once the speed of the electric motor was altered, the speeds of the decorticating drums and the fan automatically changed. The speed of the 5 hp electric motor was varied by the use of a 3-phase 5.5 kW Mdaoud frequency inverter. When the frequency setting of the frequency inverter is changed it automatically changed the speed of the electric motor connected to it. The speeds were established using a digital tachometer. The performance indices investigated were Decorticating efficiency, Cleaning efficiency, Percentage seed loss, Mechanical damage index and Decorticating performance index.

Performance Indices: Equations 1 to 6 were given by NSAE/NCAM/SON (1997) for the calculation of the performance indices.

$$A = B + C + D \qquad 1$$

$$E_T = \left(1 - \frac{D}{A}\right) \times 100\ \% \qquad 2$$

$$E_c = \left(1 - \frac{q \times G}{A}\right) \times 100\ \% \qquad 3$$

$$E_L = \left(\frac{H}{A} \times 100\right)\% \qquad 4$$

$$E_D = \left(\frac{E}{A} \times 100\right)\% \qquad 5$$

$$DPI = 100 \times E_c E_T (1 - E_D) \qquad 6$$

Where: E_T = Decorticating Efficiency; E_c = Cleaning Efficiency; E_L = Percentage seed loss; E_D = Mechanical damage index; DPI = Decorticating performance index

A = Total amount of fruits fed into the machine (kg); B = amount of decorticated seeds at seed outlet (kg); C = amount of decorticated seeds at other outlets (kg); D = amount of un-decorticated seeds at all outlets (kg); E = amount of damaged seeds retrieved at all outlets (kg); G = amount of chaff in seed outlet (kg); H = amount of all seeds (whole, damaged, and un-decorticated) at chaff outlet (kg); q = seed to chaff ratio.

Statistical Analysis: The statistical analysis adopted for the machine performance evaluation was a 5 × 2 × 2 factorial experiment in Completely Randomized Design, with three replicates using Statistical Products and Service Solutions (SPSS) 18.0. Analysis of variance (ANOVA) was used to analyze the significance of each of the factors on each of the performance indices. Duncan Multiple Range Test (DMRT) was also used to analyze the mean difference between machine speeds.

RESULTS AND DISCUSSION

The Isometric view and the Exploded view of the developed decorticator are shown in figures 1and 2 respectively. A picture of the fabricated decorticator is also shown in figure 3.

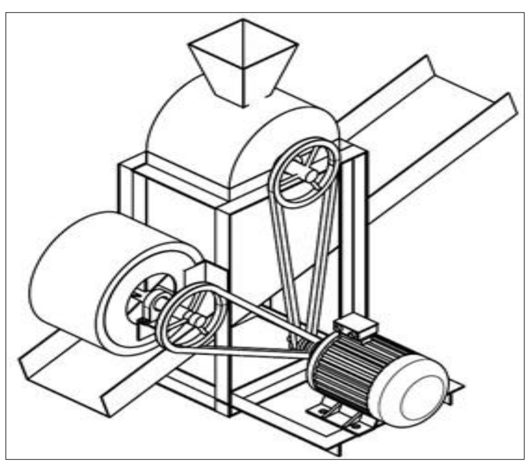

Fig 1: Isometric View of the Decorticator

From the Analysis of variance test and Duncan Multiple Range Test it was found out that for decorticating efficiency, the ANOVA indicated that the machine speed and moisture content were significant at P ≤ 5%. The DMRT showed that decorticating efficiency changed as machine speed varied. For cleaning efficiency, the ANOVA showed that the machine speed and moisture content were significant at P ≤ 5% level. The DMRT showed that the levels of the machine speed varied statistically from one level to the other. For Percentage seed loss, the ANOVA depicted that machine speed and moisture content were significant at P ≤ 5% level. The DMRT indicated that for percentage seed loss, decorticating speed and machine speed were statistically different from one level to the other.

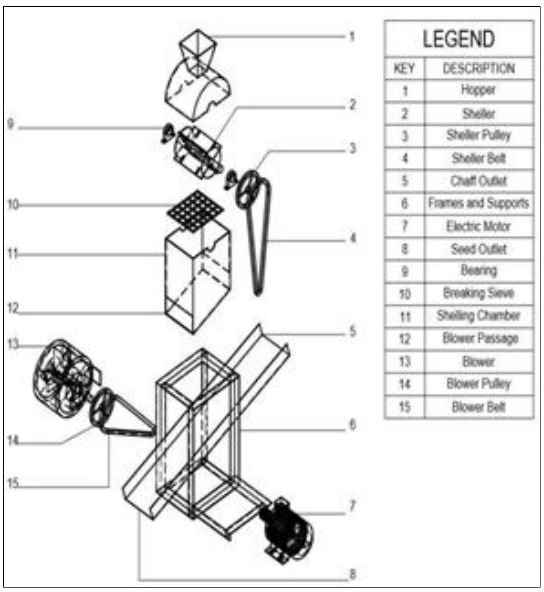

Fig 2: Exploded View of the Decorticator

Fig 3: Picture of the Decorticator

For the mechanical damage index, the ANOVA indicated that the machine speed and moisture content were significant at 95% confidence level. This shows that for mechanical damage index, machine speed at each level was statistically different from one to another.

