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Performance Characteristics of a Stationary Impact Decorticator on Jatropha Seed

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Abstract*— Jatropha (curcas species) is a major source of bio-fuel, one of the prominent obstacles in its processing is the decorticating of the seed. An identified decorticator was modified and the evaluation was carried out on Jatropha seed using four speeds (650, 800, 950 and 1100 rpm); three masses (200, 400 and 600g) with two replications. The mean decorticating efficiency ranged from 23.5 to 79 % and the overall average mean decorticating efficiency was 56.54 %. The mechanical seed damage ranges from 13 to 51 % with average mean of 27.51 %. The cleaning efficiency was 14.89 to 53.7 %, while the seed loss ranged from 3.5 to 13 % for the four speeds. The maximum obtained decorticating efficiency for the machine was 79 %. Generally, the machine decorticating efficiency, cleaning efficiency, percentage of seed damage increased and percentage of seed loss decreased with increase in drum speed and throughput.

***Keywords*— Jatropha seed; decortications; machine speed ; machine efficiency.**

I. INTRODUCTION

Jatropha curcas (physic nut) is a drought resistant perennial poisonous shrub (normally up to 5 meters in height) belonging to the Euphorbiacae family, it is an uncultivated non-food wild species. With recent increase in environmental awareness due to the mounting evidence that global warming is occurring due to greenhouse gas emission, the public is yawning for renewable fuel sources with little or no competition with food, this has led major investors to be in search of a fuel source that is clean and does not trade off with crop land and the possible solution is Jatropha seed. Jatropha commonly called American purging nut, *arbol santo*, *curcas* bean, *tuba tuba*, wild castor seed etc is classified among the plant which produces adverse effects in human or economic animals by means of toxic substances it contains [1]. Jatropha grows well in marginal or poor soil, with annual rainfall around 750 mm, it tolerates adverse climatic conditions such as high temperature, low moisture content and soil fertility and can also withstand dryness in semi-arid and it produces for about 50 years after gestation period of 2 to 3 years. [2,3]. The seed is not edible due to presence of toxic constituents such as phorbol ester, curcin, trypsin inhibitors, lectins and phytates as such it residue serves as a feedstock for biodiesel production due to its incompetence for consumption [3,4]. The plant is native to the Central America and has become naturalized in many tropical and subtropical countries including India, Cambodia and China in Asia; Tanzania, Ethiopia, Ghana, Mozambique, Nigeria, Cameroon, Zambia and Mali in Africa; Mexico, Colombia and Brazil in Central and South America etc where it is formerly used as living fence to protect gardens and field from cattle's and wild animals [5]. It produces throughout the year. The jatropha fruit contains 4 to 5 seeds. The seed consist of a hard black shell of 37 % by weight and a soft white kernel of 63 % by weight and moisture content of 7 % having 32 to 40 % oil. Jatropha curcas oil-rich nut can potentially yield 1.5 – 2.5 t/ha biodiesel of the crop grown on marginal land that was unsuitable for food production [3,6] Also Jatropha cake or meal can be used as solid biomass for the production of energy or as fertilizer and even as animal feeds. The sap is often used by some culture to stop bleeding and stem as chewing stick.

There is evidence that curcas has the possibilities for reclaiming marginal soil by re-anchoring the soil with its substantial root system. In thorny, the plant's deep roots would recycle nutrient and reduces the possibilities of erosion [3]. Jatropha has varying economic importance, some of which include: it's crude vegetable oil, a renewable source of energy potential substitute for fossil fuel like diesel, kerosene and other fuel oil; a raw material for the production of soap, cosmetic, insecticide, wool etc; barren and denuded areas rehabilitation and its cake as organic fertilizer can curtail the dependence on chemical fertilizer as well as input for biogas and charcoal production [5].

