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Performance evaluation of locust beans de-pulping machine

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Abstract

Paucity of information on performance parameters of the newly developed machine limit its extension, adoption and commercialization. Hence, this study focused on the performance evaluation of a newly developed locust bean de-pulping machine. The machine consists of a frame, stainless steel one-end closed vertical cylindrical sieve, set of paddles with brushes, stainless steel water bath with inlet and outlet, and prime mover (GX 200 gasoline engine). It was evaluated at 150, 250 and 350 rpm operating speed levels, 65, 76, 84% wb moisture content levels, and 5, 10 and 15 kg sample weight in triplicates by employing factorial design. The data obtained was analyzed using IBM SPSS version 16 computer package to carryout analysis of variance (ANOVA), separate and compare the means. The result showed maximum de-pulping efficiency of 98.95% and machine capacity of 40.55 kg/h both at 350rpm operating speed, 84% wb moisture content level of 5 kg and 10 kg sample weight respectively. Its optimal operating condition was found to be at 350 rpm operating speed, 84%wb moisture content level and 10 kg sample weight. De-pulping efficiency of the machine increased with an increase in the operating speed and moisture levels but decreases with increase in sample weight, while machine capacity increased with increase in the operating speed, moisture level and sample weight. The ANOVA result showed that the operating speed has significant effect on de-pulping efficiency and machine capacity, while moisture content and sample weight have no significant effect on both de-pulping efficiency and machine capacity at 95% level of significance. The machine is therefore adjudged suitable for extension, adoption and commercialization.

Keywords: De-pulping efficiency; Locust beans; Machine capacity; Operating speed; Performance evaluation.

1. Introduction

Locust beans (*Parkia biglobosa)* crop is a member of the *Leguminosae* family commonly grown in Africa and used basically as condiment and ingredients in soup preparation (Olaoye, 2011; Adewumi, 1993; Kourouma *et al*., 2011). It is a perennial tree which produces fruits in pod form consisting of yellowish powdery pulp with seeds embedded in it (Simonyan, 1988). Locust bean is known as "iru" or "dawadawa" in Nigeria (Olaoye, 2011). Fermented locust bean seeds are used as spices in soup preparation in some African countries such as Nigeria, Togo, Ghana, Sierra lonne (Aremu *et al*., 2015; Odunfa, 1981). The seeds are valued and consumed due to their high protein content. The fermented locust bean contains about 40 % protein, 32 % fat and 24 % carbohydrate (Campbell-Platt, 1980).

The extraction of locust beans seeds from its pod requires de-podding, de-pulping, and drying. De-pulping is the process of removing the pulp to expose the embedded seeds. It is a necessary process before further processing of the seeds into food products. There is wet and dry method of de-pulping de-podded locust beans. The traditional method of de-pulping the beans is a wet method and it involves the washing of the de-podded beans using a perforated calabash and woven basket. De-podded locust beans are placed in the basket and submerged in a flowing river, stream or pond for soaking before de-pulping. During de-pulping, the mixture of the seeds and pulp is stirred with hands and the slurry washed out

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through the pore spaces while the basket or calabash is being agitated in the water medium. The pulp is washed into the water and the seeds retained inside the calabash or basket. The traditional method is labour intensive and time consuming. This method requires large volume of water and de-pulping efficiency is a function of availability of water and strength of the processor. The processing of locust bean is mainly done by local women in Africa (Adewunmi, 1995) hence, mechanical equipment are required to reduce the drudgery that women are exposed to as well as improve the quality and quantity of locust beans product for human consumption.

Consequently, Oloko (2006); Ajayi (1991), and Olaoye (2011) developed some locust beans processing machines to eliminate the drudgery and fatigue associated with the traditional method of processing the crop. Nevertheless, existing technologies developed for de-pulping locust beans are limited in capacity, efficiency and adequate information on their performance parameters. Hence, this work seeks to evaluate the performance of the locust bean de-pulping machine recently designed and fabricated at National Centre for Agricultural mechanization (NCAM), Ilorin, Nigeria.

