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Effects of Quantity of Peanut Kernels and Decorticating Speed on the Performance of a Peanut Decorticating Machine

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Abstract: *Arable farming of peanut is common in Sub-Saharan Africa. Most often, the processing is done domestically using manually operated decorticators that are ineffective, slow and time consuming. Most motorized decorticators used were mostly fabricated without considering some vital parameters such as the physical properties of the peanut, its moisture content and speed of the decorticator. This results in high kernels breakages and field losses. The objective of this study was to evaluate the performance of a peanut decorticator scaled for domestic use in terms of the quality of kernels recovered at varying speeds. Three set of peanut input (1kg, 3kg and 5kg) were each tested at different decorticating speeds of 150, 180 and 200 rpm respectively. The output parameters measured were; decorticated peanut, un-decorticated peanuts, bruised and spit kernels. Subsequently, decorticating efficiency, cylinder loss (%) and spilled loss were determined. The results obtained showed that there is a positive relationship between the decorticating speed and feeding rate on the spit/bruised kernels. While mechanical damage on the kernels was observed to be decreasing with increase in decorticating speed and feeding rate, results obtained showed that the highest decorticating efficiency of 98.99 % was obtained at decorticating speed of 200 rpm and feeding rate of 5 kg while the lowest decorticating efficiency of 70.75 % was obtained at decorticating speed of 150 rpm and feeding rate of 2 kg.*

Keywords: *Peanut; Decorticating Speed; peanut kernels; peanut quality; decorticating efficiency*

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I. Introduction

Peanut is an important oilseed crop cultivated in most parts of the world (Naim *et al*., 2010) having a worldwide production of more than 10 million tons per year (Bano and Negi, 2017). Developing countries dominated the world production figure in about 97% of the global area and 94% of the global production (FAO, 2019). It contains 48-50 % oil and 26-28% protein, and is a rich source of dietary fiber, minerals and vitamins (Ntare, *et al*., 2014). However, manual decortication of the pods is laborious, time consuming and cost involving operation.

Traditionally peanut pods are decorticated by manual efforts thereby constituting bottleneck to the large-scale production and processing. Method of decorticating peanut has remained traditional most developing countries. This is usually done by breaking the shell by hand pressure, De Lucia and Assennato (2017). However, with recent clamour for increased food production, De Lucia and Assennato (2017) and awareness on arable farming, Awotide *et al.* (2015); Jeffrey and Maria (2014), farmers are beginning to acquire agricultural product processing machines individually and collectively. Peanut decorticators have been developed over the years to meet immediate needs of the farmers Nwakaire (2011) and there they are continuously being modified to meet various geographical location needs as well as available technology; Pavasiya *et al.* (2018) and Girish *et al* (2015). Nowadays, mechanized peanut decorticators have been developed in various designs and capacities. However, high cost of such decorticators, their subsequent maintenance, availability of spare parts, low efficiency, high percentage of breakage and high cost of importation, Kyung-Min *et al.* (2007), made traditional methods still dominant. Performance evaluation has been reported for various work to determine the influence of input parameters into the decorticators and their effect on the output, Osayi *et al.* (2021). The development of peanut decorticating machine that would address these challenges is therefore, necessary to reduce the burden, reduced pod breakage and drudgery associated with traditional hand decortication becomes paramount, hence the objective of this study. This study, therefore, presents the performance evaluation of a peanut decorticator using two input variables: *quantity of peanut* using different *decorticating speeds* in order to improve the kernels quality by reducing bruises and breakages to meet the standards of the importing countries and in turn serves as leverage for creating jobs for the teaming unemployed youth population.

II. Materials and Methods

A peanut decorticator was designed and developed for decorticating about 1000 kg peanut per hour. The peanut decorticator (Figure 1) was fabricated at the workshop of the National Centre for Agricultural Mechanization (NCAM), Ilorin. It was fabricated with locally available materials: Mild Steel (MS) angle bar, MS flat bar, MS rod, MS sheet, MS shaft, rubber pad, ball-bearing, and 5 kW electric motor Different parts of the decorticator were described below while the detailed specifications were given in Table 1.

