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THE DEVELOPMENT OF LOCUST BEAN DECORTICATOR WITH SEPARATOR.

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Abstract

The Locust bean decorticator with separator was developed and tested in the National Center for Agricultural Mechanization (NCAM). Dried harvested locust bean fruit bunches were detached from its bunch manually. The fruits were manually fed into the machine through the feeding tray. The operational time were taken using digital stop watch and recorded accordingly.
It was tested using 3kg of the dried pods in three replicates. The machine preliminary test gave an average separation efficiency of 48.6 percent (%) and decortication efficiency of 82.8 percent (%) on dry base.

Key words: locust bean, decortication, separation

Introduction

Locust bean tree is a leguminous crop peculiar to the tropics. It is common in Nigeria particularly in the Northern and South Western Nigeria (Sunmonu *et al*., 2017). It can also be found throughout the savannah lands of North Central Nigeria covering Benue, Kaduna, Kwara, Kogi, Nassarawa and Plateau States (Tor *et al*., 2018). The tree is common around villages where it is left standing when land is cleared for farming operations (Adeola, R. G. 2015). The various types of African locust bean tree are *Parkiaclappertoniana*, *Parkia Bicolor*, *ParkiaFilicoidea* and *ParkiaBiglobosa.*

The fruit is a brown, leathery pod about 10 to 30 cm (about 4 to 12 in) long and contain yellow pulp of an agreeable sweet taste. The pulp can be eaten or turn into pulp flour in which lie a number of seeds. The pods are often used for livestock feed (Microsoft Encarta**,** 2009). At maturity the pod length averages 232 mm ($173 \le L \ge 290$ mm) with a mean diameter of about 15 mm ($10 \le d \ge 20$

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mm) (Simonyan, K.J. 2012). The mature fruit of the locust bean occur in large bunches, of which the pod varies between12 -30cm by length and 12-25mm by breath (Egeruoh *et al*., 2015).

According to Adedokun, *et al*., (2016) the tree is the source of a natural nutritious condiment which features frequently in the traditional diet of both rural and urban dwellers in at least seventeen West African countries including Nigeria. However, lack of technology in processing the plants often resulted in its total economic, nutritional and therapeutic values not maximally obtained.

Decortication is the process of removal of an outer layer such as bark, rind, or a husk from a plant or part of a plant (Microsoft Encarta, 2009)**.** Locust bean decortication therefore, is the process by which the pod of the locust bean is broken for the purpose of separating and removing the pod from the pulp-carrying seed. So far there have been some machines that decorticate but without separator, there is therefore every need to incorporate separator at various stages of operation to ease off the stress of winnowing after decorticating.

So far, Peter (2019) reported that Ajayi (1991) produced a thresher (and not a decorticator) specifically for shelling locust bean pods in order to obtain the seeds for further processing. While Simonyan (2012) asserts that Oni (1990) developed locust bean fruit decorticator but it was observed that: the effects of cylinder speed, moisture content and interaction between the cylinder speeds were significant, he suggested drying the pods prior to machine decortications will assist in the operation; this is a deficiency and can increase down time for any stage in production. Also some husk fibers entangled the shelling cylinder studs as mechanical shelling progressed.

According to Olaoye (2010) the required decorticating machine is to decorticate the locust bean pod through threshing action similar to the effect created by a tooth peg threshing mechanism. The hydrocyclone developed for the separation of hulls from the cotyledons of locust bean was designed in accordance with Rietma's optimum design for classification. However, using two different machines will increase down time, cost; the possibility of water leakages and splashing in the case of hydrocyclone developed for the separation will make the surroundings untidy. Also, Okunola (2019) reported that the locust bean are dehulled by abrasive action and then conveyed to the washing unit under the dehulling unit. The coat floats on the water which is collected by lowering the outer concentrate of the washing unit with hand operated handle. By this method, the pulps are wasted through washing and cannot be harvested for further untapped use and the seeds cannot be stored if not dried which takes another processing period of time aside making the surroundings untidy with possibility of bacterial growth.

From investigations and studies carried out, most of the available decorticators for the locust bean come without a separator thereby creating the problem of having to separate the pod from the pulp on dry base. In order to alleviate this problem, it is pertinent that a separator be incorporated into the decorticating operation. This will help ensure that the productive time lost in separation is channeled into other production units.

