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Research Article

Design, Fabrication and Performance Evaluation of Groundnut Dehulling and Separating Machine

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ABSTRACT

The process of oil extraction can be enhanced by dehulling, oil produced from groundnut seeds serve as a good source of protein, vitamin, fat, oil, and crude fibers. A groundnut dehulling machine was developed, having two dehulling rollers, rubber beaters, screen, blower unit, seed and chaff outlet. The separator unit has a centrifugal blower, screen and collecting tray. It's powered by 3 hp electric motor, which transmits constant speed of 3636 rpm to the blower and 1000 rpm to rubber beaters. Groundnut used was at 7.32% moisture content (w.b). Dehulling was achieved through the compression and shearing action of the rotating dehulling roller against the stationary dehulling roller. The effect of dehulling roller clearance (6.5 mm,7.0 mm, 7.35 mm and 7.5 mm) and speed (700 rpm and 750 rpm) was evaluated on dehulling efficiency, machine capacity, mechanical damage and separation efficiency. The result obtained after testing the machine shows that 7.35 mm clearance and 700 rpm of the dehulling roller gave optimum average dehulling efficiency 95.80%, separation efficiency 81.40% and the least mechanical damage 11.01%. Machine capacity of 97.98 kg h^{-1}. was obtained at 750 rpm and 7 mm dehulling roller clearance. The results obtained during evaluation was statistically analyzed, multiple linear model equations which are capable of predicting the effect of dehulling roller clearance and speed on dehulling efficiency, machine capacity, mechanical damage and separation efficiency was developed.

RESEARCH ARTICLE

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- Impact force,
- Compression and shearing action

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important grain legume that grows in wet conditions in semi-arid regions of the world (Rao, 1980). As major crop in most of the tropical and subtropical regions, groundnut ranks 12th in the world crop production. It is grown in all continents with a total area of 24.6 million hectares, and a production of 41.3 million tons in 2012 (FAO, 2013). It's cultivated on subsistence and commercial bases for food and industrial purposes (Thakur *et al.*, 2013; Mohammed *et al.*, 2018).

There are two main types of groundnut: The America groundnut (*Arachis hypogea*), and the Africa groundnut, the Bambara nut (*Voandzeia subterranean*). Both are grown in Western Africa as a protein source. The groundnut seed composed of approximately equal weight of fatty and non-fatty oil (Sedara *et al.*, 2020). Dehulling is a process employed to get rid of the outer pericarp and testa (hull) of most cereal grains, grain legumes, nuts and oilseeds using mechanical means, the removal of grains from their stalk, pod or cub can be achieved either by stripping, impact action and rubbing or any combination of these methods. The most popular method of shelling which is still widely used in the northern part of Nigeria is the method of crushing or pressing the pods between the thumb and the finger to break off the pods and release the seed. This method has low efficiency, it is time consuming, and has high demand of energy. In addition, the output per-man hour is as low as 1-2.5 kg of groundnut.

Figure 1. Groundnut fruit and its manual dehulling process.

Dehulling process for other legumes such as sorghum and millet is accomplished either traditionally by hand pounding of tempered grain using pestle and mortar or mechanically using abrasive de-hullers (Munck *et al.*, 1982). There have been several attempts to make machines that dehull legumes and other seeds such as sorghum, cowpeas, maize, etc. Most groundnut dehulling machines fabricated in Nigeria are either too expensive or not efficient, the persistent increase in the demand for groundnut and ground product renders the traditional method of dehulling and separation incompetent, laborious and time consuming. Since the local method of production could not match the demand there is a prompt need to develop a machine which will reduce drudgery, number of labour required and the time for dehulling and winnowing of kernel from the husk.

MATERIALS AND METHODS

Design Analysis

Determination of crops sizes

The variety of groundnut used for evaluating the machine is "SAMNUT 24". The length, thickness and width of the pods and seeds of each groundnut were determined by measurements using Vernier caliper. Twenty samples were randomly selected from the bulk of one hundred each of groundnut (Maduako and Hannan, 2004).

$$da = \frac{L+W+T}{3} \quad (1)$$

$$dg = LWT^{\ 1/3} \quad (2)$$

Where: L is mean length of the seeds (mm)

W is mean width of the seeds (mm)

T is mean thickness of the seeds (mm)

Average size of groundnut pod (T) equals 7.9 mm

Average size of groundnut seed (T) equals 7.2 mm

The seed sizes were classified into three categories namely small, medium and large based on their length. The dimensional classification was based on the calculated average dimension (D) and the associated standard deviation (ςx). Then, small, medium, and large size seeds were so defined that their specific (X) dimension satisfies the following three inequalities (Pradhan *et al.*, 2013):

Small size group $D < X - \varsigma x$ (3)

Medium size group $D - \varsigma x < X < D + \varsigma x$ (4)

Large size group $X > D + \varsigma x$ (5)

Determination of crops shapes

The shapes of the crops were determined from the aforementioned measured dimensions. However, the shapes of the pods and seeds were expressed in terms of roundness (R) and sphericity (S) index by Karaj and Muller (2010);

Roundness, R (%):

$$R = \left(\frac{W}{L} + \frac{T}{L} + + \frac{T}{W} +\right)/3 \quad (6)$$

Sphericity, S (%):

$$s = \frac{(L * W * T)^{\frac{1}{3}}}{L} \quad (7)$$

The seeds of groundnut varieties were further classified according to Mazhar *et al.* (2013): when the ratio of length to width (L/W) fall within the range of 1.51 - 1.71 the variety was classified *Ellipticus* which is ellipsoid in shape, when the ratio falls within 1.85 - 2.31 the variety was classified *Oblongus* which is long cylindroids in shape and when the product of length and the ratio of width to thickness *(W/T)*L* fall within the range of 1.29 - 2.08 the variety was classified *Subcompressus* which is sub – compressed and long in shape, while for 2.17-3.51 the variety was classified *Compressus* which is more compressed and broad in shape.

Determination of crushing strength

The crushing strength of the groundnut pod at different orientations of the pods was determined using hardness testing machine (Huber *et al*., 1992);

$$Cs = \frac{W}{A} \tag{8}$$

Where:

Cs = Crushing strength (kg mm^{-2})

W is Weight required for cracking the seeds (kg)

A is Projected area of the seeds under load (mm^2)

Crushing strength (0.1180 kg mm^{-2})

Power required for dehulling

The power required for shelling groundnut/cowpea pods as reported by Abubakar and Abdulkadir (2012) is expressed as follows.

$$H = W K_k F_C \, Log\frac{L_1}{L_2} \tag{9}$$

Where:

H is Power (kW) (0.385 kW) (0.523Hp)

F_C is Crushing strength of groundnut (N m^{-2})

K_k is Kick's constant (1.2)

W is Average weight of unshelled groundnut (kg)

L_1 is Average length of unshelled groundnut (m)

L_2 is Average length of shelled groundnut (m)

Determination of dehulling drum shaft torsional moment

Hall and Hallowenko, (1982) gave torsional moment (M_t) as;

$$M_t = \frac{60\text{P}}{2\pi\text{N}} \tag{10}$$

Where:

P is power required for dehulling (0.385 kW),

S is speed of the dehulling drum (rpm) is 700 rpm and 750 rpm,

$$M_t = \frac{60(385)}{2\pi(750)} \tag{11}$$

M_t = 4.91 N m

Dehulling drum shaft diameter

The shaft size was selected using the relationship given by Khurmi and Gupta, (2005);

$$d_s = \frac{16}{\pi\tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \tag{12}$$

Where:

ds is shaft diameter (mm)

K_b is shock and fatigue factor applied to bending moment (1.5)

K_t is shock and fatigue factor applied to torsional moment (1.0)

M_t is torsional moments (4.91 N m)

τs is allowable stress of the galvanized steel shaft (40 N mm^{-2})

d_{sa} is 34 mm

Blower shaft diameter

The shaft size (d_s) was selected using the relationship given by Khurmi and Gupta, (2005); From equation (12).

$$\frac{16}{\pi\tau_s}\sqrt{(1.5\ x\ 75.11)^2 + (1\ x\ 48.65)^2} \tag{13}$$

d_s is 25 mm

Power Transmission Parameters

Pulley diameters and speed ratio relationship

The pulleys diameter was determined using the expression outlined by Sanjay (2010) as;

$$N_1 D_1 = N_2 D_2 \tag{14}$$

Where:

N_1 is speed of driving pulley (rpm),

N_2 is speed of driven pulley (rpm),

D_1 is diameter of driving pulley (cm),

D_2 is diameter of driven pulley (cm).

The sizes and speeds of 5 pulleys were determined; prime mover pulley (D_m is 8.7cm and Np is 1450 rpm), rubber beaters shaft pulleys (Drb is 12.6 cm and Nrb is 1000 rpm), dehulling roller unit pulleys (Ddr is 700/750 rpm and 18/16.8 cm) and the blower shaft pulley which is connected to the beaters shaft with a belt (Dbs is 5.5 cm and 3636 rpm).

Belt length

The effective belts length was selected using the relationship outlined by Sanjay (2010) as;

$$L_b = \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} + 2x \quad (15)$$

Where:

D_1 is diameter of driver pulley (cm)

D_2 is diameter of driven pulley (cm)

x is center distance between the driver and driven pulley (cm)

Centre distance

The center-to-center distance between the driver and driven pulleys were estimated using the expression given by Khurmi and Gupta (2007) as;

$$D_2 < x < 3(D_1 + D_2) \quad (16)$$

Belt tension

The following expressions were used to determine the belt tension (Sharma and Kamlesh 2006; Sanjay 2010);

$$M_t = (T_t - T_s)R \quad (17)$$

$$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta} \quad (18)$$

Where:

Tt and Ts is tension in tight and slack side of belt respectively (N)

R is radius of the shaft pulley (mm)

μ is coefficient of friction between the pulley and belt

θ is angle of contact between the pulley and belt (°)

β is half angle of groove of the pulley (°) when μ is 0.25, $2\beta = 34°$, and $\theta = 170°$

Therefore, the tensions in the tight and slack side of the fan belt were determined 877.45 N and 6.5×10^{-61} N respectively while those of cylinder belt were 1755 N and 1.6×10^{-60} N respectively.

Blower Design Parameters

Air discharge through the blower

The air discharge through the blower was determined from the expression below (Joshua, 1981);

$$Q = VD_aW_a \tag{19}$$

Where: Q is air discharge rate (m^3 s^{-1})

V is velocity of air required for cleaning (19.48 m s^{-1})

Da is depth of air stream (0.118 m)

Wa is width over which the air is required (0.512 m)

Q=19.48 x 0.118 x 0.512

Q = 1.177 m^3 s^{-1}

Number of blades required

The terminal velocity of the seeds was determined from the expression given below

$$V_t = 3dg\left(\frac{\rho_s-\rho_f}{\rho_f}\right)^{1/2} \tag{20}$$

Where:

Vt is theoretical terminal velocity (m s^{-1})

g is gravitational acceleration = 9.81 m s^{-2}

d is geometric mean of kernel physical dimensions = 0.0107 m

ρs is particle density = 746 kg m^{-3}

ρf is fluid (air) density = 1.275 kg m^{-3}

$$V_t = 3(0.0107\ x\ 9.81)\left(\frac{746-1.275}{1.275}\right)^{1/2} \tag{21}$$

Vt = 7.59 m s^{-2}

The following relations were used to determine the number of blades required as reported by Mohammed, (2009).

$$D = 1.265 * \left(\frac{(AB)^2}{(A+B)}\right)^{1/5} \tag{22}$$

Where:

D is chaff's outlet dimensional parameter

A is length of the chaff's outlet extended out of the main section (0.189 m)

B is width of the chaff's outlet extended out of the main section (0.512 m)

D is 0.534 m

Hence, number of blades (N_b) can be determined with the following relation

$$N_b = \frac{4WDV_t}{\pi L d^2} \tag{23}$$

Where: Nb is number of blades required

d is diameter of air flow rate channel (0.620 m)

W is width over which air is required (0.512 m)

L is width of the inlet duct minus the clearance (0.723 m)

Vt is terminal velocity of the seed (7.59 m s^{-1})

Nb is (9 blades)