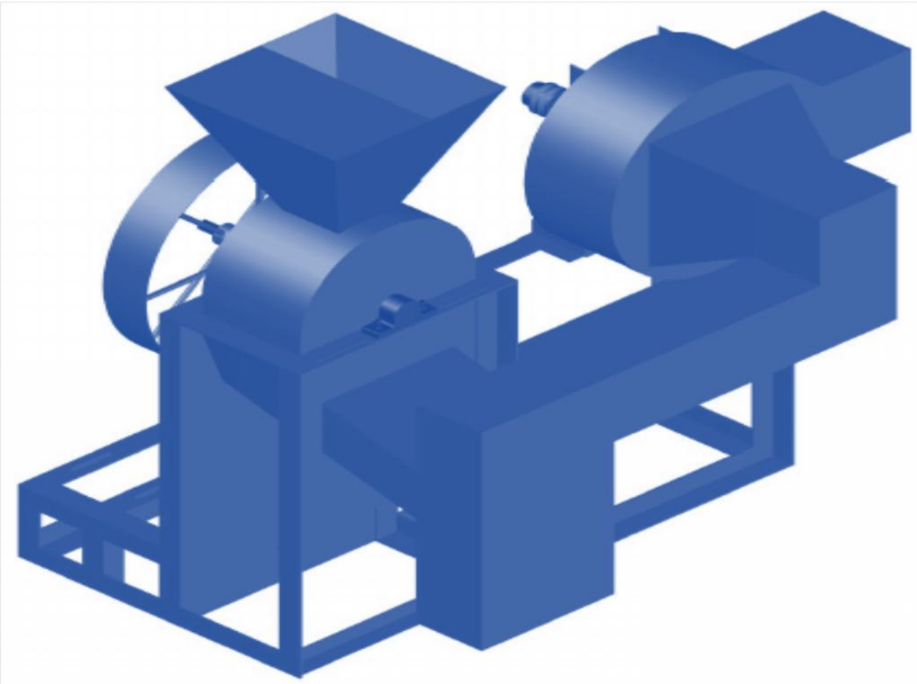

Figure 1: Pictorial view of the developed groundnut decorticator

Table 1. Specifications of peanut decorticator

Item/Part	Specification
Length (mm)	1160
Height (mm)	850
Width (mm)	700
Weight (kg)	74
Length of Decorticating drum (mm)	420
Concave length (mm)	400
Concave radius (mm)	185
Sieve size (mm)	250 x 580
Sieve aperture (mm)	12
Hopper capacity (kg)	8 – 10
Clearance (mm)	20
Mode of operation	Motorized
Source of power (kW)	5

Description of the developed groundnut decorticator

The developed groundnut decorticator (Figure 1) used for the study consists of the hopper, frame, decorticating drum, drum housing, main shaft, blower, pulleys, belt, bearings and a 5 kW electric motor The detailed description of the modified parts of the decorticator is given below:

Frame: The frame of the decorticator was constructed from angle iron of 50 x 50 x 5 mm. It supports the entire arrangement of other components and also serves as the decorticator stand and prime mover seat. It has a total length of 1.16 m and a maximum height of 850 mm. The decortication and blower chambers are joined to the frame by arc welding while the main shaft, blower shaft, decorticating drum cover, blower cover and belt protector were bolted together for ease of assembling, disassembling and transportation.

Hopper: The feed hopper is that part of the decorticator through which groundnut in-shell are fed to the decorticating drum. A permissible vertical height of 380 mm was determined so that a man of average height can load the pods. The bottom width is 140 mm to allow easy down flow of pods into the drum. It is a trapezoidal frustum, with a square top of 410 mm having both ends opened to ensure free flow of pods. The upper part of the hopper was covered half-way by a sheet of metal to prevent splitting the pods due to impact force of the decorticating drum. The material for the hopper is galvanised steel plate. It is chosen because of its ability to be forged with ease and its greater strength gives it a desirable advantage. It also resists corrosion when painted.