Decorticating Efficiency: From figure 4, it could be seen that the Decorticating efficiency increased as the machine speed increased, having the largest value of 93.25% at the speed of 1500 rpm and the least value of 90 % at the speed of 1100 rpm. The same trend was claimed by Atiku *et al.* (2004), for Bambara groundnut sheller that at higher speed, more seeds were decorticated than at lower speed. This implies that as more energy is impacted on the shaft, the decorticating efficiency increased. Similar trend was also reported by Fironzi *et al.* (2010) in the study of the effect of rollers Differential Speed on decorticating efficiency of rubber roll husker for paddy rice and coffee.

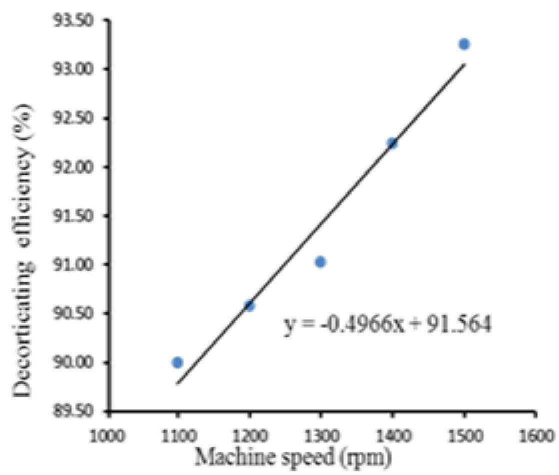

Fig 4. Effect of Machine Speed on decorticating efficiency

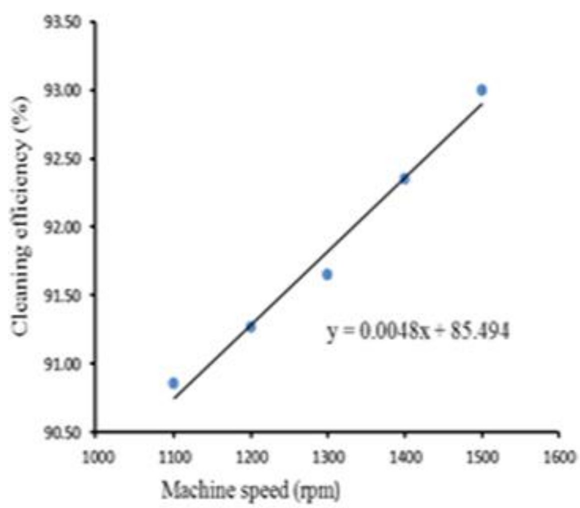

Fig 5. Effect of Machine Speed on cleaning efficiency

Cleaning Efficiency: The cleaning efficiency increased with higher machine speed as depicted in figure 5. This may be because more flow of the mixture of seeds and chaff could be experienced at higher machine speed. This result is similar to that of the research carried out by Bedane *et al*. (2008) who reported that, seeds within turbulent air flow experience higher velocity to move out of the machine. In addition, Akintade and Bratte (2015) reported higher cleaning efficiency as the speed of fan increased for evaluation of a roasted groundnut blanching machine. Hence, it was recommended that a combination of drum speed and fan speed that has an equivalent least percentage seed loss should be looked for. However, the maximum cleaning efficiency was 93 % at machine speed of 1500 rpm and the lowest cleaning efficiency of 90.86 % at 1100 rpm machine speed were achieved as depicted on the graph.

Percentage Seed Loss: It can be deduced from figure 6 that as the machine speed increased there was a corresponding increase in the percentage of seed loss. The least percentage seed loss was 1.49 % at machine speed of 1100 rpm while the highest was 2.19 % at 1500 rpm. This result is similar to that of Raji and Akaaimo (2005) for *Prosopis Africana* seeds which showed lower percentage seed loss at lower speed and higher percentage seed loss at high speed. Furthermore, Akintade and Bratte (2015) reported that as fan speed increased more seeds escaped from the outlet due to higher kinetic energy when roasted groundnut blanching machine was evaluated.

