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Design and Fabrication of a Motorized Castor (*Ricinus communis* L.) Seed Decorticator

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Abstract

A motorized castor (*Ricinus communis* L.) seed decorticating machine was designed, fabricated and evaluated for performance. The motorized castor (*Ricinus communis* L.) seed decorticating machine consists of mainframe, hopper, shelling drum, aluminum spikes, screen, bearings, electric motor, pulley, belt, fan, grains outlet and chaff outlet. The machine is powered by a single-phase, five horse-power (5hp) electric motor. The performance of the machine was evaluated by varying three factors (feed rate, machine speed and moisture content) at three levels each using design expert software version 6.08 for the analysis. The parameters under investigation were shelling capacity and shelling efficiency. The machine has a maximum shelling efficiency of 94.5% at a feed rate, machine speed and moisture content of 1.5Kg, 1000rpm and 6%$_{wb}$ respectively. The maximum shelling capacity of the machine was 500.1kg/h obtained at a feed rate, machine speed and moisture content of 2Kg, 900rpm and 6%$_{wb}$ respectively. The machine is therefore observed to perform best at a feed rate, speed and moisture content of 2Kg, 900rpm and 6%$_{wb}$ respectively with a shelling capacity and shelling efficiency of 500.1Kg/h, 92.6% respectively. The material used for the fabrication of the machine were locally sourced and the total cost of the machine is one hundred and sixty-seven thousand, four hundred and fifty naira only (₦167, 450.00).

Keywords: Castor; Design; Fabrication; Decorticator; Motorized; Evaluation

1. Introduction

The castor plant (*Ricinus communis L.*), belonging to the family Euphorbiaceae, is not only native to Africa (being of Ethiopian origin), but also widely distributed throughout the tropical, subtropical and even warm temperate regions of the world [1], [2]. Castor plant is native to the southeastern Mediterranean Basin, Eastern Africa and India but is also available throughout tropical regions. Castor oil which has a variety of use is gotten from castor seed. A very important raw material for the chemical and polymer industries is castor oil, used as biodiesel stock [3], [4] and [5]. With the numerous applications of castor oil, its worldwide demand accounts for 0.15% of vegetable oils [6]. More than 80% of the castor oil supply could be traced to India and Brazil. In India, castor is cultivated in an area of 8.4 lakh ha under both irrigated and rainfed conditions. Due to the high oil content of castor and its adaptability to grow under drought and saline conditions, it has the potential for be used in bioenergy and industrial feed stock [7]. The first country in the world to exploit hybrid vigour of castor crop on commercial scale is India [8]. Castor is considered to be a drought hardy crop which grows well under dry and warm regions receiving a rainfall of 500-750 mm. To produce higher yields, it requires a moderate temperature of 20-26°c and low humidity [9]. High temperature above 41°C at flowering time even for a short period results in blasting of flowers and poor seed set [10].

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The plant is drought and pest resistant, and can be grown practically anywhere land is available. In Katsina (latitude 130N of the Equator; Longitude 70, 32'E of Greenwich Mean Time), Katsina State – Nigeria, it is commonly found in marginal lands around major drainages/water-ways notably in K/Kaura, K/Marusa, K/Durbi and K/Sauri areas, where it grows lavishly as weed. The wild *Ricinus communis* L. plants in these areas are annuals of the dwarf (1-2 metres tall) type [11]. While the seeds are of the small (8-10mm long; 5-6mm wide), oval-shaped and dark-chocolate coloured variety [2]. These seeds come under the general classification of 'variety minor' believed to be the commonest variety in Northern Nigeria [12].

It has green, reddish to purple stems and finger–like leaves, some cases of greyish green and whitish stems have also been observed. In the wild, castor plant can reach up to 9 meters, but cultivated varieties generally grow to between 1-4 meters. Dwarf-hybrid varieties grow to an average height of between 0.9 to 1.5 m, compared to 1.8 to 3.7 m for normal varieties. The plant is a fast –growing, suckering perennial shrub. The plants can be found also in Kenya growing wildly with several varieties being observed. The castor seed is the source of castor oil, which has a wide variety of uses. The seeds contain between 40 %-60 % oil that is rich in triglycerides, mainly ricinolein [13]. The seeds also contain toxins e.g. proteins called ricin. These toxins are also present in lower concentrations throughout the plant.