Decorticating drum housing: The decorticating drum consists principally of a rotating cylinder/drum and a stationary concave sieve. The upper part is a half drum made of galvanised metal sheet folded such that it serves as guide for the groundnut in-shell being processed and as a protective cover for operator; the lower part of the housing serve as collector of the shelled mix. It also houses the screen and decorticating shaft arrangement. It has a length of 400 mm and a diameter of 410 mm.

Decorticating drum: The decorticating drum rotates and thus does the decortication process by rubbing action (Figure 2). It is cylindrical in shape and has a diameter of 370 mm. The decorticating unit consist of 6 flat shelling bars fitted at equal distance with tapered pegs of 10 mm length and 13 mm diameter spirally arranged with which it rubs the pods against the screen while it rotates. The bars were made from cast iron in order to minimise contamination due to corrosion. Each bar is 210 mm long and 50 mm wide with 16 pegs on 2 rows. The drum was mounted on the main shaft via two 25 mm diameter support bearings.

Screen: The screen was a slot/capsule-like perforated metal with apertures allowing only the shelled mix material to pass through as recommended by Singh (1993) and Somposh *et al.* (2005). It was fastened to the housing with bolt and nuts as shown in Figure 2. The screen sizes were selected based on the geometric sizes of the groundnut varieties under consideration. The oblong-shaped screen aperture was 12 mm while the concave clearance determined was 20 mm based on the impressive results of some pre-decortication tests and the geometric dimensions of the groundnut pods measured.

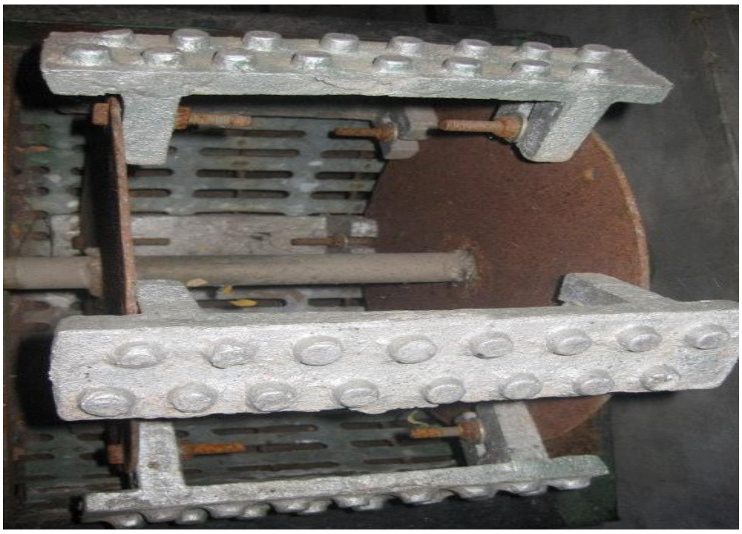

Figure 2: Screen and decorticating drum of the decorticator

Blower: The cleaning unit consists of a five-blade fan powered through the pulley belt from the decorticating unit and provides the current of air. The circular air inlet through which air is allowed in and discharged in the direction perpendicular to the fan axis. Preliminary tests were run to determine how the blowing unit functioned and the speed of rotation to ensure flow of air that separates the kernels from the husks. Both the preliminary and actual tests were conducted in the laboratory.

Moisture content: The moisture content of the peanut was measured by oven dry method drying for 72 hours at 103°C (Koushkaki *et al.* 2017). Initial moisture content of the peanut was around 12% which was reduced to 8% by oven and then packet in poly bags. The moisture content of the peanut during the study was maintained at around 8% (wb) since Kushwah *et al.* (2016) and Oluwole *et al.* (2007) found better decorticating efficiency and with minimal damage of the peanut kernels maintaining similar moisture content.

