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Optimization of the NCAM Prototype Locust Bean Depodder with Separator

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Abstract
A study was conducted to compare the conventional method of depodding locust beans with the developed prototyped depodding machine developed at the National Centre for Agricultural Mechanization (NCAM) in Ilorin, Nigeria. The conventional method was found to be time-consuming and energy-intensive, with low output and efficiency, as well as poor hygiene standards. The NCAM machine consists of four main units: a hopper, depodding chamber, separator, and discharge unit. It was tested at three different operating speeds (150, 250, and 350 rpm) and the results were analysed using visualization and linear regression models to optimize the machine's performance. The NCAM machine was found to perform optimally at 250 rpm, with a maximum depodding efficiency of 93.0%, cleaning efficiency of 86.0%, and a very low percentage loss of 25.0%. The machine was concluded to be more efficient than the conventional method, as it saved time and energy, reduced material waste, and eliminated health hazards. It is recommended that further evaluations be conducted on the machine using a wider range of samples.

Keywords*: Locust Bean, Depodding, Separation*

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I. INTRODUCTION

The locust bean tree is a type of legume that grows in tropical regions, particularly in Nigeria. It is found in the Northern and South Western parts of the country (Sunmonu *et al*., 2017), as well as in the savannah lands of North Central Nigeria, including the states of Benue, Kaduna, Kwara, Kogi, Nasarawa, and Plateau (Tor *et al*., 2018). The tree is often found in the vicinity of villages and is left standing when land is cleared for farming (Adeola, R. G. 2015). There are several varieties of the African locust bean tree, including Parkiaclappertoniana, Parkia Bicolor, ParkiaFilicoidea, and ParkiaBiglobosa.

The fruit of the locust bean tree is a brown, leathery pod that measures approximately 10 to 30 cm in length. It contains yellow pulp with a sweet taste and several seeds, which can be eaten or turned into pulp flour. The pods are often used as livestock feed. At maturity, the length of the pod averages 232 mm, with a diameter of about 15 mm. The mature fruit of the locust bean tree grows in large bunches, and the size of the pod can vary between 12 and 30 cm in length and 12 and 25 mm in width (Egeruoh*et al*., 2015).

Okunola (2019), reported that the locust bean pods are dehulled using abrasive action and then conveyed to a washing unit. During this process, the coat of the pods floats on the water and is collected by lowering the outer concentrate of the washing unit using a hand-operated handle. However, this method has some drawbacks, including the waste of the pulps through washing, the inability to harvest the pulps for further use, and the need for additional drying time for the seeds before they can be stored. Additionally, this method can create an untidy environment with the possibility of bacterial growth.

According to previous research, most locust bean machines listed still has a lot to be desired in terms of efficiency and efficacy of the final product which is a result of the absence of a separator. hence this study aims to optimize the already developed prototype locust bean decorticator with a separator mechanism, using low cost and available material, yet possessing high depodding capacity and efficiency rate.

II. MATERIALS AND METHOD

2.1. Design Consideration.

In the design of theNCAM Developed Prototype Locust Bean Depodding, machine following were taken into consideration: -

i. *Availability of construction materials*: materials of adequate strength and durability were used for the fabrication, which were sourced locally.

ii. *Cost:* low-cost materials that give adequate strength and stability were used for the fabrication

iii. *Physical and mechanical properties of the locust bean pods*: relevant geometric mean diameter of the locust bean was considered for the design of the machine.

iv. Basic considerations were given to the design of the size, speed and capacity of the machine.

2.2. Description of the Developed NCAMPrototype Locust Bean Depodding Machine

The locust bean depodding machine consists of various parts that work together to remove the seeds from the pods. These components include: a feeding tray to input the detached pods into the machine, a decorticating unit with two drums that rotate in opposite directions to break down the pods, a separating unit made up of a mesh-like drum with iron bars to sift out the seeds, a diesel engine to provide the necessary power to operate the machine's mechanisms through belt connections on their extension pulleys, a pulp outlet tong angled to allow for easy delivery of the pulp, a blower to blow away the separated pods through the pod discharge floor, and a speed reduction gear to slow down the separating unit and increase the time for separation to occur.