Figure 2 and Figure 3 shows the blower's blade design, front and side view

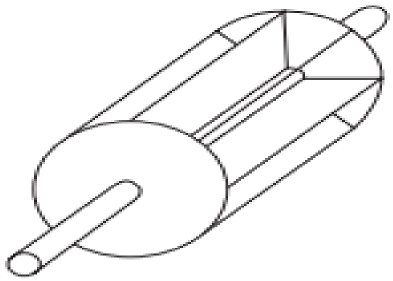

Figure 2. Isometric view of the blower's blade

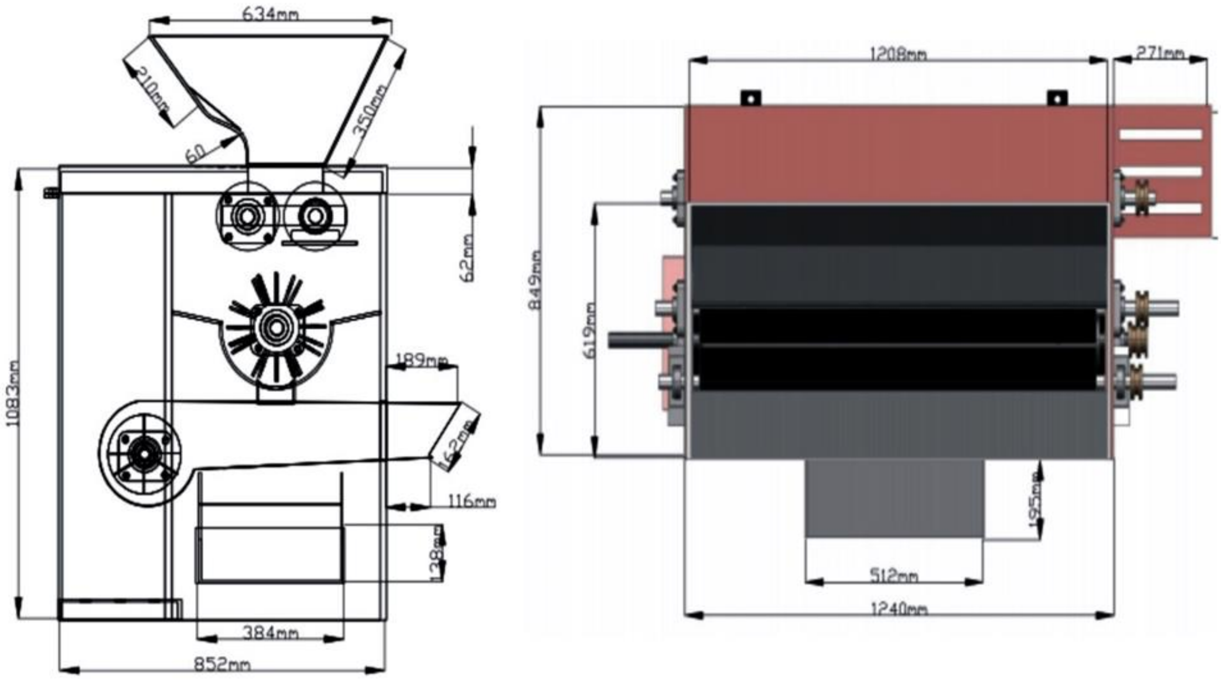

Figure 3. Groundnut dehuller side and plan (solid) view.

Machine's Performance Evaluation

The quantity of groundnut used was in three categories (1 kg, 2 kg, 3 kg), this variation in mass was examined and the effect of dehulling roller clearance (6.5 mm,7.0 mm, 7.35 mm and 7.5 mm) and speed (700 rpm and 750 rpm) was evaluated on dehulling efficiency, machine capacity, mechanical damage and separation efficiency.

M_1 is initial weight

M_2 is mass of dehulled broken seeds

M_3 is mass of dehulled unbroken seeds

M_4 is total mass of chaff at chaff outlet

M_5 is mass of un-dehulled seed

M_6 is total mass of product at the (seed) outlet

M_7 is ($M_6 + M_4$)

M_8 is mass of chaff in M_6

Dehulling efficiency (D_e) $= \frac{M_3}{M_1} * 100\%$ (24)

Mechanical damage (M_d) $= \frac{M_2}{M_1} * 100\%$ (25)

Machine capacity (M_c) $= \frac{M_1\ (kg)}{dehulling\ time\ \ (h)}$ (26)

Separation efficiency (S_e) $= \frac{1}{2}([\frac{M_8}{M_8+M_4} + \frac{M_4}{M_8+M_4}] * 100)$ (27)

Data Analysis

The performance evaluation results were subjected to statistical analysis to determine the mean, standard deviation, coefficient of variation, linear and nonlinear regressions using MINITAB (12) software. One-way ANOVA was used to test for significance effects, interactions and to determine the most appropriate concave clearance, mass and speed on dehulling efficiency, machine capacity, mechanical damage and separation efficiency of the machine.

Linear regression equation: $y = b_0 + b_1x$ (28)

Nonlinear regression equation: $y = b_0 + b_{1x2}$ (29)

Where x is independent variable, y is dependent variable and b_0 and b_1 are coefficients.

Figure 4. Effect of dehulling on the groundnut seed.

RESULTS AND DISCUSSION

Effect of Clearance and Mass Feed on the Machine Performance

Figure 5 and Figure 6 illustrates how machine performance is affected by dehulling clearance and mass fed at 700 rpm and 750 rpm. At 2 kg and 3 kg mass fed, dehulling efficiency increases as the dehulling clearance increases from 6.5 mm to 7.5 mm while 1 kg mass exhibit a different trend, the dehulling efficiency increased as the clearance increased from 6.5 mm to 7.35 mm, a subsequent drop in dehulling efficiency occurred as the clearance was increased from 7.35 mm to 7.5 mm (Figure 5). Moreover, it may be concluded that dehulling efficiency will decrease if the feeding rate continually increase during dehulling operation, this is in agreement with Maduako *et al.* (2006) that operation parameters which include feed rate, operating speed and clearance affects the overall performance of dehulling machine. Mass fed and clearance does not have a significant effect on machine capacity and separation efficiency while the speed of the dehulling drum (cylinder) and the blower has significant effect. There is a decrease in mechanical damage as dehulling clearance increase while increase in mass does not have significant effect on mechanical damage.