Experimental Design/Procedure

The peanut variety (SAMNUT 14) used for the study was obtained from the Seed Unit of Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. The pods were cleaned using the cyclone separator to remove the impurities and non-matured pods. A known weight of peanut pods were manually loaded in the hopper and the decorticator was set to run at the concave clearance settings of 20 mm and sieve size of 12 mm. Kittichai (1984) developed a power-operated groundnut (peanut) decorticator and found the best performance of the decorticator was achieved at 20 mm clearance. Similarly, Saleh (2015) developed and evaluated a hybrid decorticator and found 12 mm sieve aperture and 20 mm concave clearance having the optimum decorticating efficiency. Before the peanut pods were released into the decorticating chamber, the decorticator was run empty to stabilize the rotation. Peanut pods were then continuously fed to the decorticator until the measured quantity was fed in. Decortication was replicated three times for each weighted sample. The average weights of clean kernels recovered, split/bruised kernels, and un-decorticated pods were determined at the end of each run. The quantity of shells winnowed out by the decorticator and those collected with the seeds were also noted. The performance of the peanut decorticator was determined in terms of decorticating efficiency, clean kernels recovered, spilled and cylinder losses, winnowing/cleaning efficiency and kernel damage. The performance criteria as reported by Ajayi *et al.* (2016); Mohammed and Hassan (2012) and Alonge and Kosemani (2011) are expressed in equations 1 - 8.

$$Split\ and\ Breakage, K_{sb}\ (\%) = \frac{W_{sb}}{W_t} \times 100 \quad (1)$$

where:
Ksb = Split/Breakage percentage
Wt = Weight of total kernels, kg
Wg = Weight of total feed, kg

$$Undecorticated\ Kernels, U_{dc}, (\%) = \frac{W_u}{W_t} \times 100 \quad (2)$$

where:
Ung = Un-decorticated kernels, %
Wu = Weight of un-decorticated peanut, kg

$$Decorticating\ Efficiency, D_e = \frac{(W_c + W_{sb})}{W_t} \times 100 \quad (3)$$

$$Clean\ Kernels\ Recovered\ (\%) = \frac{W_c}{W_t} \times 100 \quad (4)$$

$$Winnowing\ Efficiency, E_w = \frac{(W_c + W_{sb}) - W_h}{W_c + W_{sb}} \times 100 \quad (5)$$

where:
Ec = Winnowing efficiency, %
Wc = Weight of cleaned peanut kernels recovered, kg
Wh = Weight of peanut husk, kg

$$Cylinder\ loss\ (\%) = \frac{Weight\ of\ cylinder\ loss\ kernels}{Total\ Kernels} \times 100 \quad (7)$$

$$Spill\ Kernel\ Loss\ (\%) = \frac{Weight\ of\ Spilled\ Kernels}{Total\ Kernel\ Weight} \times 100 \quad (8)$$

III. Results and Discussion

The performance of the decorticator was evaluated with varying seed weights of 2 kg, 3 kg and 5 kg of peanut and decorticating speeds of 150, 180 and 200 rpm. One of the major problems of peanut decortication is the kernel damage. In order to minimize kernel damage, proper design considerations such as the physical properties of the peanut pods were taken into consideration while constructing the decorticator, sieve aperture and concave clearance etc. The results of the performance test of the modified peanut decorticator are presented in Table 2.

