DEVELOPMENT AND PRELIMINARY EVALUATION OF *JATROPHA CURCAS* FRUIT DECORTICATOR

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ABSTRACT

The local ways of decorticating Jatropha Curcas fruits using mortar and pestle or by cracking with hand is time consuming, unhygienic, labour intensive and grossly inadequate to meet the present demand of Jatropha seeds processing and other value-added products in the country as the oil from the seeds can serve as alternative fuel for diesel engines. To overcome these challenges, variables that influence this very important decorticating process require proper attention. A Jatropha Curcas fruit decorticator was designed and it consists of feed hopper, threshing unit, frame, bearings, and shell outlets. The design of the machine was based on the selected engineering properties of Jatropha fruits and all materials used for the construction were sourced locally. The machine was evaluated for its performance and data obtained from the test were analyzed statistically with software SPSS 18 using a 3×3 factorial experiment in a Completely Randomized Design. The results showed that the highest decorticating and cleaning efficiencies were 93.9 % and 98.4 % respectively while the highest percentage seed loss and mechanical damage index were 12.5 % and 6.3 % respectively. The study also revealed that the decorticating efficiency, cleaning efficiency, seed loss and mechanical damage index increased with increase in decorticating speed. This machine could make large scale production of biodiesel from Jatropha Curcas achievable.

Keywords: Design, Fabrication, Jatropha Curcas, Preliminary evaluation, Decorticating.

1. INTRODUCTION

Jatropha Curcas is a shrub tree which can survive in any part of Nigeria with next to zero support as it is drought-resistant, perennial and multipurpose like the cassava plant as detailed by Oyebanji (2017). It is a deciduous tree, shedding its leaves during the dry session and can develop to a stature of 3-5 m, and may stay profitable for the next 30 to 50 years (Oyebanji, 2017). Jatropha has a profound taproot and four shallow lateral roots. The taproot secures the plant in the soil, stabilizing the soil against landslides, and the lateral roots forestall soil disintegration. The trunk is secured with a smooth dark bark that oozes watery and clingy latex when cut. The trunk is protected with a smooth grey bark that exudes watery and sticky latex when cut. The leaves are smooth, 4-6 lobed, 10-15 cm long and wide, and are usually pale green in colour (Pramanik, 2003). Inflorescences grow at the apex of the branches and bear approximately 10 or more ovoid fruits (Makkar *et al.*,2008). Jatropha flowers and fruits develop during the rainy season or all year-round in humid regions. The pods contain numerous elliptic seeds and become yellow when they develop or mature. Dry Jatropha contains about 38% husks and 62% seeds. The seeds are similar to that of castor seeds in shape, and are dark in colour (Pramanik, 2003). They comprise of 30-40% testa (shells), 60-70% kernel and 44 – 62% oil content (Oyebanji, 2017).

Jatropha Curcas is a plant with numerous utilizations and extensive potential. Luckily, the plant is treasured for its therapeutic purposes and does not deliver any poisonous material to the immediate environment; rather, it cleans the environment (Openshaw, 2000). It was found that 23 percent of carbon dioxide (CO_2) in the territory where Jatropha Curcas is planted is absorbed by the plant per annum (Belewu and Ogunsola, 2010). Clearly, none of the plant part is useless, every part of the plant has its helpfulness; the leaves can be utilized for rearing of silkworm (Openshaw, 2000). In small scale ventures, it is used for dyeing and in medications as mitigating substance. The seeds may be used as insecticides and the oil extracted can be used for producing fuel, soap and varnish. Seed cake obtained after oil extraction can be used for manure, solid fuel, or biogas production. Nontoxic species or detoxified seed cake can be utilized as part of raw materials for making feed for domestic animals (Makkar *et al.*,2008; Openshaw, 2000).