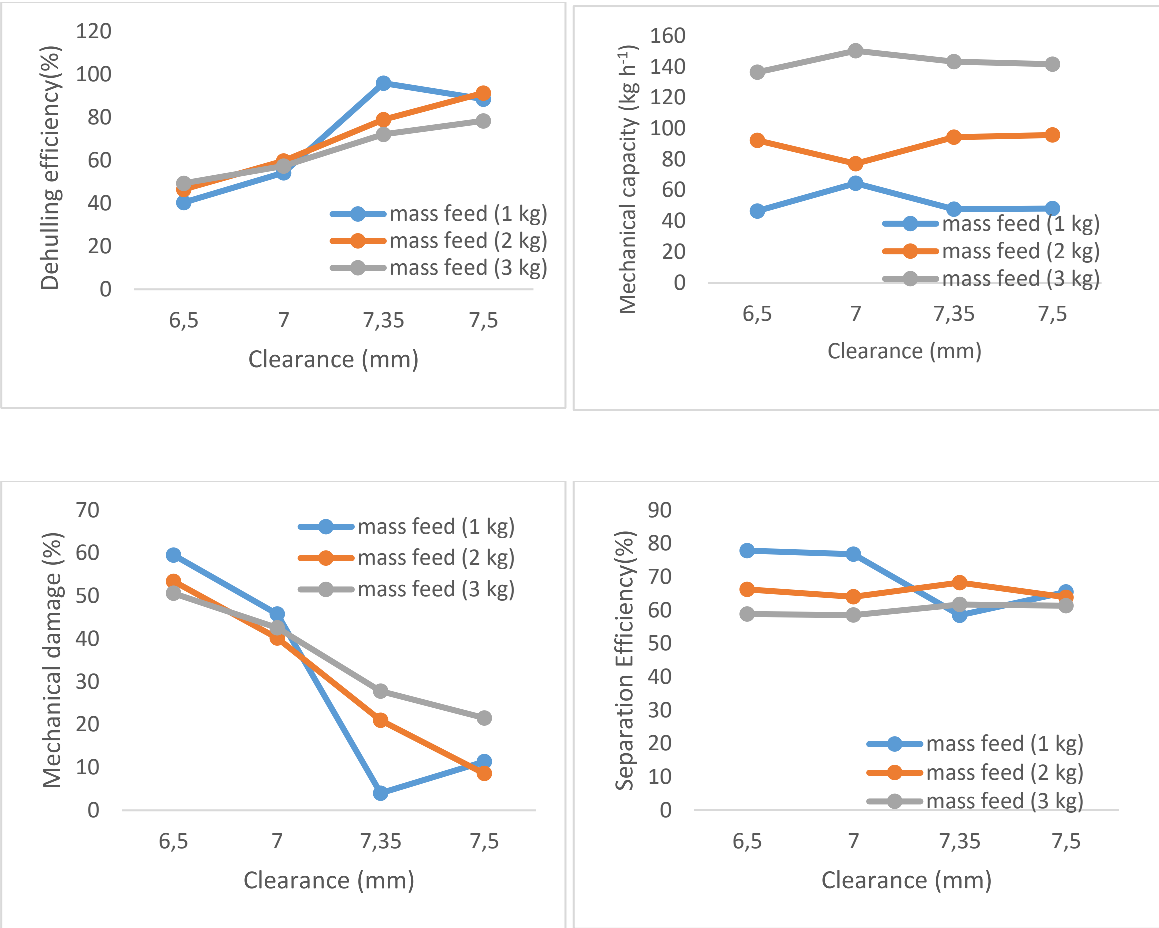

Figure 5. Machine performance vs clearance at three different mass feed and dehulling roller speed of 750 rpm.

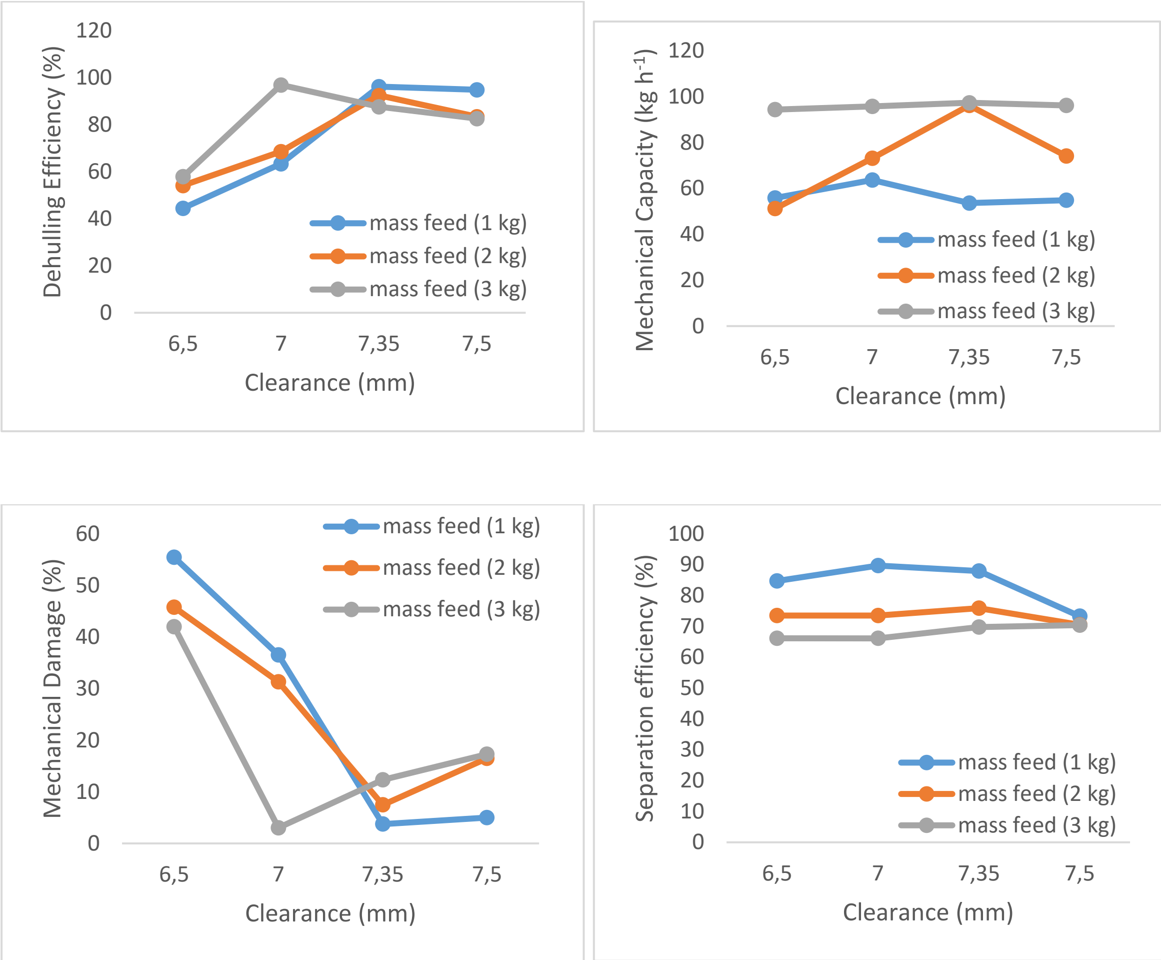

Figure 6. Machine performance vs clearance at three different mass feed and dehulling roller speed of 700 rpm.

Effect of Speed on the Machine Performance

Dehulling efficiency reduces as speed increases from 700 rpm to 750 rpm (Figure 7), due to the fact that groundnuts fed into the hopper have less retention time as they undergo compression and shearing action. Optimum mechanical damage of 62% and machine capacity was recorded at 750 rpm, Figure 8 shows that a decrease in mass fed and dehulling speed will lead to a decrease in machine capacity. However, mechanical damage does not only depend on mass fed and dehulling speed but also depends on the impact force exerted on the groundnuts by the rubber beaters as shown in Figure 9. This indicated that whole kernel recovery is dependent on seed sizes and speed Gupta and Das (1999).

Separation efficiency was optimum at 700 rpm of the dehulling roller (Figure 10). When the speed was reduced from 750 rpm to 700 rpm, groundnuts were able to pass through the clearance between the dehulling rollers at a reduced speed, this enables proper compression and cracking of the nuts which aids the separation process at the blower unit.