Table 2: Results of output parameters for 2 kg, 3 kg and 5 kg shelling

Speed (rpm)	Weight of Pod (W_t)	Clean Kernels Recovered (W_c)	Split/Bruise Kernels (W_{sb})	Unshelled Pods (W_u)	Cylinder loss (C_l)	Spilled Kernels (K_{sb})	Unshelled Pods (K_{ud})	Cylinder loss (C_l)	Spilled kernel loss (K_{sb})	Clean Kernel Recovered (K_{cl})	Decorticating efficiency (D_e)
	(kg)						(%)				
150	2	0.93	0.485	0.490	0.025	0.001	24.50	1.25	0.05	46.50	70.75
180	2	1.37	0.332	0.230	0.024	0.018	11.50	1.20	0.90	68.50	85.10

200	2	1.85	0.025	0.018	0.018	0.017	0.90	0.90	0.85	92.50	93.75
150	3	1.98	0.265	0.299	0.135	0.215	9.97	4.50	7.17	66.00	74.83
180	3	2.53	0.090	0.090	0.027	0.204	3.00	0.57	6.80	83.33	87.33
200	3	2.78	0.072	0.051	0.017	0.036	1.70	0.56	1.20	92.66	95.67
150	5	3.70	0.445	0.550	0.138	0.140	11.00	2.76	2.80	74.00	82.90
180	5	3.99	0.265	0.255	0.216	0.210	5.10	4.30	4.20	79.80	85.10
200	5	4.80	0.100	0.070	0.010	0.000	1.40	0.20	0.00	96.00	98.00

The results obtained (Fig. 3**)** showed that, there is a positive relationship between the decorticating speed and feeding rate on the clean kernels recovered. The percentage of clean kernels recovery was observed to be increased with increase of decorticating speed and feeding rate. Increasing decorticating speed from 150 to 200 rpm tends to increase the average rate of clean kernels percentage from 46.50 to 96.00 % at feeding rates from 1 to 5 kg. This increase may be attributed to the fact that the geometric dimensions of the decorticated peanut pods were taken into consideration while constructing some vital components of the decorticator. These components include the sieve aperture and the concave clearance of the decorticator. Results obtained were in perfect agreement with the earlier discovery of Saleh (2015) that graded peanuts decorticated with 12 mm aperture and 20 mm clearance results in obtaining maximum clean kernels. At the same time, the results indicated that, clean kernels recovery increased with an increase in feeding rate. Increasing feeding rates from 1 to 5 kg increased the average rate of kernels recovery from 0.93 to 4.80 kg at decorticating speeds ranged from 150 to 200 rpm. Maintain the moisture content of the peanut at 8% was another factor that minimize kernel breakage as Gore *et al.*, (1990) rightly observed that splitting of peanut kernels was very common when moisture content below 8 %, but at high level of moisture content (10% and above), more bruising and hull damage were observed.