Castor oil, like other seed oils, is extracted from the ripe or mature seeds of the plant after sun drying, and following a sequence of seed processing operations that may include dehulling, pod or seed coat removal, winnowing, sorting, cleaning, grinding or milling, preheating etc. [14] and [15]. Oil extraction is usually achieved by mechanical expression or solvent extraction, or both. Average oil content for all castor seed varieties is about 46-55% oil by weight [1]. - actual yield depending on particular seed variety, geographical origin/climatic conditions, and on the oil extraction method(s) used. However, unlike castor seeds which have been widely reported as containing the toxic glycoprotein ricin, the toxic alkaloid ricinine and toxic castor bean allerges (CBA), castor oil is non-toxic [16] and [17] as these toxic ingredients are not carried along with the oil during extraction.

The demand for Castor (*Ricinus communis L.*) seed is high and this is due to the afore mentioned industrial uses. However, the post-harvest processing for the crop which also involves its decorticating has been done in conventional and inefficient ways which result in large quantities of castor being lost. Hence the need to design and fabricate a motorized Castor (*Ricinus communis L.*) seed decorticator.

2. Material and methods

2.1. General Description of the Motorized Castor Decorticator

The motorized castor seed decorticator fig 1 has the following component part: mainframe, hopper, shelling drum, aluminum spikes, screen, bearings, electric motor, pulley, belt, fan, grains outlet and chaff outlet.

The mainframe is the part of the machine that forms the structure on which all other parts are rested on to withstand the vibration of the machine during operation. It was made from 50 X 50 X 5mm mild steel angle iron. The dimensions of length, breadth and height of the mainframe are 750mm X 260mm X 800mm respectively. The hopper is the part of the machine that allows the castor to be fed into the machine. It was made from 2.5mm mild steel sheet to form the shape of a cuboid with dimensions 355mm x 250mm x 70mm.

The shelling unit is the part of the machine that breaks the castor pod to allow the kernel separated from the shell. It consists of aluminum spike tooth cylinder and a concave screen. The aluminum spike tooth is made from aluminum casting and attached to the shaft by bolt and nut fastening via a flange. The screen was made from a plate of 2.5mm thickness and aperture of 16mm was made to form the concave screen. The shaft was made from 25mm mild steel shaft and was carried by pillow bearings at both end of the shaft.

The blower is the part of the machine that does the cleaning action taking advantage of the difference in terminal velocity. It is a centrifugal type fan and is attached to the mild steel shaft and enclosed in a cylindrical housing. The blower is placed below the concave screen at the lower part of the main frame to give a height of fall of the castor before coming in contact with the stream of air. The grains outlet is at the lowest part of the machine where the grains were collected. It was also made from 2.5mm mild steel sheet and form to tilt at an angle for easy flow of the castor. The chaff outlet is the part where the chaff is being collected. It is directly opposite the blower to enable free flow of the chaff out of the machine. The machine is being powered by an electric motor which is placed on the electric motor base and the drive is connected by belt and pulley drive.

2.2. Design Consideration

The design of the machine was based on the engineering properties of the castor seed. The fan was incorporated for cleaning of the threshed castor. The quality of the castor was also considered, bearing in mind the terminal velocity of the castor. The quantity of the seed to be threshed in an hour, suitability of the material for the fabrication work, power requirement of the castor decorticator for effective and efficient of shelling operation. The moisture content of the castor was equally considered portability and affordability by the end users. Finally, the ergonomics and aesthetic of the machine was also taken into consideration.

2.3. Material Selection

The following were considered for the selection of material used for the motorized castor seed decorticator:

- Availability of local materials for fabrication of the component parts of the machine
- Durability of the material
- Ease of fabrication
- Cost of the materials
- Ease of maintenance
- Weight of the material
- Rigidity of the material

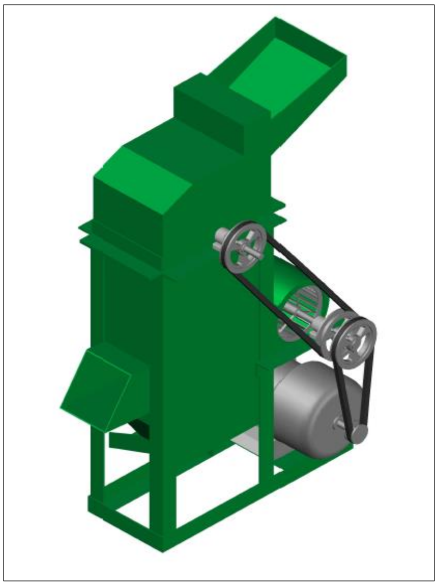

Figure 1 The motorized castor seed decorticator

2.4. Design Calculations and Analysis

The design calculation and analysis aim at determining the necessary parameters which would assist the selection of appropriate materials for the various components part of the machine.