MATERIALS AND METHOD

Design Consideration

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In the development of locust bean decorticator with separator, the following were put into consideration:

i. The shape and size of the fruit to be decorticated
ii. Moisture content of the fruit: the fruit must be dried enough to enhance decortication.
iii. Terminal velocity of the pulp and pod
iv. The power requirement
v. Material selection

Design Calculations

Feeding tray design

The feeding tray was constructed from a 2 mm thick mild steel and has dimension of 450×530×100mm. The design was to ease feeding and decortication along the pod

$V = \text{lwh}$ ………………………………………………… (1)

Source: *www.mathsteacher.com, 2012*

Where,
V represents volume (m^3)
L represents length (m),
W represents width (m),
H represents height (m),

Shaft design

$T = \frac{\pi}{16} \times \text{d}^3; M = \frac{\pi}{32} \times \sigma b \times \text{d}^3$............…………………… (2)

Source: Kurhmi, R.S. and Gupta, J.K. 2003

Where,
T represents Twisting moment (or torque) (Nm),
M represents Bending moment (Nm),
σ_b represents Bending stress (Nm^2),
d represents Shaft diameter (m).

Terminal velocity

$V_t = \sqrt{\frac{2mg}{\rho A C_d}}$ ..………………………………………….... (3)

Source: www.Wikipedia.com.2014

Where,
V_t represents terminal velocity (m/s),
m represents the mass of the falling object (kg),

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g represents the acceleration due to gravity(m/s²),
C_d represents the drag coefficient,
ρ represents the density of the fluid through which the object is falling (kg/m^3),
A represents the projected area of the object (m^2).

Belt design

$$L = \pi(r_{2+}r_1) + 2x + \frac{(r_2+r_1)^2}{x} \quad \text{…………………………….…… (4)}$$

Source: Kurhmi, R.S. and Gupta, J.K. 2003

Where,
L represents length of belt (m),
x represents distance between the driving and driven pulley (m),
r_1 represents radius of driving pulley (m),
r_1 represents radius of driven pulley (m)

Power

$$P = \frac{(2T\pi N)}{60} \quad \text{…………………………………………….. (5)}$$

Source: Kurhmi, R.S. and Gupta, J.K. 2003

Where,
P represents Power requirement (Nm),
T represents Twisting moment (or torque) (Nm),
N represents Speed (rpm).

MATERIAL FOR CONSTRUCTION

The project was executed at the Engineering and Scientific Services workshop (ESS) in the National Centre for Agricultural Mechanization (NCAM) with the use of various power tools. Metal sheet of 1.5 mm thick, galvanized metal sheet of 0.5 mm thick, pulleys, bearing, mild steel of 25 mm diameter, belts, rollers, 15 mm width × 300 cm length × 3 mm thick iron bars, 6 × 6 mm angle bar, prime mover.

DESCRIPTIONOF THE DESIGNED MACHINE

The machine is made up of the feeding tray which allows the bunch-detached pods to be fed into the machine; the decorticating unit consisting of two (2) decorticating drums overlaid with rasper each, rotating in different direction to each other which allows for impact and abrasion giving room for decortication process; the separating unit is a grill like drum constructed with iron bars spaced equally to serve as a mesh to separate the pod from the pulp; the prime mover is a diesel engine, it gives the torque and power required to drive the machine mechanisms through the belt connections on their extensionary pulleys; the Pulp outlet tong is inclined and equal to the angle of repose of the pulp to allow for free delivery of the pulp; the blower provides the air necessary to blow away

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the separated pod through the pod discharge floor; and the speed reduction gear which reduces the speed of the separating unit in order to cause enough resident time for separation to occur. The machine was drawn using the Autodesk inventor as shown in Fig. 1.

Below are the orthographic views and the isometric view of the machine.