While there are a number of reasons why Jatropha is grown, arguably the biggest one is as a potential bio- diesel. The synthesized solid CaO- La_2O_3 mixed metal oxide catalysts were utilized in transesterification of jatropha curcas oil as feedstock to produce biodiesel; under the optimized conditions at 65^o C, 4 % catalyst dose with 24:1 MeOH to jatropha oil molar ratio, the transesterification reaction exhibited 86.51 % of biodiesel yield [4]. A drawback of jatropha oil is that it can be high in FFA. Jatropha contains about 14 % FFA, which is far beyond the limit of 1% FFA level that can be converted into biodiesel easily by transesterification using an alkaline catalyst. Acid pretreatment is usually necessary to convert high FFA oil into biodiesel [7]. In countries like India and

Mexico, the use of edible oil for biodiesel is prohibited if it is its first use. A viable alternative in such countries is Jatropha, which produces inedible oil and does not compete with food. There is a rapidly growing interest in using Jatropha as a feedstock for the production of biodiesel, particularly because Jatropha is a wild plant that can grow in dry and marginal lands without irrigation and the oil from jatropha can be converted as easily to biodiesl that meets the American and European standards as any other oil feedstock thus, country like USA have Jatropha as one of the future feedstocks non-food crop for biofuel production to reach the natural biofuel goals without major encroachment on prime farm land. The net energy value for Jetropha is 236 GJ/ha/year- on the assumption of Jetropha seed production of 12.5 t/ha / year [6,7].

Jatropha being a major source of bio-fuel, one of the prominent obstacles in its processing is the decorticating of the seed. De-hulling has been practiced for a long time in history and has taken different forms [8]. Jatropha seed requires 600 to 900 revolutions per minute (rpm) to crack the seed. According to [3] the dehulling principle is based on provoking slight pressure and friction on the fruits within the dehuller that results in the opening and coming loose of the fruit shells. Also a semi mechanical dehuller universal nut sheller (UNS) utilise friction that is provoked by the vertical turned mill inside an outer bell shaped hollow concrete shell with the adjustable lock nut on the top of the vertical axe for desired fruit size had been used to dehull 125 kg/hr of dry seed [3]. Although, it is formerly done manually, aided by the use of mortar and pestle, after pounding, the mixture is washed and sun dried, before further processing for oil extraction. This is usually associated with high level of drudgery, tedious and time wastage couple with material wastage.

Reference [9] Designed and fabricated an okra threshing machine; observed highest threshing efficiency of 99.99 % at drum speed of 500 rpm combine with 55 mm concave clearance. The machine threshing and cleaning efficiencies increased with increase in drum speed.

In order to meet the high demand for the end product of this wonder seed and economic situation, there is need for mechanized Jatropha decortications. Thus, the objective of this work is to appraise the effects of impact force on decortications and quality of Jatropha seed.

II. MATERIALS AND METHODS

A. *Materials*

Jatropha pods were sourced from different parts of Oyo state. The pods were sun dried and manually threshed. Seed sample was taken from the bulk and the initial moisture content obtained by oven dry method. An existing 266 kg/hr Sunflower Decorticating Machine was adopted for the experiment and electric weighing balance of 0.01 g sensitivity was used for weight measurement. t.

B. *Description of the machine*

The machine consists of basic units as frame, decorticating, separating and the power unit. The frame is rectangular in shape and made of 50 x 50 mm angle iron. It bears the total weight of the machine. The decorticating unit consists of the hopper, housing and beater. The hopper retains the seed before it is introduced into the decorticating chamber. It is in the form of top half open box with one side welded to the beater housing. The housing is cylindrical in shape, housing a shaft of 30 mm diameter with fixed beaters along its path. The separating unit consist of duct and the blower. Decorticated seeds and chaff fall through the duct into air stream generated by the blower. The chaff is blown away through the chaff outlet while the seeds fall out through the seed outlet. Both the mean (beater) and the blower shafts are connected to the power source (electric motor or i.c. engine) using belts and pulley arrangements. The machine is as presented in Plate 1 and Figure1.