Figure 1: Views of The Developed NCAMPrototype Locust Bean Depodding Machine

2.3. Performance Evaluation of the Developed Prototype Locust Bean Depodding Machine

2.3.1. *Test Methodology:*

The NCAM Developed Prototype Locust Bean Depodding machine, after Fabrication of the machine, preliminary tests were carried out using harvested and dried locust bean pods. The time taken to fully de-pod was recorded with a stopwatch, while the weight was measured and also recorded in 3 replicates. The locust bean pods used were gotten from the local market in Ilorin, Kwara state and were then sorted, cleaned and weighed to ensure that only healthy pods were used to evaluate the machine parameters

2.3.2. *Test Parameters:*

The test parameters are expressed and carried out according to Odum, *et.al.,* (2015).

i. Percentage of Unthreshed Pod (%), $PP_{UU}=qq_{UU}$ / $GG_{tt}\times 100\%$ 1

Where: $qqUU$ represents the quantity of unthreshed pod obtained from chaff/pod outlet (kg),
GG_{tt} represents the total pulp/seed received at the seed/pulp outlet (kg)

ii. Percentage of broken pulp (%), PP_{cc} = qq_{cc} / GG_{tt}×100% 2

Where: qq_{cc} represents the quantity of cracked/broken pulp from chaff/pod (kg),
GG_{tt} represents the total pulp/seed received at the pulp/seed outlet (kg)

iii. Percentage Clean Grain at The Chaff Outlet (%),PPu= qq_{ll} / GG_{tt}×100% 3
Where: $qqll$ represents the number of good pulps obtained from chaff/pod outlet (kg),
GG_{tt} represents the total pulp/seed received at the seed/pulp outlet (kg)

iv. Percentage Seed Loss (%), PP_{ss} = qq_{aa} / GG_{tt}×100% 4
Where: $qqaa$ represents bb_1+bb_2+ss_1 (kg), bb_1 represents clean seed/pulp at sieve overflow (kg), bb_2 represents clean seed/pulp at sieve underflow (kg), ss_1 represents stuck seed/pulp in the machine (kg) andGG_{tt} represents total pulp/seed received at the seed/pulp outlet (kg).

v. Total loss, Tl =PP_{UU}+ PP_{cc}+ PP_{ll}+PP_{ss} 5
Where: PP_{UU} represents the Percentage of the unthreshed pod (%), $PPcc$ represents the Percentage of cracked/broken pulp (%), PP_{ll} represents Percentage of clean/pulps at the chaff outlet (%), $PPss$ represents the percentage of seed loss (%)

vi. Depodding Efficiency (%), D_E =100 $-PP_{cc}$ or 100 $-PP_{UU}$ 6

Where: $PPcc$ represents the Percentage of cracked/broken pulp (%), while $PPUU$ represents the Percentage of the unthreshed pod (%)

vii. Cleaning Efficiency (%), C_E=GG_{cc} / GG_{tt}×100% 7
Where: $GGcc$ represents clear pulp/seed received at the pulp/seed outlet (kg), $GGtt$ represents total pulp/seed received at the pulp/seed outlet (kg)

viii. In**p**ut Capacity (kg/h), Ic= =WW_{uu} / T_t 8
Where; $WWuu$ represents the weight of the unthreshed pod fed into the machine (kg), and T_t represents the time taken to thresh the pod (hr.).

2.4. Statistical Analysis:
The data collected were analysed using visualization and linear regression models to identify the relationship between the independent variable (operational speed) and the dependent variables (depodding efficiency, total percentage losses and cleaning efficiency). The Pulp optimization model in Python was then used to optimize the process. The test was conducted three times to ensure accurate data collection.

III. RESULT AND DISCUSSION

Table 1, shows that the Operational Speed used during the depodding operation had a significant effect on the depodding efficiency, cleaning efficiency and the total percentage losses of the machine operated using a constant mass of 3.0kg of locust bean pods.

It was observed that at 150rpm speed, the machine depodding efficiency was in the range of 80.36 to 86.26%, cleaning efficiency was also in the range of 47.98-49.75, while total percentage losses were at 56.8-61.66% respectively.

It was observed that at 250rpm speed, the machine depodding efficiency was in the range of 89.0 to 93.0%, cleaning efficiency was also in the range of 78.0 to 86.0%, while total percentage losses were at 25.0-34.0% respectively.

It was observed that at 350rpm speed, the machine depodding efficiency was in the range of 83.0 to 90.0%, cleaning efficiency was also in the range of 65 to 84, while total percentage losses were at 54 to 68.0%, respectively.

As the operational speed increased from 150 to 350 rpm, it was noted that the machine performed optimally at 250 rpm, with the highest depodding efficiency, the highest cleaning efficiency, and the lowest total percentage losses of 93.0%, 86.0%, and 25.0% respectively. The significant difference in machine performance was likely due to the fact that 250 rpm was fast enough to effectively remove the seeds from the pods, but not too fast to minimize losses. This may be attributed to the increased abrasive and high-impact action from the machine beaters on the pods, which enhanced the machine's efficiency as depicted in Figure 1.