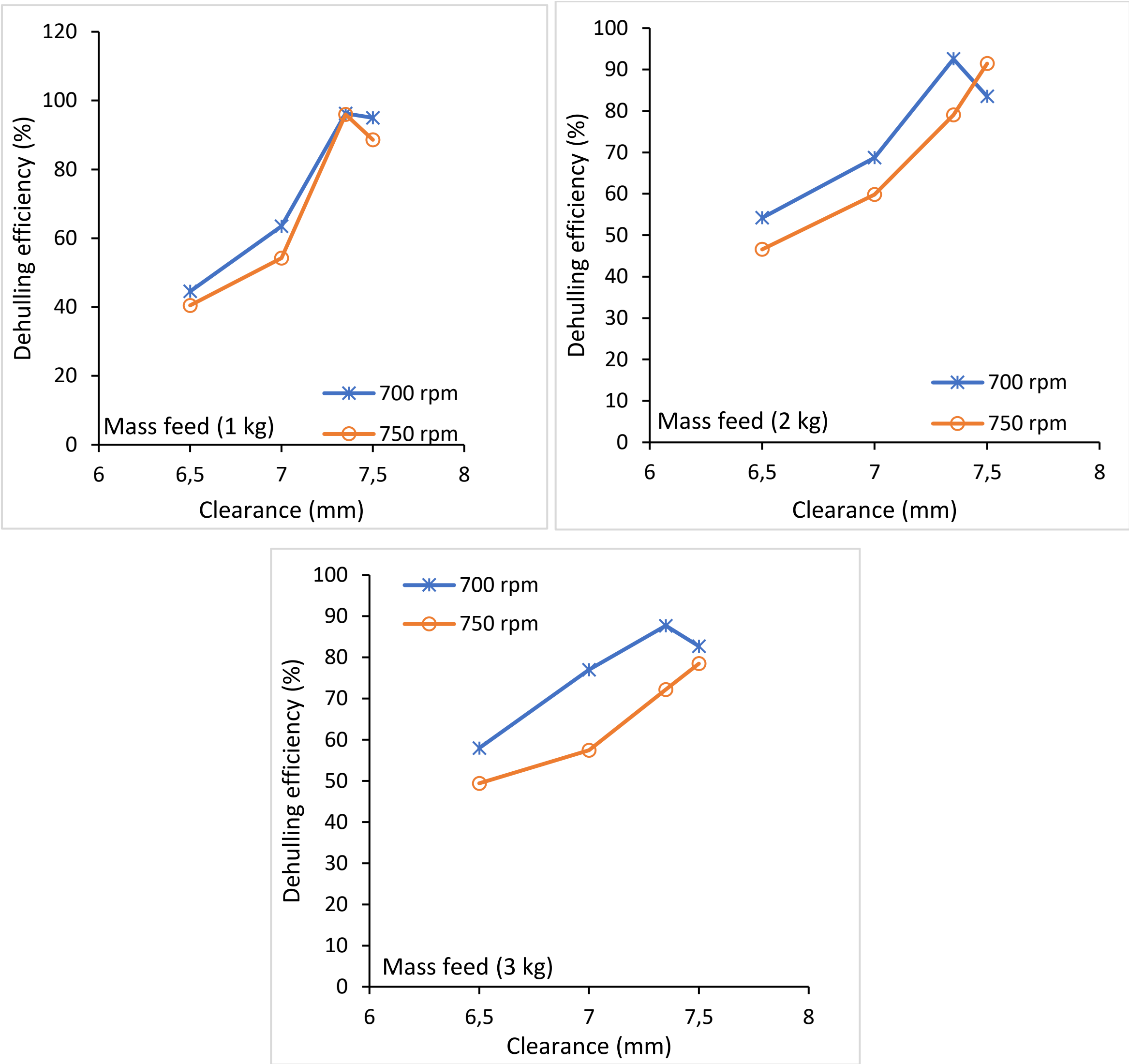

Figure 7. Effect of dehulling rollers clearance and speed at different mass feed on dehulling efficiency.

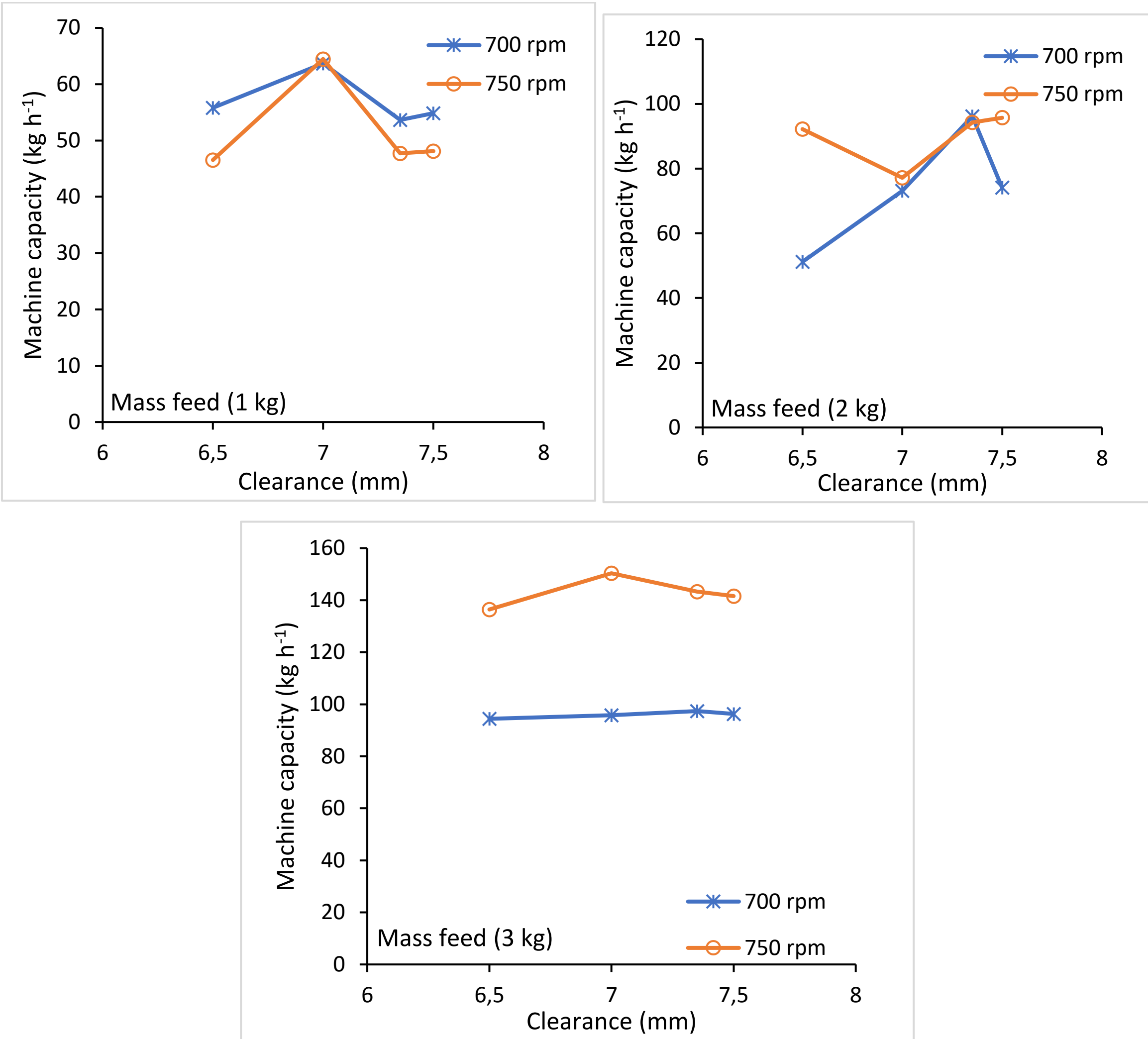

Figure 8. Effect of dehulling rollers clearance and speed at different mass feed on machine capacity.