The decorticating process of Jatropha fruit is of great significance for the process of Jatropha seeds oil expression in terms of both oil quality and quantity. The process can be performed either manually or by mechanical means (Achten *et al.*, 2008; Kheiralla *et al.*, 2016; Lim *et al.*, 2014). The conventional techniques of decorticating consumes a lot of time, labour intensive and tedious, this method causes damage to the fingers of the labourers and low yield rates, which was estimated at a limit of 50 kg of dried Jatropha fruits per expert per 8 hours of work hour per day (Pradhan *et al.*, 2010; Lim *et al.*, 2014). It was claimed that these old techniques of shelling

Jatropha can be substitutedwith mechanical methods which would help increase the yield of the kernels and consequently optimize the Jatropha oil extraction process (Kheiralla *et al.,* 2016). Development of automated decorticator for the detachment of kernel from husks and shell of Jatropha fruit, is the current research trend with the aim of achieving large-scale production of Jatropha oil so as to enhance the processing of biodiesel production as alternative to conventional diesel (Kheiralla *et al.,* 2016).

Pradhan *et al.* (2010) designed, manufactured and tested a hand operated decorticator for Jatropha fruits. It was revealed that the developed machine was influenced by both the moisture content and the clearance betweenthe concave sieve and the rotating blades. The machine efficiency of 90.96% was accomplished at optimum fruit moisture content of 7.97% (d.b.) and a concave clearance of 21 mm. Ting *et al*. (2012) developed and evaluated Jatropha Sheller which comprised of a revolving chamber, fixed chamber, mainframe and a transmission system, with decorticating limit of 120 kg/hr. The outcomes indicated that the designed decorticator attained itsoptimum working conditions (shelling efficiency of 99 % and Shelling capacity of 110.8 kg/h) at Jatropha fruit moisturecontent of 9.5% (d.b.), roller speed of 750 rpm and clearance of 6 mm.

The local ways of decorticating jatropha fruits using mortar and pestle or by cracking with hand is time consuming, unhygienic, labour intensive and grossly inadequate to meet up with the present demand of Jatropha seeds processing and other value-added products. To overcome these challenges, variables that influence this very important decorticating process required proper attention. Therefore, the objectives of this research were to develop a Jatropha Curcasfruit decorticator and carry out preliminary evaluationof the machine.

2. MATERIALS AND METHODS

2.1 Design Considerations

The engineering properties of Jatropha fruit used for this design were those described by Salawu *et al* (2013) at 7.5% moisture content. The machine should achieve a reduction in the overall production cost thereby increasing the productivity and reduced seed losses and damage. It should run at a speed that would remove the chaff without breakage and separate chaff from the seeds. The cost of the machine should be affordable by farmers and cheaper than similar imported machines. Materials used for the fabrication should be readily available and adaptable to the common varieties of Jatropha.

2.2 Design of Machine Components Parts

The average values of parameters used in the machine design are presented in Table 1.

Table 1: Summary of the parameters used in the development of the Jatropha Fruit Decorticator.

S/N	Parameter	Formula	Value	Reference
1.	Design of Hopper	$V = \frac{1}{3}\left(A_1 + A_2 + \sqrt{A_1 + A_2}\right)h$	8201438.8 mm^3	Ogundipe*et al.*, (2011)
2.	Shaft Design	$d^3 = \frac{16}{\pi S_s}\sqrt{(k_b M_b)^2 + (K_t M_t)^2}$	20 mm	Khurmi and Gupta (2004)
3.	Power Required to Drive the Machine	$P_T = P_D + P_F$ $P_D = m \times \omega^3 \times r^2$ $P_D = m(\frac{2\pi N}{60})^3 r^2$	$P_D = 2.770$ kW	
4.	Power to Drive the Fan	$P = \frac{QPs}{\varepsilon}$	$P = 219.4$W	
5	Fan Belt Length	$L_F = 2C_F + 1.579(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4C_F}$	$L_F = 602$ mm	Shigley and Mitchell (2002).
6	Drum Belt Length	$L_d = 2C_d + 1.579(D_1 + D_3) + \frac{(D_1 - D_3)^2}{4C_d}$	$L_d = 1119$ mm	Shigley and Mitchell (2002).