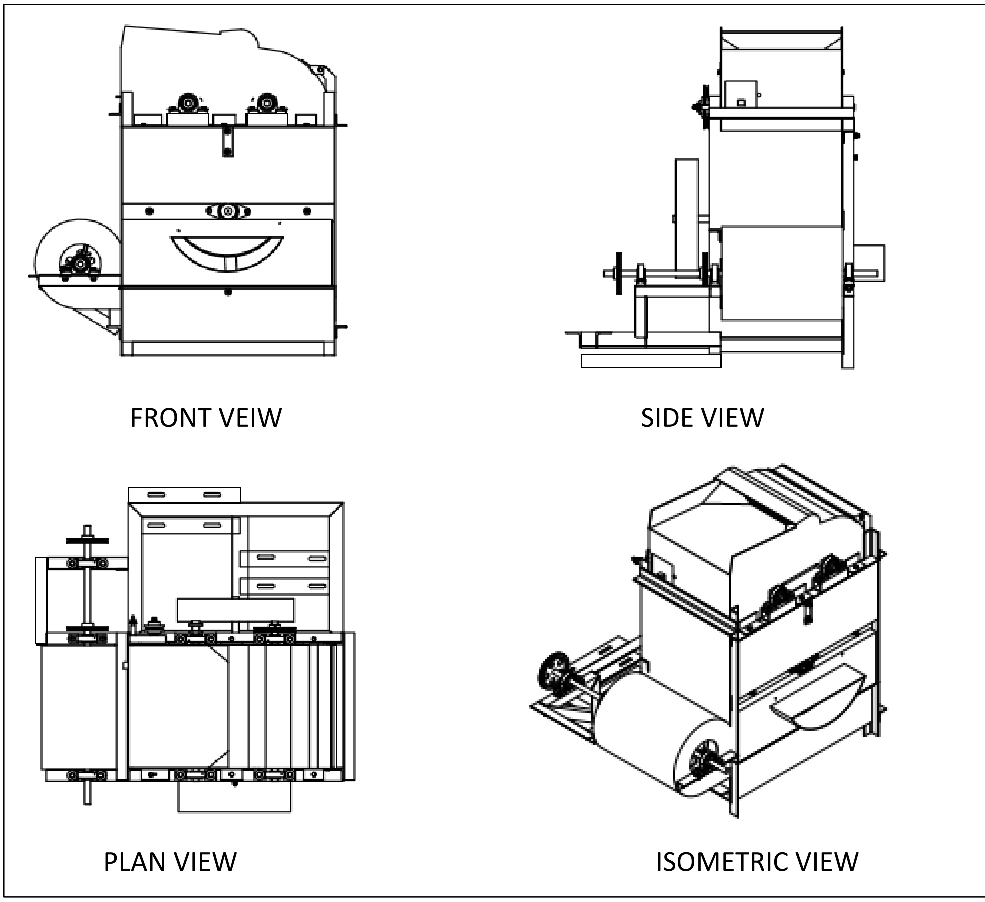

Fig. 1. The orthographic views and the isometric view of the machine.

TEST PROCEDURE

The dried and harvested locust bean fruit bunches were detached from its bunch using cutlass. Some quantity of the fruit were weighed using the digital scale and recorded.

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The fruits were manually fed into the machine through the feeding tray one at a time. The operational time were taken using digital stop watch and recorded accordingly. The following performance test parameters were determined.

(1) Percentage of unthreshed pod (%), $P_U = \frac{q_U}{G_t} \times \frac{100}{1}$ …………………… (6)
Source: (Odum, O.et.al. 2015)

Where
q_U represents quantity of unthreshed pod obtained from chaff/pod outlet (kg)
G_t represents total pulp/seed received at the seed/pulp outlet (kg)

(2) Percentage of broken pulp (%), $P_c = \frac{q_c}{G_t} \times \frac{100}{1}$ ………………………. (7)
Source: (Odum, O.et.al. 2015)

Where
q_c represents quantity of cracked/broken pulp from chaff/pod (kg)
G_t represents total pulp/seed received at the pulp/seed outlet (kg)

(3) Percentage of clean grain at the chaff outlet (%), $P_l = \frac{q_l}{G_t} \times \frac{100}{1}$ ….… (8)
Source: (Odum, O.et.al. 2015)

Where
q_l represents quantity of good pulps obtained from chaff/pod outlet (kg)
G_t represents total pulp/seed received at the seed/pulp outlet (kg)