2. Materials and methods

2.1. Materials

Locust beans fruits were sourced from Ganmo market, Kwara state, Nigeria and de-podded by using NCAM locust bean de-podding machine. The recently designed and fabricated locust bean de-pulping machine, digital weighing scale, tachometer, electrically powered oven, digital stop watch, water, plastic bowls and baskets were used in the work.

2.2. Description of the Machine

The machine consists of a frame, stainless steel one-end closed vertical cylindrical sieve, set of paddles with brushes mounted on a Ø25mm shaft, Ø25mm block bearing, stainless steel water bath with inlet and outlet, and GX 200 gasoline engine as the prime mover (figure 1).

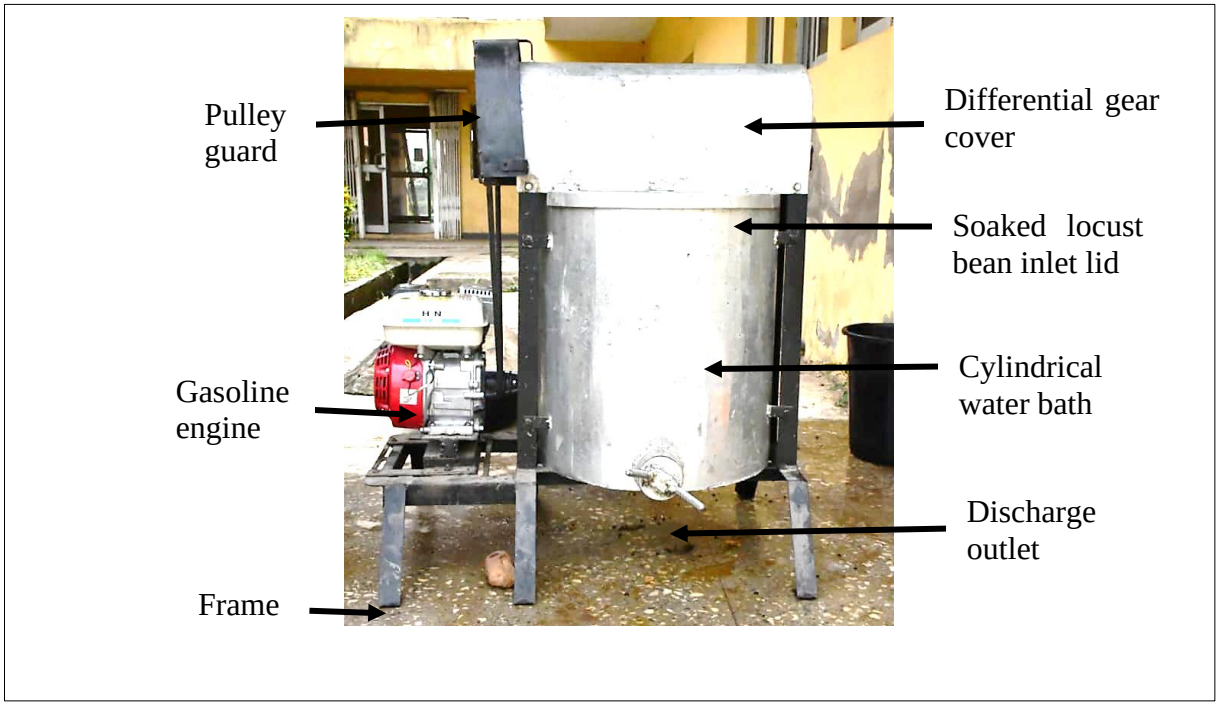

Figure 1 NCAM locust bean de-pulping machine

During operation, the rotating set of paddles with brushes mounted on the Ø25mm shaft provides the agitation and abrasion required to de-pulp the soaked locust bean seeds inside the sieve which is submerged in water. The paddles attached to a vertical shaft are driven by the gasoline engine through a differential gear arrangement. The soaked seeds are fed into the sieve together with water through the lid during operation. The yellowish pulp is discharged from the sieve into the water bath while the cleaned seeds are retained inside the sieve in the process. At the end of the operation, the yellowish pulp slurry in the water bath is discharged out of the machine through a tap before opening the sieve gate to discharge the de-pulped/ cleaned locust beans seeds.