2.3 Description of the machine components and operation

The Jatropha fruit decorticator was designed and fabricated. Its components consists of hopper, decorticating shaft, decorticating chamber, belt and pulley drive assembly, bearing, speed reduction electric motor and its seat, idler pulley, decorticated seed outlet and chaff discharge chute. Figures 1 , 2 and 3 show the Orthographic projections, Isometric view and the exploded view of the machine respectively.The machine was conceived to be cost effective, easily adjusted, easily assembled and dismantled and easily fabricated by the local fabricators. The machine works on rotating impact principle, mature-dry Jatropha Curcasfruits were fed through the hopper of the machine. The fruits dropped by gravity on the decorticating shaft with the bars hitting the fruits against the walls of the decortication chamber. The bars are lined with rubber material. The fruits are cracked by the rotating impact of the bar before falling on a perforated concave sheet of metal. At this point, the seed and the chaff fall through the perforated concave. After this, the mixture of the seeds and the chaff moves into the cleaning unit. A centrifugal fan in the cleaning unit of the machine supplies the air stream that separates the chaff from the seeds. The chaff is discharged at the chaff discharge end while the seeds are collected at the seeds delivery chute.

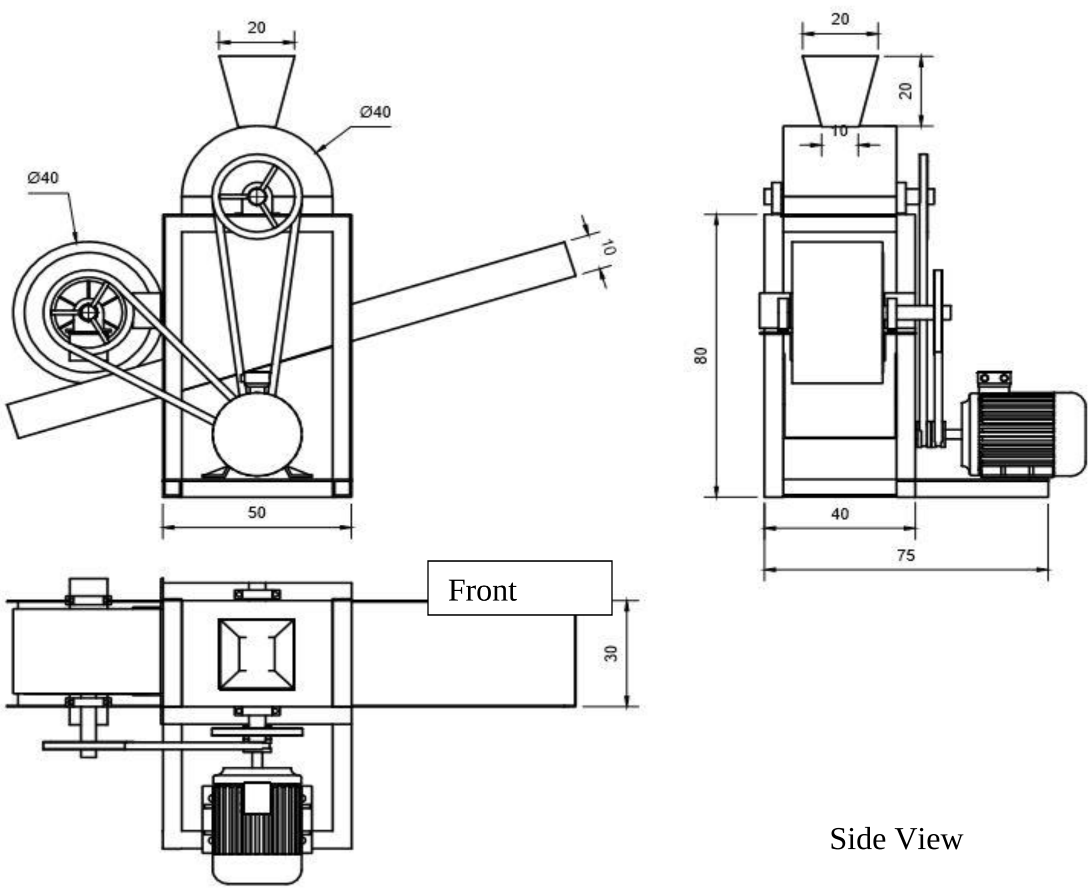

Figure 1: Orthographic Projections of the Jatropha Decorticator

Plan View

All dimensions in mm

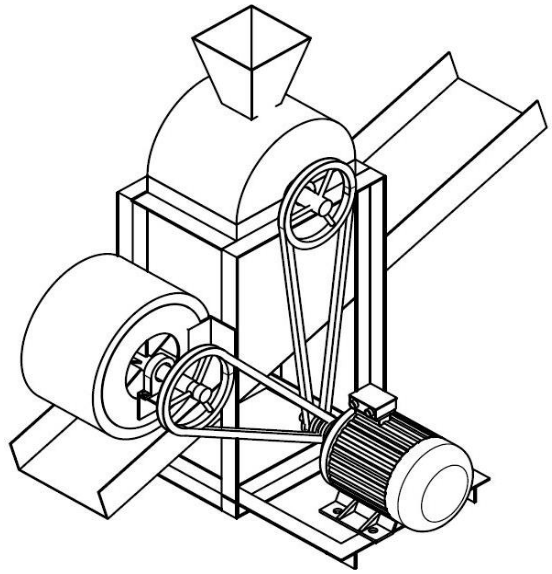

Figure 2: Isometric View of the Machine.

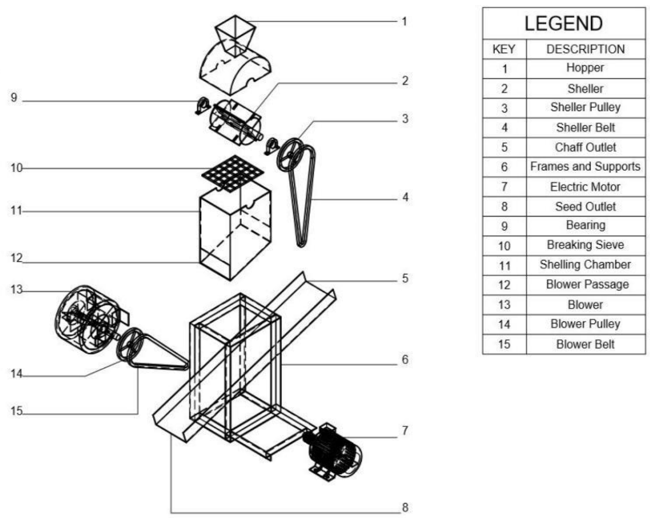

Figure 3: Exploded View of Designed Machine

2.4 Sample Preparation

Jatropha Curcas (Linnaeus) variety fruitswere harvested from the *Jatropha Curcas*plantation of the University of Ilorin permanent site, Ilorin. For the purpose ofpreliminary evaluation,160 kg of *Jatropha Curcas*fruits were sun dried until they attained 7.5% (dry basis) moisture contentbefore they were used for the experiment. Manual decorticating of 0.07kg of *Jatropha Curcas*seeds were done in five replicates. This was used to establish the average seed to chaff ratio.

2.5 Assessment of the Performance of the Designed Jatropha Decorticator

The following performance indices expressions were obtained from the Nigerian Industrial Standard Test Code for grain threshers prepared by NSAE/NCAM/SON (1997) as presented in equations 1 – 5.