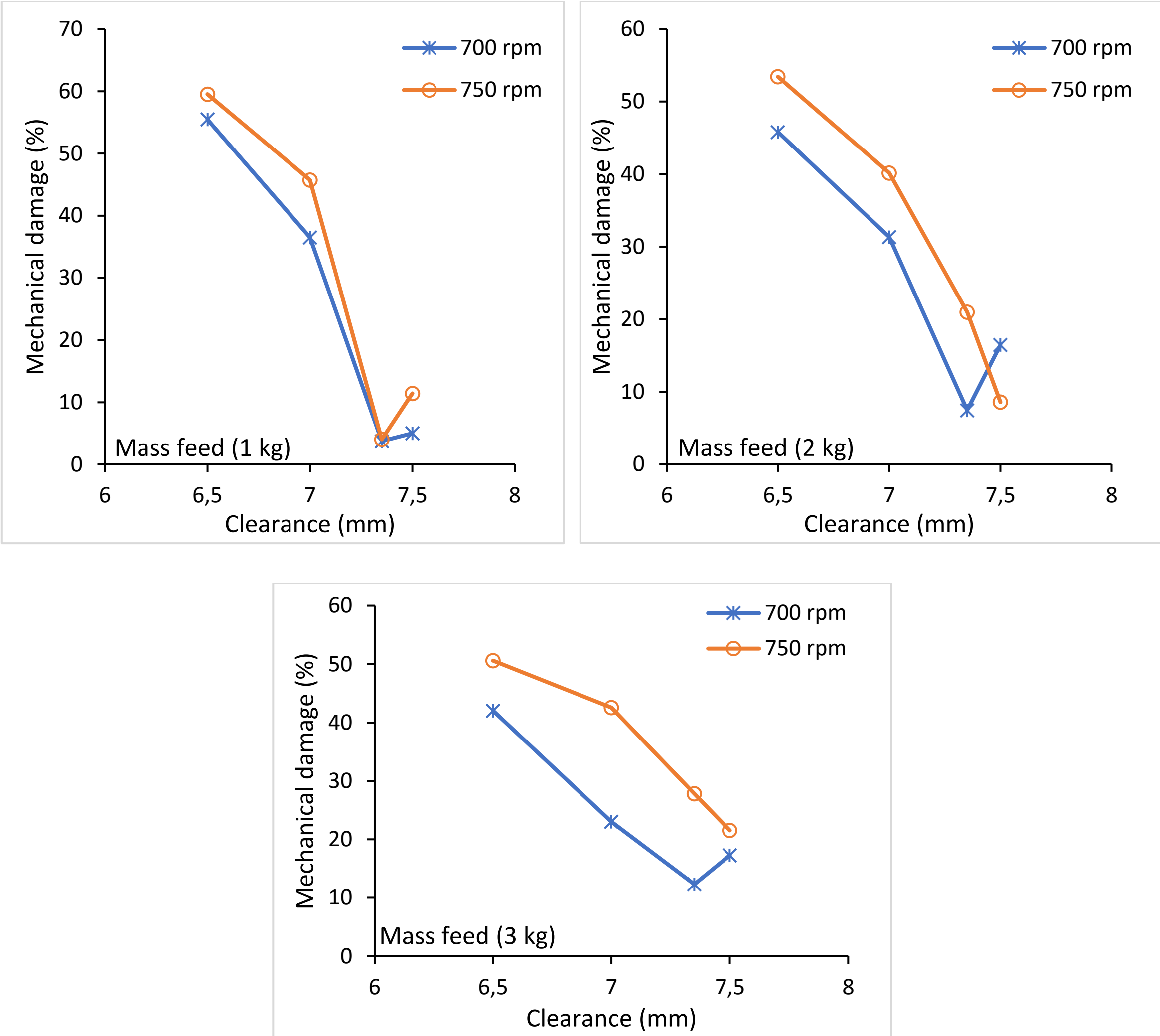

Figure 9. Effect of dehulling rollers clearance and speed at different mass feed on mechanical damage.

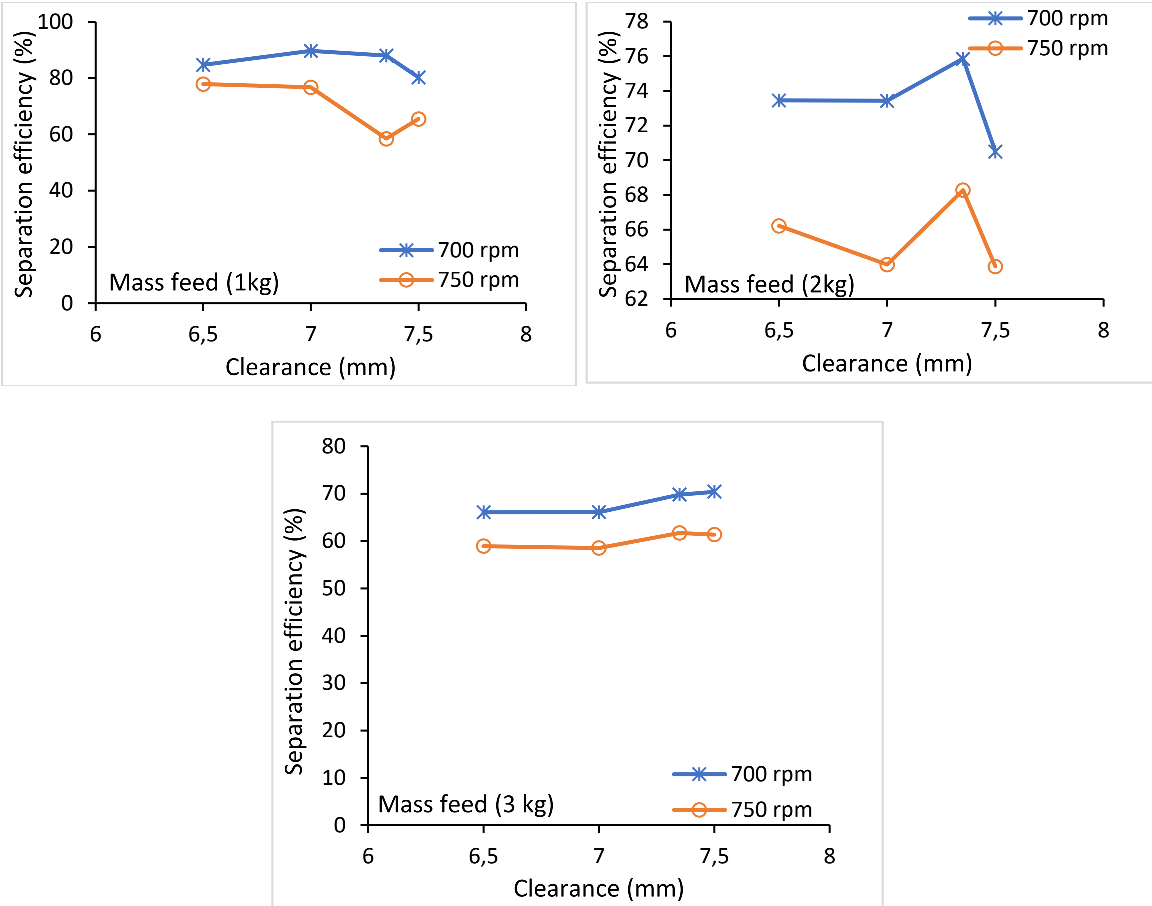

Figure 10. Effect of dehulling rollers clearance and speed at different mass feed on separation efficiency.