Table 1: Effect of Operating Speed on The Depodding Machine

S/NO	SPEED (rpm)	T_l(%)	D_E (%)	C_E (%)	Ic (kg/h)
1	150	61.66	80.36	47.96	102.74
2	150	61.11	81.82	48.99	177.52
3	150	56.80	86.26	49.75	140.19
4	250	34.00	90.00	81.00	152.00
5	250	32.00	93.00	78.00	154.00
6	250	25.00	89.00	86.00	148.00
7	350	54.00	83.00	67.00	105.00
8	350	65.00	90.00	84.00	123.00
9	350	68.00	87.00	65.00	115.00

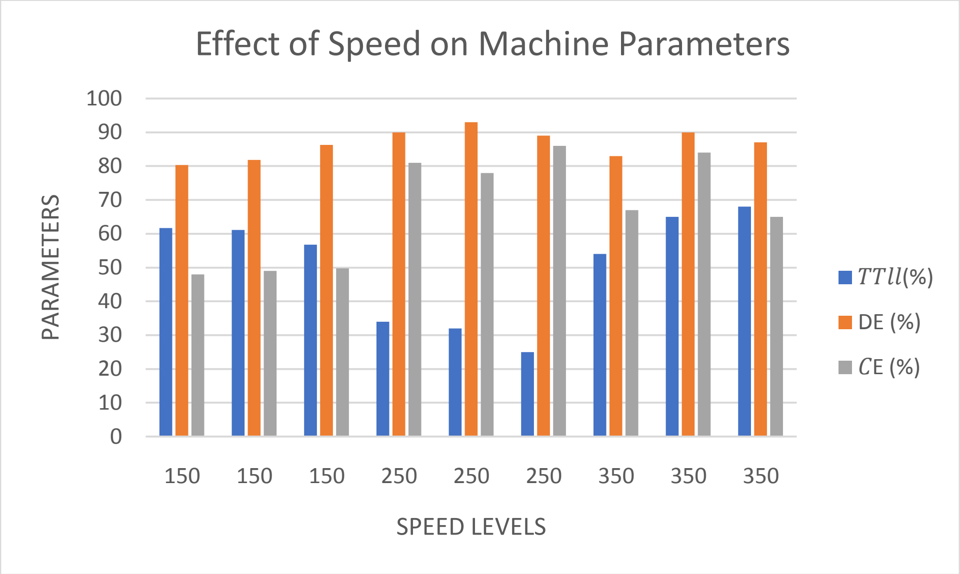

Fig:1. The Effect of Operating Speed on The Depodding Machine

A linear regression model was used to establish the relationship between the independent variables (speed) with the dependent variable (depodding efficiency, cleaning efficiency and the total percentage losses) operation in equation 9 (depodding efficiency), equation 10 (cleaning efficiency) and the equation 11 (total percentage losses).

Optimization of the model using the Pulp model framework in Python showed that the highest depodding efficiency, cleaning efficiency, and low total percentage losses could be achieved at an operational speed of 250 rpm. The sensitivity analysis of the system indicated that a slight increase in the optimal speed by 0.13 rpm would improve the optimal depodding efficiency of the machine operation, according to Equation 9. Similarly, a 0.12 rpm increase in the optimal speed would increase the cleaning efficiency of the machine operation, as shown in Equation 11. On the other hand, a -0.01-rpm reduction in the optimal speed would reduce the total percentage losses associated with the machine operation. The optimization equations for the depodding efficiency, cleaning efficiency, and total percentage losses, given in Equations 9, 10, and 11, highlight the importance of speed as a key factor in achieving an effective and efficient depodding and cleaning operation.

$$D_E = 0.0144Vo + 83.20 \quad (9)$$

$$C_E = 0.12Vo + 87.5 \quad (10)$$

$$T_L = 55.2 - 0.01Vo \quad (11)$$

Where D_E is the depodding efficiency measured in %, C_E is the cleaning efficiency measured in %, Vo is the machine operational speed in (Rpm), and T_L is the total losses during the sieving operation measured in %.

IV. CONCLUSION AND RECOMMENDATION

The motorized prototype depodding machine was developed, built, and tested to assess its performance. The highest depodding efficiency was obtained by varying the speed of the machine. A regression model was established for the processes and optimized, which revealed the linear relationship between the machine's depodding efficiency, cleaning efficiency, total percentage losses, and operational speed. Based on the analysis, it can be inferred that the machine performed optimally at an operational speed of 250 rpm, producing the best results of 93.00% depodding efficiency, 86.00% cleaning efficiency, and 25.00% total percentage losses. The machine has the potential to overcome the challenges associated with manual processing and reduce losses during locust bean depodding operations. It is recommended that further evaluations be conducted on the machine using a wider range of samples of different weights and species.

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