Total seed input per unit time, A (kg); = B+C+D 1

Decorticating Efficiency, $E_D = \left(1 - \frac{\mathrm{D}}{\mathrm{A}}\right) \times 100\%$ 2

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

Percentage seed loss, $E_L = \left(\frac{\mathrm{H}}{\mathrm{A}} \times 100\right)\%$ 4

Mechanical damage index, $E_D = \left(\frac{\mathrm{E}}{\mathrm{A}} \times 100\right)\%$ 5

where; E_c = Cleaning efficiency (in decimal), E_D = Decorticating efficiency (in decimal), E_D = Mechanical damage index (in decimal), E_L = Percentage seed loss (in decimal), B =mass of decorticated seeds at seed outlet per unit time (kg).C = mass of decorticated seeds at other outlets per unit time, (kg), D = mass of un-decorticated seeds at all outlets per unit time (kg), E = mass of damaged seeds collected at all outlets per unit time (kg). G = mass of chaff in seed outlet per unit time, G (kg), H = mass of all seeds (whole, damaged and un-decorticated at chaff outlet per unit time, H (kg), q = Seed/Straw ratio

2.6 Statistical Analysis

The Analysis of Variance of a 3×3Factorial Experiment using Complete Randomized Design (CRD) for each of the measured parameters was done with Statistical Package for Social Science (SPSS) software version 18. The selected factors were: three levels of decorticating shaft speed (700, 800 and 900 rpm) and three levels of fan speed (1300, 1500 and 1700 rpm). The selected levels of parameters were based on literature and trial experiment. The aim of this factorial experiment was to simultaneously examine all combinations of all factor levels on the performance of the machine. Duncan Multiple Range Test (DMRT) was used to analyze the mean difference between the decorticating shaft speeds.

3. RESULT AND DISCUSSION

3.1 Technical Specifications of the *Jatropha Curcas*Fruits Decorticator

The technical specifications of the designed Jatropha Curcas fruits decorticatorare presented in Table 2. Also, the preliminary evaluation results of the designed Jatropha Decorticator are presented in Table 3.Figure 4 shows decorticated jatropha seeds after the preliminary evaluation of the designed machine while Figure 5 presents the JatrophaCurcas chaff collected after decortications.

Table 2: Technical Specifications of the DesignedJatropha Decorticator

Item	Specification
Machine overall dimensions	1400 ×750 × 1200 mm
Diameter of larger pulley	150 mm
Diameter of small pulley	85 mm
Motor Power / Speed	5hp/ 1440 rpm
Decorticating speed	800 rpm
Number of belts	2
Diameter of the drum shaft	25 mm
Fan outlet diameter	20 mm
Throughput capacity	145 kg/h

Table 3: Preliminary EvaluationResults of the Designed JatrophaDecorticator

Test Number	Speed (rpm)	Decorticating Efficiency (%)	Cleaning Efficiency (%)	Percentage Seed Loss (%)	Mechanical Damaged Index (%)
	700	77.4	97.2	8	4.8
	800	87.5	98.8	9.2	5.8
	900	93.9	98.4	12.5	6.3

Each run of this experiment was replicated eight times at a fan speed of 1300 rpm.

Table 4 depicts the results of Duncan's Multiple Range Test (DMRT) for the different parameters measured. For decorticating efficiency, the analysis of variance (ANOVA) indicated that the decorticating shaft speed is significant at P≤ 5%. The DMRT shows that decorticating efficiency changed as decorticating shaft speed varied. For cleaning efficiency the ANOVA showed that the fan speed was significant at P≤ 5% level. The DMRT shows that the level decorticating shaft speed varied statistically from one level to the other.For Percentage seed loss, the ANOVA depicts that decorticating speed, fan speed were significant at P≤ 5% level. The DMRT indicates that for percentage seed loss, decorticating shaft speed were statistically different from one level to the other. For the mechanical damage index, the ANOVA indicates that the decorticating shaft speed and fan speed were significant at 95% confidence level. The DMRT shows that for mechanical damage index, decorticating shaft speed at each level is statistically different from others.