(4) Percentage of seed loss (%), $P_s = \frac{q_a}{G_t} \times \frac{100}{1}$ …..…………………... (9)
Source: (Odum, O.et.al. 2015)

Where
q_a represents $b_1 + b_2 + s_1$ (kg)
b_1 represents clean seed/pulp at sieve overflow (kg)
b_2 represents clean seed/pulp at sieve underflow (kg)
s_1 represents stuck seed/pulp in the machine (kg)
G_t represents total pulp/seed received at the seed/pulp outlet (kg)

(5) Total loss, $T_l = P_U + P_c + P_l + P_s$ …………………………………… (10)
Source: (Odum, O.et.al. 2015)

Where
P_U represents Percentage of unthreshed pod (%)
P_c represents Percentage of cracked/broken pulp (%)
P_l represents Percentage of clean/pulps at the chaff outlet (%)
P_s represents percentage of seed loss (%)

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(6) Threshing efficiency (%), T.E $=100-P_c$ or $100-P_U$ …………... (11)
Source: (Odum, O.et.al. 2015)

Where
P_c represents Percentage of cracked/broken pulp (%)
P_U represents Percentage of unthreshed pod (%)

(7) Cleaning/Separation efficiency (%),$C/S_{eff} = \frac{G_c}{G_t} \times \frac{100}{1}$ ………….. (12)
Source: (Odum, O.et.al. 2015)

Where
G_c represents clear pulp/seed received at the pulp/seed outlet (kg)
G_t represents total pulp/seed received at the pulp/seed outlet (kg)

(8) Clear pulp/seed received at the pulp/seed outlet (kg),$G_c = G_t - F_M$ …. (13)
Source: (Odum, O.et.al. 2015)

Where
G_t represents total pulp/seed received at the pulp/seed outlet (kg)
F_M represents Fine mixtures of pulps/seed received at the pulp/seed outlet (kg)

(9) In**p**ut capacity (kg/h), $I_c = \frac{W_u}{t}$ ………………………………………. (14)
Source: (Odum, O.et.al. 2015)

Where
W_u represents weight of unthreshed pod fed into the machine (kg)
t represents time taken to thresh the pod (hr.)

RESULT AND DISCUSSION

It was observed that the separation occurred with a gradual rotation of the separation unit, with this verification, a speed reduction gear box was mounted and linked to the separation unit with belt in order to give enough resident time for separation, and at this point a perfect separation occurred. Also, the rate of feed is a factor, as it was notice that a gradual feed rate aided much separation than a quicker feed rate.

Table 1 represents the performance parameters of the machine using locust bean fruits. From the table, the machine preliminary test has the following: an average of 17.89 percentage of unthreshed pod and 14.16 percentage average broken pulps due to low moisture content of the pods; an average of 27.32 percentage of clean grain at the chaff outlet and 59.86 percent average total loss due to leakages; an average separation efficiency of 48.57percent (%) and decortication efficiency average of 82.81percent (%). This shows that the machine has not performed optimally in separation of pulps from pods after decortication. However, there is need to extend the length of

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the brackets on each side of the two decorticating drums to prevent pulps and pods escape during decortications.

Table 1: Parameters and readings from the machine preliminary test.

s/n	Parameters tested for	Result of the performance test			
		First replicate	Second replicate	Third replicate	Average
1	P_U(%)	19.64	18.18	13.74	17.89
2	P_c(%)	14.88	11.11	16.48	14.16
3	P_l(%)	26.19	30.30	25.48	27.32
4	P_s(%)	0.95	1.52	1.10	1.19
5	T_l(%)	61.66	61.11	56.80	59.86
6	T.E (%)	80.36	81.82	86.26	82.81
7	G_c(kg)	0.50	0.65	0.53	0.56
8	C/S_{eff}(%)	47.96	48.99	49.75	48.90
9	I_c (kg/h)	102.74	177.52	140.19	146.15

CONCLUSION

Base on the preliminary test finding of the machine, the following conclusion were made.

1. The separation efficiency of the technology is 48.57percent (%) on average.

2. The machine can decorticate with an efficiency of 82.81percent (%).

3. The through put capacity averages 140.14kg/hr.

4. The machine is fit for the processing of locust bean pulp with further modification on the cleaning unit.

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