Plate 1: A Seed Decorticator

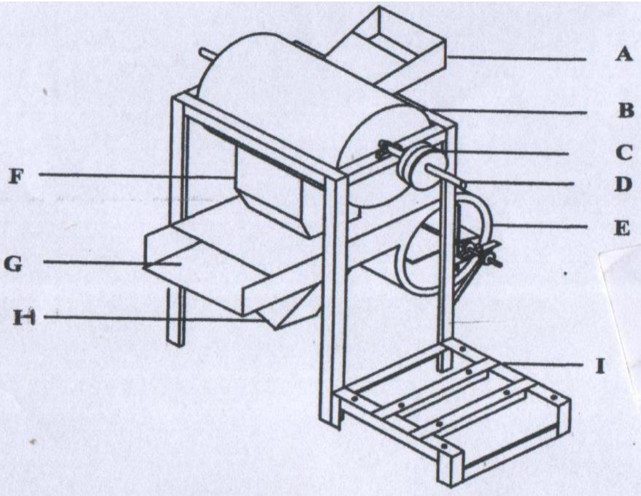

Fig.1. Isometric view of seed decorticator

A - Hopper, B - Auger housing, C - Pulley, D – Auger shaft, E - Blower, F – Duct, G - Chaff outlet, H - Seed outlet, I - Engine seat.

C Evaluation

Evaluation of the developed decorticator was carried out on yield and quality of the decorticated seed on mass bases. Seed decorticating was based on impact action. The quality of these seeds was determined in terms of visible damage. The machine was evaluated using three masses (200, 400, 600 g) and four speeds (600, 750, 900 and 1050 rpm). Speed variation was achieved by the use of step turned pulley on the motor and speed confirmed by the use of a tachometer

Prior to the machine evaluation, seed bulk moisture content was determined by oven dry method by taking a sample from the bulk at a temperature of 130^{o} C for one hour. The machine was set on level ground and the electric motor was switched on, and allowed to run idle for a minute. A known mass of Jatropha seeds were poured into the hopper and the decorticating time recorded using stop watch. The decorticated product from the seed outlet and chaff outlet were collected separately and each sample separated manually into decorticated, un-decorticated, damage, chaff (Plate 2) and their weight taken using an electric weighing machine (±0.01 g). The experiment was replicated two times. Dependent variables viz: threshing efficiency, clearing efficiency, percentage of damaged grains, percentage of grain loss were determined using Nigerian Standard Test Code (NSTCGT) for Grain Thresher [10] National Agricultural Technology Information Centre, India [11] test code and RNAM [12]. The analysis of variance (ANOVA) was used to examine the variation in results of all experiments obtained under the various independent variables and their interaction at 95 % confident limit and the means separated using Duncan Multiple Range Test (DMRT)

The independent variables were calculated as:

I Percentage of un-decorticated seed

$$(G_t) = \frac{J}{G_T} \times 100 \quad (1)$$

Where, J = Weight of un- decorticated seed at all outlets per unit time (kg), G_T = Total seed input (kg)

II Threshing efficiency

$$(\eta_{Thr}) = 100 - G_t \quad (2)$$

III Cleaning efficiency

$$(\eta_{Cl}) = \frac{K}{W_G} \times 100 \quad (3)$$

Where, K = Weight of whole seed at main seed outlet per unit time (kg),

W_G = Weight of whole seed at all seed outlet per unit time (kg)

IV Percentage of damage seed

$$(D_{Gd}) = \frac{E}{Gt} \times 100 - F \quad (4)$$

Where, E = Weight of damage seed collected at all outlet per unit time (kg), F = Percentage of damage of seed in all total input before threshing (%)

Plate 2 Decorticated, un-decorticated and chaff of

Jatropha seed

V Percentage of seed loss

$$(G_L) = \frac{G_t}{G_T} \times 100 \quad (5)$$

Where, G_T = weight of all seeds (whole, damage and un- decorticated at chaff and other outlet per unit time (kg)

Please do not revise any of the current designations.