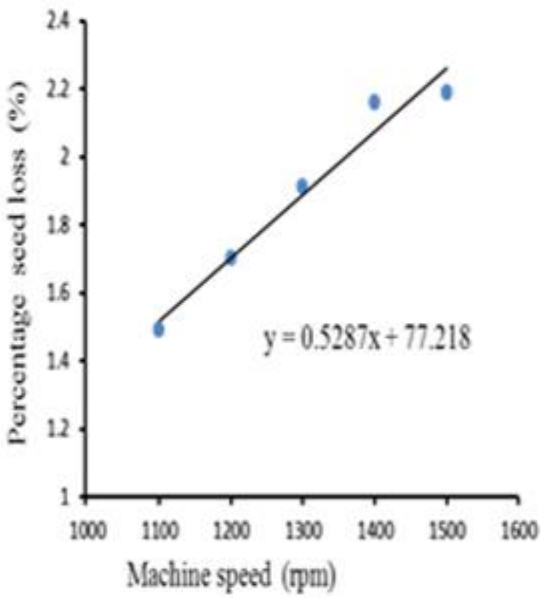

Fig 6. Effect of Machine Speed on Percentage seed loss

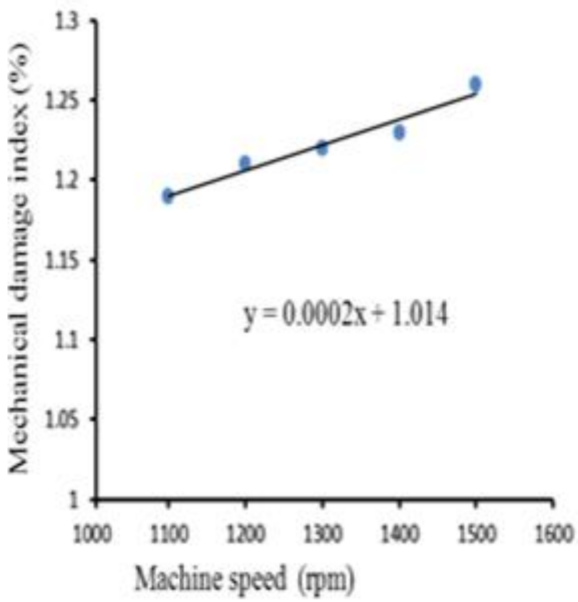

Fig 7. Effect of Machine Speed on Mechanical damage index

Mechanical Damage Index: Figure 7 indicates that increase of mechanical damage index as the machine speed increased. This could be as a result of higher impact energy exerted on the fruits, thereby causing kernel breakage.

Hence, the need for the selection of the suitable operating speed for the machine to avoid higher mechanical damage on the seed. Also, the figure indicates that the highest mechanical damage value was 1.26 % at machine speed of 1500 rpm. Similar research was done by Onyechi *et al.* (2014) for castor seed shelling machine. It was recorded that a higher breakage was observed at the higher operating speed. This could be as a result of higher impact energy exerted on the fruits, thereby causing the seed to break. Also, Zaalouk (2009) reported that as decorticating speed rose, there was an increase in mechanical damage index for performance evaluation of local beans thresher.

Decorticating Performance Index: This computation was carried out in accordance with the research carried out by Bedane *et al.* (2008). Decorticating performance index for seed processing incorporates Decorticating efficiency, Cleaning efficiency and mechanical damage index in its evaluation of seed processing system. Figure 8 illustrates the best decorticating performance index of 91.28 % at machine speed of 1500 rpm while the least decorticating performance index was 90.50 % at machine speed of 1100 rpm.

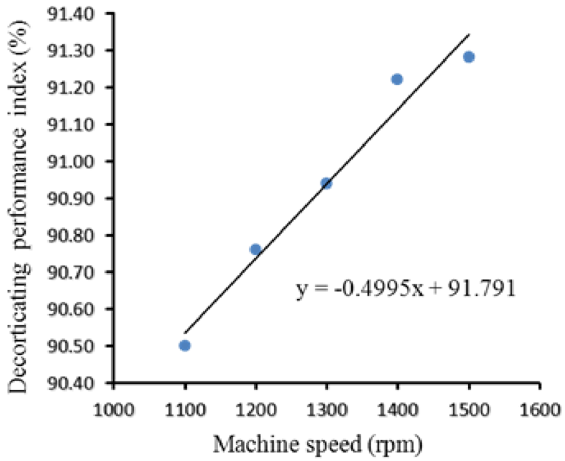

Fig 8. Effect of Machine Speed on decorticating performance index

Conclusions: A Jatropha decorticator was developed. It was observed from the performance evaluation that the highest decorticating and cleaning efficiencies were 93.25 % and 93%, respectively. The study also revealed that the decorticating efficiency, cleaning efficiency, percentage seed loss and mechanical damage index increased with increase in machine speed. The best decorticating performance index for the machine was 91.28 % at an operating machine speed of 1500 rpm. Having achieved this, a satisfactory oil expression from the seeds could be guaranteed.

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