2.3. Performance Evaluation of the Machine

The machine was evaluated at 150, 250 and 350 rpm operating speed levels as stated in Olaoye (2011), moisture content levels of 65, 76, 84% wb and sample weights of 5, 10 and 15 kg based on the results of the preliminary investigations done on the machine. A factorial design was employed in the study and each treatment was done in triplicates. The varying moisture levels were obtained by adding one (1) litre of water at 25 ^{o}C to each kilogram of samples and allowing it to soak for 15, 20 and 25 minutes followed by moisture investigation using oven method (Akinfiresoye *et al*., 2020). In each experiment, based on preliminary studies, 25 litres of water was used during depulping operation. In each case, the soaked locust beans was introduced into the machine through the lid and the water was continuously splashed until all the seeds were de-pulped. The stop watch was used to measuring the time taken for adequate de-pulping. After discharging the slurry, the seeds were also discharged through the same outlet and weighed.

The performance parameters: de-pulping efficiency (DE) and machine capacity (C_m) were calculated using equations 1 and 2 as in Olaye (2011) and Shittu and Ndrika (2012).

$$D_e = \left(\frac{M_{cs}}{M_{ui}}\right) 100 \quad (1)$$

Where,

D_e = De-pulping Efficiency, %

M_{cs} = Weight of cleaned (A clean seed is consider to have more than ¾ of the seed surface exposed and devoid of locust bean pulp), kg

M_{ui} = Weight of material collected at seed outlet of the de-pulping machine, kg

$$C_m = \frac{M_{us} + M_{bs}}{T} \quad (2)$$

Where,

C_m = Machine capacity, Kg/h

M_{us} = Weight of unbroken-shelled seed, Kg

M_{bs} = Weight of broken-shelled seed, Kg

T = Time taken to complete operation, h

3. Results and discussion

The maximum de-pulping efficiency and machine capacity were 98.95% at 350rpm, 84% wb, 5 kg sample weight and 40.55 kg/h at 350rpm, 84% wb, 10 kg sample weight respectively. From Figure 1, de-pulping efficiency of the machine increases with increase in the operating speed and moisture levels but decreases with increase in sample weight as shown in Figure 2. On the other hand in Figures 3 and 4, machine capacity increases with increase in the operating speed, moisture level and sample weight.

The data obtained from the work were subjected to analysis of variance (ANOVA) and the Duncan multiple range test to compare the means The ANOVA in table 1 shows that operating speed has significant effect on de-pulping efficiency and machine capacity at 95% level of significance. But moisture content and sample weight levels considered have no significant effect on both de-pulping efficiency and machine capacity at 95% level of significance. This is in contrast to Akinfiresoye *et al*., (2020) and Olaoye, (2011); and it could be attributed to the presence of paddles with brushes in the NCAM developed machine. A separation and comparison of means in terms of operating speed from Table 2 shows that the means are significantly different at 95% level of significance. That means, the effect of a particular level of operating speed on de-pulping efficiency and machine capacity is significantly different from each other. This implies that the 350 rpm operating speed at which the highest means was obtained is the optimal operating speed of the machine. This optimal operating speed is in agreement with Olaoye (2011). An optimal operating speed of 350 rpm gave rise to the optimal operating condition of 350 rpm operating speed, 84%wb moisture content level and 10 kg sample weight.