Figure 4: Decorticated Jatropha Seed.

Figure 5: The Jatropha Curcas Chaff Collected.

Table 4: Means of levels of Decorticating shaft Speed for different Parameters measured

Measured Parameters	Decorticating Shaft Speed		
	1	2	3
Decorticating Efficiency (%)	81.586[a]	86.986 [b]	88.938[c]
Cleaning Efficiency (%)	80.198[a]	85.307 [b]	86.705[c]
Percentage Seed Loss (%)	8.168[a]	8.862 [b]	11.353[c]
Mechanical Damaged Index (%)	4.949[a]	5.668[b]	6.065[c]

Mean speeds with different letters along the same row are statiscally different from each other at $P \leq 0.05$

3.2 Decorticating Efficiency

Decorticating efficiency increased with increase in the decorticating shaft speed, having the highest value of 93.9% at the speed of 900 rpm and the lowest value of 77.4% at the speed of 700 rpm. The same trend was reported formelon seed shelling machinewhere at higher speed (2190 rpm), more seeds were shelled than at lower speed(2100 rpm)(Shittu and Ndrika, 2012). This may infer that as the energy impacted on the shaft increases, the decorticating efficiency increases. The result also shows that increase in decorticating shaft speed leads to increase in the mass of the decorticated fruit.

3.3 Cleaning Efficiency

The cleaning efficiency however, increased (97.2 % to 98.8 %) with higher decorticating shaft speed but dropped slightly at the speed of 900 rpm and may be due to the flow of more mixture from seeds and chaff to be separated at a time (Akintade and Bratte, 2015). However, the maximum cleaning efficiency was 98.8% at decorticating shaft speed of 800 rpm. This result is similar to that of Bedane *et al*. (2008) where it was reported that seeds at high speed air stream experienced higher kinetic energy of escaping through the machine. Also, Akintade and Bratte (2015) reported for evaluation of a roasted groundnut that higher cleaning efficiency of 91.39% was recorded as the machine speed increased.

3.4 Percentage Seed Loss

It can be deduced from Table 3 that the percentage seed loss increased (8 % to 12.5 %) between the 700 rpm and 900 rpm of decorticating shaft speed. This result is similar to that of Raji and Akaaimo (2005) for *prosopis Africana* seeds which showed lower percentage seed loss at lower speed(300 rpm) and higher percentage seed loss at high speed(450 rpm). Also, Akintade and Bratte (2015) reported for evaluation of a roasted groundnut that as machine speed increased more seed escaped from the outlet due to higher kinetic energy.

3.5 Mechanical Damage Index

Table 3 indicates steady increase from 4.8 % to 6.3 % of mechanical damage index as the decorticating shaft 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. This is in line with the report of Olaoye and Adekanye (2018) on the studies on some properties influencing cracking and separation of palm nuts in a mechanical cracker cum separator for palm nuts. The result in this study is also similar to that of Onyechi *et al.* (2014) for castor seed shelling where higher breakage efficiency (20.01 %) at the higher operating speed(1080 rpm) was reported. Also, Zaalouk (2009) also reported that increase in decorticating speed (11.72 to 15.38 m/s) resulted in increase in mechanical damage index (2.40 to 2.90 %) for performance of local beans thresher.

4. CONCLUSIONS

A unit of *Jatropha Curcas* fruit decorticator was developed and evaluated. From the design and preliminary evaluation carried out on the *Jatropha Curcas* fruit decorticator, it was observed that decorticating efficiency increased with increase in the decorticating shaft speed, having the highest value of 93.9% at the speed of 900 rpm and the lowest value of 77.4% at the speed of 700 rpm. The cleaning efficiency also increased with higher decorticating speed but dropped slightly at speed of 900 rpm. The machine has a throughput capacity of 145kg/h and the highest percentage seed loss and mechanical damage index were 12.5 % and 6.3 %, respectively.

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