2.4.1. Design for the Hopper

The hopper was designed based on the engineering properties of castor seed. The hopper was designed to tilt 10^0 more than the angle of repose of castor as recommended for hopper design. The general angle of repose agricultural material ranges between 25^0 and 30^0. Therefore, the hopper was made to tilt $40^0$to the horizontal. The hopper was also designed to ensure easy feeding by the operator and such that it does not obstructs any other part of the machine during operation. The shape of a cuboid was chosen for the hopper after considering all afore mentioned factors. To determine the hopper dimensions, a hopper of 2kg capacity was designed for using the relation between the bulk density and the volume

Bulk density of castor: 494.57kg/m^3 [18]

Volume of castor, $V = \frac{mass\ of\ \text{castor}}{bulk\ density\ of\ \text{castor}}$

Mass of castor, $M = 2kg$

$$V = \frac{2}{494.57} = 4.04 \times 10^{-3} m^3$$

Volume of hopper= $4.04 \times 10^{-3} m^3$

2.4.2. Design for Threshing Unit.

The shelling unit was designed such that castor been fed through the hopper getting to the threshing unit gets beat by the impact of the rotary spikes thereby splitting the pod, uncovering the grains. The seed and chaff leaves the threshing unit for the separating unit via the concave aperture where the chaff is blown out with the aid of the fan and grains ejected is collected at the grains outlet.

2.4.3. Selection of shaft Diameter

For the design of shaft, the relation for shaft subjected to simple bending.

$$\sigma_b = \frac{32mbd_o}{(\pi d_o{}^4 - d_i{}^4)} \text{ [19]}$$

Where $\sigma_b -$ *bending stress*
$M_b -$ *bending moment* (Nmm)
$d_o -$ *outside diameter of hollow shaft*
$d_i -$ *inside diameter of hollow shaft*

2.4.4. Power Requirement of the Machine

The power requirement of the machine was derived using the equation given by Khurmi and Ghupta. It goes thus;

$$P = \frac{2\pi NT}{60} \text{ [19]}$$

$$T = Fr$$

Where; P is required power

- N is machine speed
- T is torque
- F = weight of shaft
- r = radius of shaft

2.4.5. Design for Belt Drive

Determination of belt tension.

$$P = (T_1 - T_2)V$$

Where;

- P = Design power in watts
- T_1 = Belt tension at tight side in Newton
- T_2 = Belt tension at slack side in Newton
- V = Speed of belt in M/S

Also, $N_1 D_1 = N_2 D_2$

Where;

- N = Speed
- D = Diameter of pulley
- 1 = Electric motor
- 2 = Machine

2.4.6. Determination of Angle of Wrap

$$\vartheta = [180 - 25\, in^{-1}\, x\,]\frac{\pi}{180} \quad [19]$$

Where;

ϑ - Angle of wrap in rad

$$2.3\, log\left[\frac{T_1}{T_2}\right] = \varphi\vartheta cos\beta \quad [19]$$

ϑ - Frictional coefficient of belt

β - Frictional coefficient of pulley

2.4.7. Determination of Length of Belt

$$L = 2x + \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} \quad [19]$$

Where;

- L = Length of belt
- C = Centre distance between two pulley
- D_1& D_2 = Diameter of driver & driven pulley

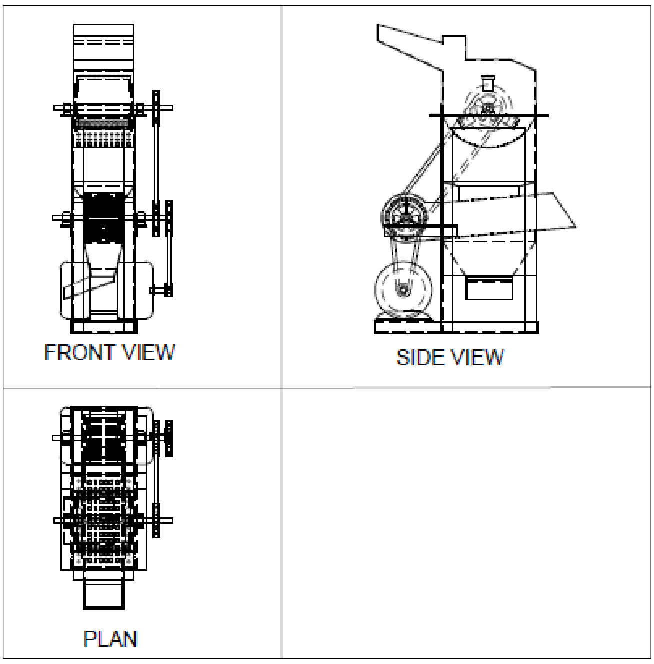

Figure 2 Isometric view of the Motorized Castor Decorticator

2.5. Fabrication Procedure and Assembly

2.5.1. Fabrication of Main Frame

The main frame is the main unit of the machine on which all other part is rested on. The frame of the machine was made from mild steel angle iron of 50mm X 50mm X 5mm. The length, breadth and height were cut to the required size with hacksaw after appropriate measuring and marking out. It was then joined with electric arc welding machine.