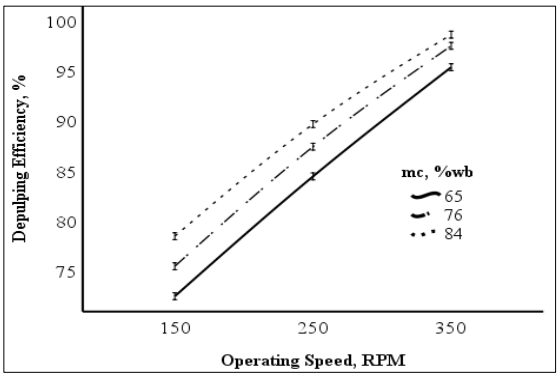

Figure 2 De-pulping efficiency vs moisture content at various operating speeds

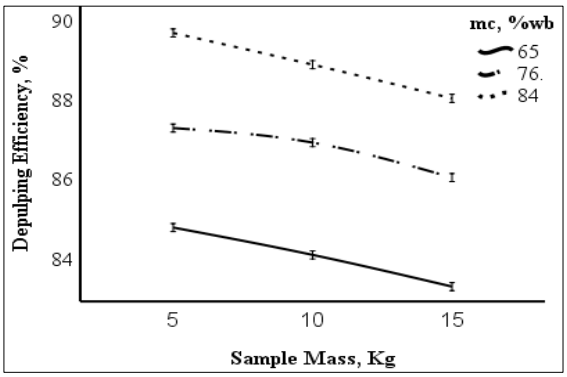

Figure 3 De-pulping efficiency vs sample quantity at various operating speeds

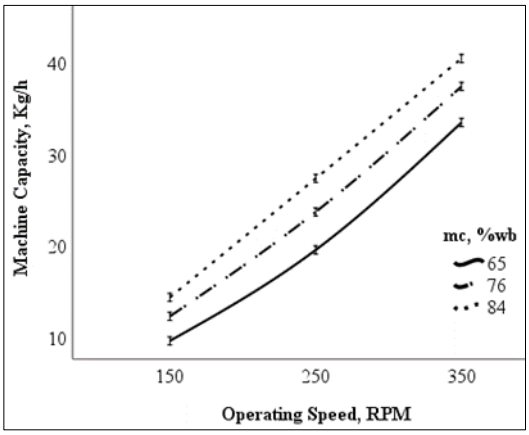

Figure 4 Machine capacity vs moisture content at various operating speeds

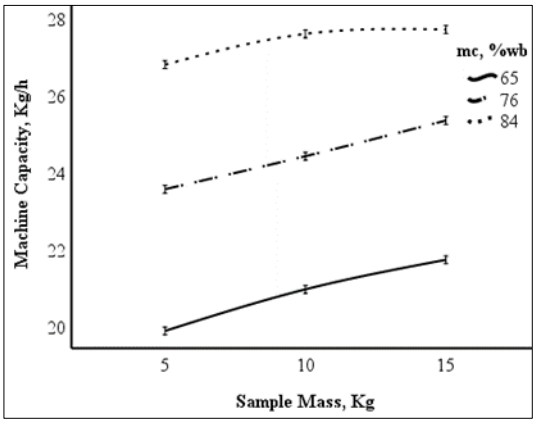

Figure 5 Machine capacity vs sample quantity at various operating speeds

Table 1 P-values of ANOVA of the performance of the machine

Sources of Variation	P-value	
	De-pulping Efficiency	Machine capacity
Operating speed (S)	0.0001	0.0010
Moisture content (M)	0.5620	0.4570
Sample weight	0.9490	0.9590

Significant at P ≤ 0.05

Table 2 Duncan multiple range test on effect of operating speed on de-pulping efficiency and machine capacity

	Operating speed levels, rpm		
	150	250	350
Depulping Efficiency, %	75^{a}	87^{b}	97^{c}
Machine Capacity, Kg/h	12^{a}	23^{b}	37^{c}

Significant at P ≤ 0.05

4. Conclusion

A locust bean de-pulping machine developed by NCAM was evaluated to enhance its extension, adoption and commercialization. The maximum de-pulping efficiency of 98.95% and machine capacity of 40.55 kg/h were obtained at 350rpm operating speed, 84% wb moisture content level, and 5 kg sample weight; and 350rpm operating speed, 84% wb moisture content level, and 10 kg sample weight respectively. An optimal operating speed of 350 rpm gave rise to the optimal operating condition of 350 rpm operating speed, 84%wb moisture content level and 10 kg sample weight. De-pulping efficiency of the machine increased with an increase in the operating speed and moisture levels but decreases with increase in sample weight, while machine capacity increased with increase in the operating speed, moisture level and sample weight. Operating speed was found to have significant effect on de-pulping efficiency and machine capacity while moisture content and sample weight have no significant effect on both de-pulping efficiency and machine capacity at 95% level of significance.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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