Statistical Test

The negative correlation between two variables shows that increase in one of the variables will lead to decrease in the other variable (e.g. increase in mass and speed will lead to decrease in dehulling efficiency and vice versa). Table 3 shows correlation value on the percentage of variation of output that can be accounted for by the input variable (e.g variation in mass feed to the machine can account for about 84.56% variation of the machine capacity while speed can only account for about 30.69%). Hence, the capacity (throughput) of the machine at a constant speed will increase with a corresponding increase in mass fed until an equilibrium throughput is attained.

Table 1. Summary of statistics at 700 rpm.

Clearance (mm)	Statistics parameter	1 kg (Mass feed)				2 kg (Mass feed)				3 kg (Mass feed)			
		DE (%)	MC (kg h^{-1})	MD (%)	SE (%)	DE (%)	MC (kg h^{-1})	MD (%)	SE (%)	DE (%)	MC (kg h^{-1})	MD (%)	SE (%)
7.5	Max.	98.17	58.44	8.28	76.13	86.66	76.76	18.24	74.20	83.65	98.34	18.10	72.08
	Min.	91.72	53.57	1.83	70.48	81.76	72.01	13.34	68.67	81.90	94.44	16.36	69.14
	Mean	94.97	54.83	5.03	73.27	83.54	74.14	16.46	70.50	82.70	96.26	17.30	70.39
	SD	2.40	2.05	2.40	2.57	1.87	1.90	1.87	2.24	0.76	1.42	0.76	1.40
	CV	2.53	3.73	47.77	3.51	2.24	2.56	11.35	3.17	0.92	2.22	4.42	1.99
7.35	Max.	99.09	56.79	7.68	90.78	97.28	98.56	10.42	79.18	91.04	98.57	15.12	74.24
	Min.	92.33	49.26	0.91	86.26	89.58	92.14	2.72	71.05	84.88	93.51	8.96	66.12
	Mean	96.26	53.65	3.74	87.95	92.54	96.20	7.46	75.87	87.69	97.38	12.31	69.80
	SD	2.53	3.01	2.53	1.90	3.13	2.70	3.13	3.24	2.57	2.18	2.57	3.08
	CV	2.63	5.61	67.59	2.16	3.38	2.81	41.92	4.27	2.93	2.24	20.87	4.42
7	Max.	66.34	65.73	40.16	94.01	70.66	76.07	35.19	78.69	97.73	98.04	41.87	69.69
	Min.	59.84	61.63	33.66	85.54	64.81	69.56	29.34	70.94	95.13	92.98	2.27	61.30
	Mean	63.48	63.69	36.52	89.67	68.67	73.16	31.33	73.44	96.97	95.73	3.03	66.08
	SD	2.60	1.59	2.60	3.22	2.30	2.35	2.30	3.04	1.07	2.06	1.07	3.17
	CV	4.09	2.49	7.11	3.59	3.35	3.21	7.34	4.14	1.10	2.15	35.33	4.79
6.5	Max.	47.68	59.25	59.57	91.03	56.37	56.18	47.54	80.99	58.04	98.97	42.18	69.49
	Min.	40.43	52.92	52.32	77.57	52.46	47.90	43.63	65.85	57.82	86.76	41.96	58.97
	Mean	44.54	55.82	55.46	84.67	54.20	51.21	45.80	73.46	57.97	94.39	42.03	66.09
	SD	3.14	2.50	3.14	5.43	1.95	3.13	1.95	5.79	0.09	4.90	0.09	4.56
	CV	7.05	4.48	5.66	6.42	3.60	6.10	4.26	7.89	0.15	5.19	0.20	6.90

Table 2. Summary of statistics at 750 rpm.

Clearance (mm)	Statistical parameter	1 kg (Mass feed)				2 kg (Mass feed)				3 kg (Mass feed)			
		Dehulling efficiency	Machine capacity	Mechanical damage	Separation efficiency	Dehulling efficiency	Machine capacity	Mechanical damage	Separation efficiency	Dehulling efficiency	Machine capacity	Mechanical damage	Separation efficiency
7.5	Max.	90.381	48.239	12.471	71.169	93.566	96.108	11.037	64.860	78.571	141.710	21.702	61.675
	Min.	87.529	47.893	9.619	61.597	88.963	95.283	6.434	63.503	78.298	141.376	21.429	61.028
	Mean	88.597	48.086	11.403	65.470	91.426	95.731	8.574	63.880	78.462	141.543	21.538	61.355
	SD	1.216	0.137	1.216	3.959	1.986	0.303	1.986	0.565	0.103	0.125	0.103	0.258
	CV	1.373	0.285	10.666	6.047	2.173	0.316	23.167	0.885	0.131	0.088	0.478	0.421
7	Max.	55.056	65.833	46.380	78.300	61.965	77.280	42.360	64.389	57.503	150.830	42.721	58.784
	Min.	53.620	63.171	44.944	75.468	57.640	77.042	38.035	63.619	57.279	149.551	42.497	58.167
	Mean	54.251	64.463	45.749	76.766	59.835	77.184	40.165	63.983	57.413	150.332	42.587	58.520
	SD	0.612	1.028	0.612	1.174	1.991	0.088	1.991	0.312	0.089	0.512	0.089	0.225
	CV	1.129	1.595	1.338	1.529	3.328	0.114	4.958	0.488	0.155	0.340	0.209	0.384
7.35	Max.	96.731	47.847	5.905	64.118	80.335	94.518	22.597	68.862	73.559	143.816	28.236	62.456
	Min.	94.095	47.596	3.269	52.505	77.403	94.073	19.665	67.418	71.764	142.586	26.441	60.161
	Mean	95.985	47.728	4.015	58.497	79.033	94.313	20.967	68.281	72.188	143.323	27.812	61.704
	SD	1.070	0.089	1.070	5.545	1.467	0.185	1.467	0.768	0.769	0.489	0.769	0.952
	CV	1.115	0.186	26.657	9.478	1.856	0.196	6.996	1.125	1.066	0.341	2.766	1.544
6.5	Max.	44.084	46.707	62.823	78.658	46.768	92.421	53.581	66.605	53.846	136.674	53.911	59.309
	Min.	37.177	46.318	55.916	75.935	46.419	91.954	53.232	65.846	46.089	136.302	46.154	58.535
	Mean	40.467	46.538	59.533	77.871	46.577	92.192	53.423	66.224	49.403	136.420	50.597	58.876
	SD	2.775	0.145	2.775	1.115	0.124	0.207	0.124	0.270	3.224	0.150	3.224	0.344
	CV	6.858	0.312	4.662	1.432	0.267	0.225	0.233	0.408	6.525	0.110	6.371	0.584

Table 3. Correlation between variables.