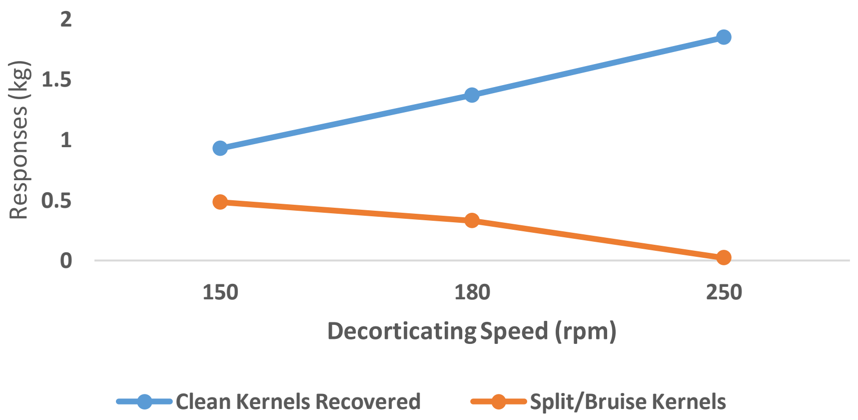

Figure 3: Evaluation at 2 kg Peanut Kernel quantity

The results (Fig. 3) also showed a positive relationship between the decorticating speed and feeding rate on the spit/bruised kernels. The mechanical damage on the kernels was observed to be decreasing with increase in decorticating speed and feeding rate. Increasing decorticating speed from 150 to 200 rpm tends to increase the rate at which decorticated kernels would be forced out of the decorticating chamber to escape through the well-designed sieve aperture with minimum damage. Similarly, the results indicated that seed damage decreased with an increase in feeding rate. Increasing feeding rates from 2 to 5 kg decreased the average of damaged kernel percentage from 0.485 to 0.025 kg at decorticating speeds ranged from 150 to 200 rpm. In contrast, Kittichai (1984) found 5.3% as the minimum percentage of breakage when he tested a developed a power-operated peanut decorticator at similar conditions.

The results obtained also revealed that, there is a positive relationship between the decorticating speed and feeding rate on the seeds losses percentage. Increasing decorticating speeds from 150 to 200 rpm tends to result in decrease the amount of kernel that were retained in the cylinder after the decortication exercise from 4.50 to 0.56 % at feeding rates ranged from 2 to 5 kg. Also, increasing feeding rates from 150 to 200 kg decreased the average of kernel losses percentage due to spilling from 7.17 to 1.20 % at decorticating speeds when 3 kg peanut was loaded. Results obtained were also in agreement with the earlier findings of Gore *et al.*, (1990). The highest kernel losses percentage of 7.17 %was obtained at decorticating speed of 150 rpm and feeding rate of 3 kg while the least kernel losses was obtained at decorticating speed of 200 rpm and feeding rate of 5 kg when no kernel was spilled (Fig. 4).

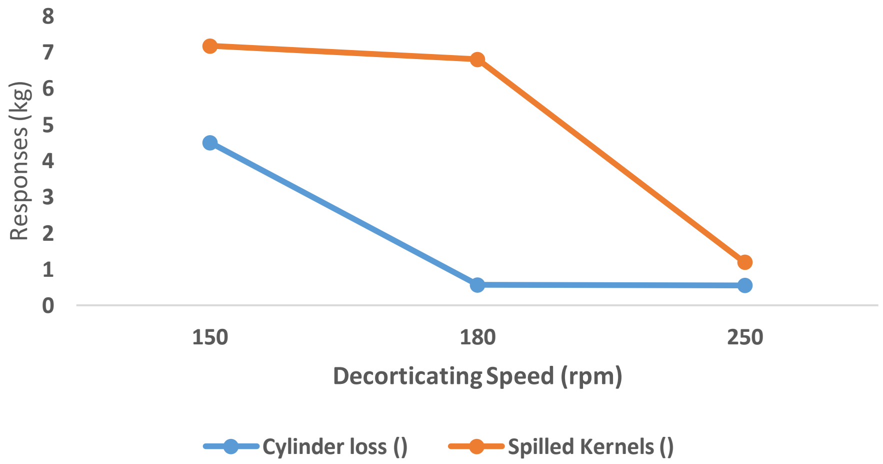

Figure 4: Evaluation at 3 kg Peanut Kernel quantity

Results obtained from the study (Fig. 5) indicated that there is an inverse relationship between the decorticating speed and feeding rate on the undamaged seeds percentage