III. RESULTS AND DISCUSSION

The result of the study on Jetropha seed decortications are presented in Table 1 to 4 and trends in Figures 1 and 2. From Table 1, the minimum and maximum performance are 23.50, 79.0 % (decortications efficiency); 14.89 %, 53.7 % (cleaning efficiency); 13.0 %, 51.0 % (seed damage) and 3.50 %, 13.0 % (seed loss). The overall mean performances are 56.54 %, 31.61 %, 27.51% and 7.36 % respectively. The seed decortications were affected mostly by the machine speed which was highly significant at 0.1 %. From Figure 1, the seed decortications efficiency, cleaning efficiency and seed damage percentage increased, while seed loss decreased with increase in speed. Machine speed 900 rpm gave the lease seed damage but not significantly different from 600 and 750 rpm. Also it gave the lease seed loss but not significantly different from1050 rpm (Table 2).

From Figure 2, the effect of crop (throughput) on decortications, cleaning and seeds damage generally increased as the throughput was increased. Decorticating efficiency increased from 47.3 to 65.34 %, cleaning from 21.61 to 41.29 % and seed damage

from 25.58 % 31.44 %. The effect of throughput on seed loss was on the reverse as seed loss decreased with increase in throughput. There was no significant difference between throughput levels for seed loss and 200 and 400 g for seed damage percentages (Table 3).

Analysis of variance showed that the effect of mass is not significant as speed and their combinations at 5 % confident limit (Table 4).

Table 1: Effects Of Machine And Crop Parameters On Jatropha Seed Decortication

S/N	Speed (rpm)	Mass (g)	Decorticating Efficiency (%) R1	Decorticating Efficiency (%) R2	Cleaning Efficiency (%) R1	Cleaning Efficiency (%) R2	Seed damage (%) R1	Seed damage (%) R2	Seed loss (%) R1	Seed loss (%) R2
1	600	200	23.50	24.80	14.90	14.89	13.10	13.00	10.00	13.00
2	600	400	44.60	44.30	19.80	19.93	19.60	20.00	10.00	9.00
3	600	600	59.20	59.70	33.80	34.20	34.00	34.20	11.80	11.80
4	750	200	30.00	29.80	19.10	18.40	17.00	18.80	8.50	7.70
5	750	400	49.10	48.00	21.50	20.80	24.70	16.50	8.50	12.10
6	750	600	58.10	58.80	34.70	35.00	34.30	30.60	7.30	6.00
7	900	200	64.50	66.80	22.40	22,00	20.20	22.50	5.00	5.33
8	900	400	69.00	69.30	46.30	45.70	22.00	22.00	3.50	5.50
9	900	600	77.30	79.00	52.60	53.70	23.40	25.00	4.20	5.33
10	1050	200	70.30	68.70	30.50	30.70	49.00	51.00	5.00	4.90
11	1050	400	66.00	65,50	41.50	39.80	40.00	39.20	5.00	4.80
12	1050	600	65.00	65.60	44.00	42.30	35.20	43.70	6.00	6.20
Mean			56.54		31.61		27.51		7.36	
Standard deviation			16.58		12.38		10.82		2.87	
Minimum			23.50		14.89		13.00		3.50	
Maximum			79.00		53.70		51.70		13.00	

95 % confidence interval

Table 2: Effects Speed On Jatropha Seed Decortication

Speed (rpm)	Decorticating Efficiency (%)	Cleaning Efficiency (%)	Seed damage (%)	**Seed loss (%)**
600	42.68^{D}	22.92^{D}	22.33^{B}	10.93^{A}
750	45.63^{C}	24.92^{C}	23.65^{B}	8.52^{B}
900	70.98^{A}	40.45^{A}	22.52^{B}	4.81^{C}
1050	66.85^{B}	38.13^{B}	41.52^{A}	5.32^{C}