Variables	S (rpm)	M (kg)	C (mm)	Dehulling efficiency (%)	Machine capacity (kg h^{-1})	Mechanical damage (%)	Separation efficiency (%)
S (rpm)	**1.0000**	0.0000	0.0000	-0.2112	0.3069	0.2112	-0.5990
M (kg)	0.0000	**1.0000**	0.0000	-0.0453	0.8456	0.0453	-0.6271
C (mm)	0.0000	0.0000	**1.0000**	0.8936	0.0846	-0.8936	-0.0955
Dehulling efficiency (%)	-0.2112	-0.0453	0.8936	**1.0000**	-0.0725	-1.0000	-0.0333
Machine capacity (kg h^{-1})	0.3069	0.8456	0.0846	-0.0725	**1.0000**	0.0725	-0.6165
Mechanical damage (%)	0.2112	0.0453	-0.8936	-1.0000	0.0725	**1.0000**	0.0333
Separation efficiency (%)	-0.5990	-0.6271	-0.0955	-0.0333	-0.6165	0.0333	**1.0000**

The negative correlation between two variables shows that increase in one of the variables will lead to decrease in the other variable (e.g increase in mass and speed will lead to decrease in dehulling efficiency and vice versa). The correlation value also shows the percentage of variation of output that can be accounted for by the input variable (e.g variation in mass feed to the machine can account for about 84.56% variation of the machine capacity while speed can only account for about 30.69%). Hence, the capacity (throughput) of the machine at a constant speed will increase with a corresponding increase in mass fed until an equilibrium throughput is attained.

Multiple Linear Model equation

Where *M* is the mass feed into the machine (kg), *S* is the speed of the dehulling roller (rpm) and *C* is the clearance between the two dehulling rollers. The product of the input factors in the model expresses the interaction between the factors.

*Separation efficiency (%) = 195.49-115.22*M+23.03*C+0.08*S*M-0.05*S*C +6.77*M*C*

*Mechanical damage (%) = 19.03+0.68*S-145.98*M+0.07*S*M-0.09*S*C+13.60*M*C*

*Dehulling efficiency (%) = 80.97-0.68*S+145.98*M-0.07*S*M+0.09*S*C-13.60*M*C*

*Machine capacity (kg/hr) = 9.63-368.29*M+69.83*C+0.53*S*M-0.09*S*C+2.72*M*C*

CONCLUSION

This study was conducted to design, fabricate a groundnut dehuller and separator. The effect of dehulling speed and clearance between the dehulling rollers was evaluated on the machine performance. Based on the experimental findings, it can be concluded that:

i. The result obtained after testing the machine shows that 7.35 mm clearance and 700 rpm speed of the dehulling roller gave the best average dehulling efficiency (95.80 %), separation efficiency (81.40 %) and the least mechanical damage (11.01 %).

ii. The capacity (throughput) of the machine at a constant speed will increase with a corresponding increase in mass fed until an equilibrium throughput is attained.

iii. Variation in dehulling roller speed and mass fed can account for only 21.1% and 4.5% variation of the mechanical damage respectively.

iv. There is no positive correlation of the dehulling roller speed and mass fed on separation efficiency.

DECLARATION OF COMPETING INTEREST

The authors affirm that there is no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Ademola Adebukola Adenigba: Conceptualization, investigation, experimentation, writing original draft and review.
Adewale Moses Sedara: Editing of the original draft.

REFERENCES

Abubakar M and Abdulkadir BH (2012). Design and evaluation of motorized and manually operated groundnut shelling machine, *International Journal of Emerging Trend in Engineering and Development, 2(4): 673-682.*

Food and Agriculture Organization of the United Nations (2013). About the world growth of groundnut. Retrieved from http://www.fao.org/faostat/en// (04/07/2018).

Gupta, R. K. and Das, S. K. (1999). Performance of Centrifugal Dehulling System for Sunflower Seeds. *Journal of Food Engineering, 42(4): 191-198.*

Hall SA and Holowenko RA (1982). *Machine design*, Schemes Outline Series, p:112

Huber JA, O Dogherty, MJ, Dyson J and Marshal CJ (1992). A study of physical and mechanical properties of wheat straw, *International Conference on Agricultural Engineering*, Upp Sala.

Joshua HC (1981). Design and selection of threshers parameter and components, *Agricultural Mechanization in Asia, Africa, and Latin America, 11(2):61-63.*

Karaj S and Muller J (2010). Determination of physical, mechanical and chemical properties of seeds and kernels of *Jatropha curcas* L. *Industrial Crops and Production, 32(2): 129-138.*

Khurmi RS and Gupta JK (2005). A textbook of machine design. 14th revised Russnogle, J., (2009). World's Largest Planter: John Deere's DB120. Corn and Soybean Digest.

Khurmi RS and Gupta JK (2007). Machine design, 14th Edition, *Eurasian Ltd,* RanNagar, New Delhi, p: 1230.

Maduako JN and Hannan M (2004). Determination of some physical properties of three groundnut varieties, *Nigerian Journal of Technology, 24(2): 12-18.*

Maduako JN, Saidu M, Matthias P and Vanke I (2006) Testing of an engine-powered groundnut shelling machine. *Journal of Agricultural Engineering and Technology (JAET), 14: 29-37.*

Mazhar K, Bahadır S, Erdal E, Ozturk I and Ozmen TB (2013). Seed size and shape analysis of registered common bean cultivars in Turkey using digital photography, *Journal of Agricultural Sciences*, *19: 219-234.*

Mohammed K, Afutu E, Odong T, Okello D, Nuwamanya E, Grigon O, Rubaihayo P and Okori P (2018). Assessment of groundnut (*Arachis hypogaea* L.) genotypes for yield and resistance to late leaf spot and rosette diseases. *Journal of Experimental Agriculture International*, *21: 1-13.*

Munck L, Back Knudsen KE and Axtell JD (1982). Industrial milling for the 1980s. *Proceedings of the International Symposium on Sorghum*. International Crops Research Institute for the Semi-Arid Tropics. Patancheru, India.

Pradhan RC, Said PP and Singh S (2013). Physical properties of bottle gourd seeds, *Agric Engineering International: CIGR Journal, 15(1): 106-113.*

Rao VR (1980). Groundnut genetic resources at the International Crops Research Institute for the Semi-Arid Tropics. In: *Proceedings of the International workshop on Groundnuts*, pp. 65- 71, ICRISAT, India.

Sanjay K (2010). A numerical approach in agricultural engineering with objective, NET, GATE, and ARS Digest, *Kalyani Publishers*, New Delhi, 110002, p: 247-256.

Sedara, AM, Lanwo R and Sedara OS (2020). Development of a Low Cost Two-Row Groundnut Planter. *Turkish Journal of Agricultural Engineering Research (TURKAGER), 1(2): 324-338.*

Sharma CS and Kamlesh P (2006). Theory of mechanisms and machines, Prentice hall of India private limited, p: 184-241.

Thakur VK, Thakur MK and Gupta RK (2013). Rapid synthesis of graft copolymers from natural cellulose fibers. *Carbohydrate Polymers, 98: 820-828.*