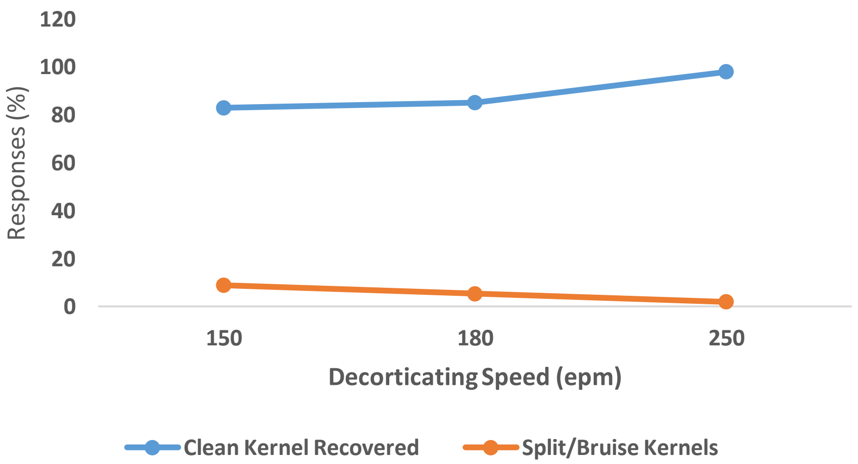

Figure 5: Evaluation at 5 kg Peanut Kernel quantity

Increasing decorticating speeds from 150 to 200 rpm led to increase the rate of clean kernels recovered 82.90 to 98.00 % at feeding rate of 5 kg. At the same time, increasing decorticating speeds from 150 to 200 rpm decreased the average of undamaged kernels from 0.445 to 0.100 kg. The highest clean (un-damaged) kernels percentage of 98.00 % was obtained at decorticating speed of 200 rpm and feeding rate of 5 kg.

Mechanical damage of 2.00 % for the modified decorticator was recorded as against 14.11% for a Hybrid decorticator at the same decorticating speed of 200 rpm. The decrease in mechanical damage realized from the modified decorticator could be attributed to the modification carried out on the decorticating drum and the sieve aperture that were designed with the average size of the peanut pod taken into consideration. That is, the cylindrical iron rods used in the old decorticator was replaced with a standard screen (Fig. 2). Also, the precise determination of concave clearance based on peanut properties (SAMNUT 14) during the design of the modified decorticator could contribute to the low kernel damage (Muhammad et al., 2017). An Improvement from 55.3% - 98% in the decorticating efficiency of a cylindrical iron rods peanut was reported after the modification (Gitau et al., 2013).

Results obtain from the study also showed that, there is a positive relationship between the decorticating speed and feeding rate on the un-decorticated pods percentage. Increasing decorticating speed from 150 to 200 rpm tends to decrease the average of un-decorticated pods percentage from 11.00 to 1.40 % at feeding rates at 5 kg (Fig. 6). The results was a great improvement when compared with what was found by Atiku *et al.* (2004). The least un-decorticated percentage they found was 12.4% for Dhaka-1 and 9.18% for BARI Badam-8, respectively.

The results also indicated that the efficiency of the decorticator increased from 82.90 to 98.00 % with increase in decorticating speed from 150 to 200 rpm at 5 kg feeding rate. It was also observed that peanut pods with one kernel per pod and those with two small kernels in their pods were mostly the ones that came out un-decorticated. This was against the decorticating efficiency of 86.6 and 88.82% obtained by Ugwuoke *et al.* (2014) when two power-peanut decorticators (Dhaka-1 and BARI Badam-8) were respectively tested at similar moisture content.