Table 3: Effects Of Throughput On Jatropha Seed Decortication

Mass (g)	Decorticating Efficiency (%)	Cleaning Efficiency (%)	Seed damage (%)	**Seed loss (%)**
200	47.30^{C}	21.61^{C}	25.58^{B}	7.43^{A}
400	56.98^{B}	31.92^{B}	25.50^{B}	7.43^{A}
600	65.34^{A}	41.29^{A}	31.44^{A}	7.33^{A}

Table 4: Analysis Of Variance For Jatropha Seed Decortication Parameters

Source of Variance	Df	Decorticating Efficiency (%)	Cleaning Efficiency (%)	Seed damage (%)	**Seed loss (%)**
Speed	3	1251.74***	482.03***	525.64***	49.56***
Mass	2	651.85***	774.89***	92.84***	0.03^{NS}
Speed x mass	6	163.33***	61.97**	127.47***	4.37**
Error	12				
Total	24				

* = significantly different at 5%, * * = significantly different at1% ,*** = significantly different at 0.1%,ns = not significantly different

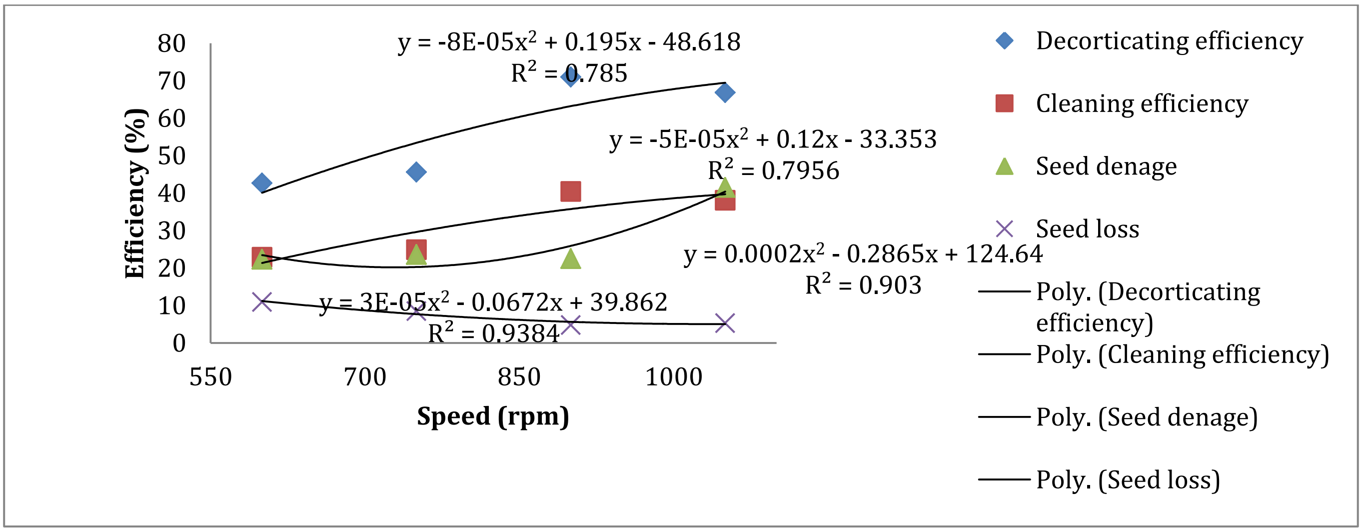

Fig. 1.Effects of Speed on Jatropha seed Decorticating Efficiency.