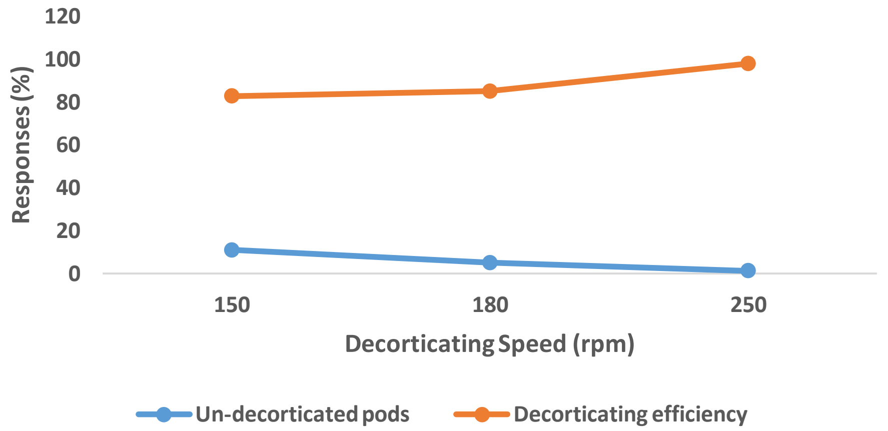

Figure 6: Evaluation at 5 kg Peanut Kernel quantity and decorticator efficiency

However, the highest decorticating efficiency of 98.99 % was obtained at decorticating speed of 200 rpm and feeding rate of 5 kg while the lowest decorticating efficiency of 70.75 % was obtained at decorticating speed of 150 rpm and feeding rate of 2 kg. Fig. 7 shows that both the kernel losses (Cylinder and spilled) as well as the rate of un-decorticated pod decreases with increase in decorticating speed.

The scatter loss realized from the modified decorticator was significantly lower than that obtained in the old decorticator (Figure 7). The scatter loss for the modified decorticator was 3.24% as compared with 9.52% for the old decorticator obtained by Ugwuoke et al. (2014). In the modified decorticator, measures were carefully taken during the construction to adhere to the design concept in order to reduce kernels scattering. Among which was providing a flood gate control which served as feed control as well as preventing peanut from spilling out from the decorticating chamber through the hopper opening. This improvement in design might significantly contribute to the increase in decorticating efficiency from 57.32 – 98.00 % was obtained.

Winnowing efficiency of the developed decorticator was 100% as there was no trace of chaff found from the kernels recovered after decortication. This is another improvement over the separation efficiencies of 97 and 98% for Dhaka-1 and BARI Badam-8 variety, respectively as reported by Ugwuoke et al. (2014).

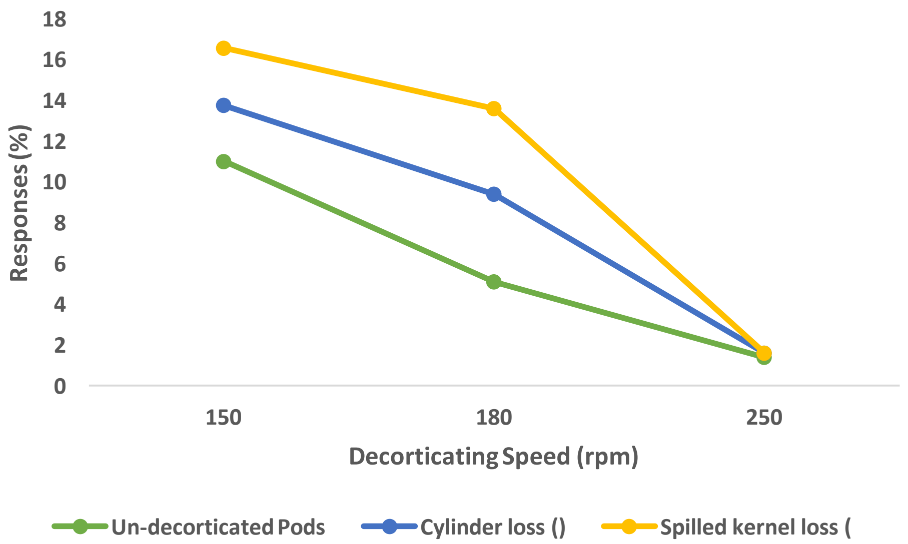

Figure 7: Evaluation Losses at 5 kg Peanut Kernel quantity

IV. Conclusion

The peanut decorticator was fabricated using materials that were sourced locally. It was also evaluated with SAMNUT 14 peanut variety obtained from the Seed Unit of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. Results obtained showed that increase in decorticating speed and feeding rate tends to decrease each of damaged kernels, decorticating losses, un-decorticated thereby increasing the machine efficiency. Similarly, increasing decorticating speed and feeding rate tends to increase each of undamaged kernels and thus decorticating efficiency of 98%. It was also observed that peanut pods with one kernel per pod and those with two small kernels in their pods were mostly the ones that came out un-decorticated or partially decorticated.

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