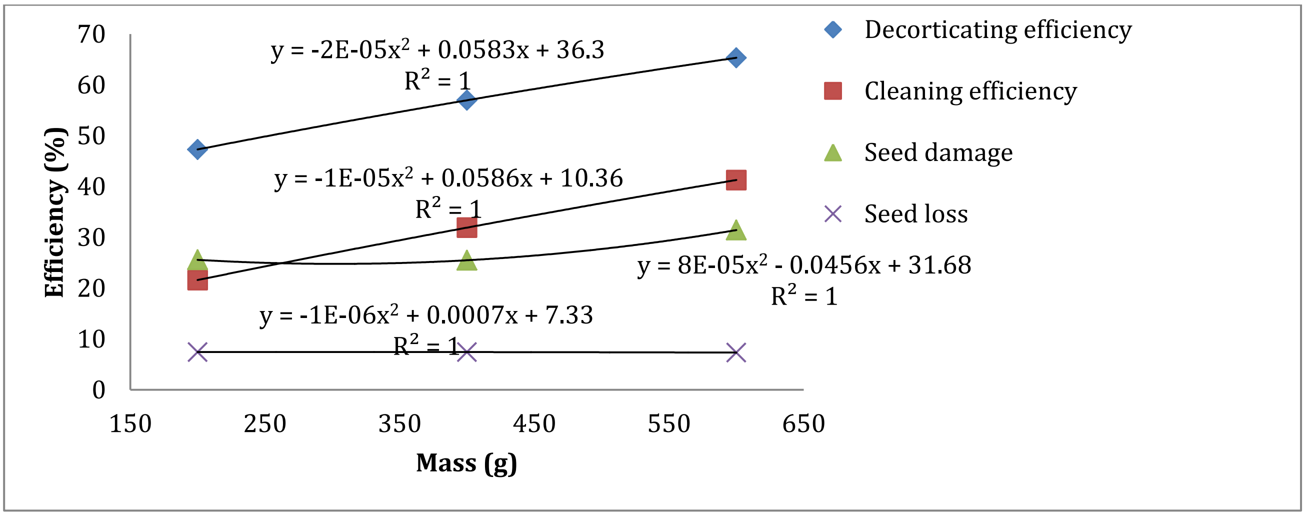

Fig. 2. Effects of Throughput on Jetropha Decorticating Efficiency.

The correlation equations between the efficiencies, speed (N) and mass (M) are expressed as:

Decorticating efficiency (η_d) =14.037 + 9.785N + 9.019M R^2 = 0.69

Cleaning efficiency (η_c) = -3.365 + 6.117N + 9.838M R^2 = 0.79

Seed damage (S_d) = 7.538 + 5.642N + 2.931M R^2 = 0.42

Seed loss (S_l) =12.633 = 2.056N + 0.50M R^2 = 0.68

The highest decorticating and cleaning efficiencies were obtained with drum speed of 900 rpm and seed throughput of 600 g, while seed damage was with 1050 rpm and 200 g seed mass. Analysis of variance showed that the effects of speed and mass on Jetropha seed decortications and their combination were highly significant at $P \leq 0.1$, save mass on seed loss which is not significant at $P \leq 0.5$.

The results of Jetropha seed decortications were in agreement with [8,9] statement that the threshing and cleaning efficiencies of okra thresher increased with increase in machine speed and that Jatropha is best threshed at machine speed of 600 – 900 rpm.

As the drum speed increases, there would be more impact force on the seeds to aid decortications and seed damage. However, more power is delivered to the fan as to generate more air stream enhancing better cleaning. Also increased in decortications as mass increased might be to the fact that more seed receive impact force from the impeller and increased in internal frictional force between seed during machine operation.

CONCLUSIONS

From the result obtained in this study, the following conclusions are drawn:

(i) The performance evaluation were 56.54 % decorticating efficiency, 31.61 % cleaning efficiency, 27.51 % seed damage and 7.36 % seed loss on the average and the highest decorticating efficiency was 79 %.

(ii) Decorticating efficiency, cleaning efficiency, percentage of seed damage increased while percentage of seed loss decreased with increase in drum speed and throughput.

(iii) The fairly high decorticating efficiency suggests that impact force might not be the best method for Jetopha seed decortications.

(iv) Seed size characteristics can be further investigated and vibrating screens incorporated to increase cleaning efficiency.

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