2.5.2. Fabrication of Hopper

The hopper was made from mild steel sheet of 2.5mm thickness. The sheet was cut with guillotine shears. The shape was formed to a cuboid by bending it with a manual bending and welded fully with arc welding machine with a dimension 280mm x 270mm x 40mm and welded at angle 40^0 to ensure easy flow of the feed.

2.5.3. Fabrication of Decorticating Drum

The decorticating drum was made with mild steel sheet of 2.5mm. It was cut with guillotine shears and bent with manual bending machine to form a cuboid shape and then welded together with electric arc welding machine, this forms the housing to the decorticating shaft. The decorticating shaft was made with mild steel shaft of 28mm, it was machined on the lathe to 25mm and then joined to mild steel flanges which holds the decorticating bars.

2.5.4. Decorticating Screen

The screen was made to form the base of the concave drums; the aperture size was based on the geometric mean diameter of the castor seed. The screen was measured and cut to size then it was drilled to 16mm aperture.

2.5.5. Fan

The fan is also a standard part purchased. The blade of a centrifugal fan purchased and incorporated into a cylindrical housing to do the cleaning action.

2.5.6. Aluminum Spike Tooth

The spike tooth was attached to the flange attached to the shaft with the aid of bolts and nut fastening in an adjustable manner to allow variable clearance setting between the drum and the screen.

2.6. Principle of Operation of the Machine

The machine is first coupled together by bolt and nut fastening. A 5hp electric motor is mounted to the machine and a belt drive arrangement transfers power to the machine. The electric motor is connected to a 240V A.C power source and the switch is put on. The castor is fed into the machine through the feeding hopper from where it comes in contact with the rotary spikes which breaks the pod and allows the kernel out after which it falls by action of gravity through the sieve. The castor kernel and shell then comes in contact with the stream of air from the blower which separates the kernel from the shell by the difference in terminal velocity. The shell is blown out via the chaff outlet while the castor drops down and is collected at the seed outlet.

2.7. Cost Analysis

Table 1 Bill of Engineering Measurements and Evaluation (BEME)

S/N	Material Specification	Quantity	Rate(₦)	Amount (₦)
1.	2.5mm mild steel sheet	½ sheet	30,000.00	15,000.00
2.	50 x 50 x 5mm 'L' iron	2½ length	6500.00	16,250.00
3.	Aluminum Spike	3	4,000.00	12,000.00
4.	30mm shaft	1.3m	10,000.00	13,000.00
5.	M10 Bolts And Nuts	2dozen	600.00	1,200.00
6.	Pillow bearing	4	3,500.00	14,000.00
7.	200mm pulley	1	4,000.00	4,000.00
8.	50mm pulley	1	2,000.00	2,000.00
9.	5hp motor	1	50,000.00	50,000.00
10.	Gl2 electrode	1 packet	3,000.00	3,000.00
11.	Cutting disc	1	1,000.00	1,000.00
12.	Grinding disc	1	1,000.00	1,000.00
13.	Machining	lump	12,000.00	12,000.00
14.	Painting	lump	8,000.00	8,000.00
15.	Workmanship	lump	15,000.00	15,000.00
	Total			167,450.00

2.8. Performance Evaluation

2.8.1. Sourcing of Experimental Materials

Castor (*Ricinus communis L.*) was purchased from a local farmer in share village, Ifelodun Local Government Area, Kwara State, Nigeria.

2.8.2. Sample Preparation

The Castor (*Ricinus communis L.*) was sorted to remove the foreign materials and unwholesome pods. The Castor was sundried for five days to reduce the moisture content and then kept in the crop processing laboratory before the experiment. The moisture content of the castor was determined using oven drying method. The castor was then divided into the various sizes according to the design layout generated. The moisture content was adjusted accordingly based on the layout and put in an air tight polythene bag so as to prevent change in the moisture content. The samples were stored in the fridge until the experiment is ready to be run.

2.8.3. Experimental Procedure

The sample prepared was fed into the machine via the feeding hopper while the electric motor was used to power the machine. The castor is fed into the machine through the feeding hopper from where it comes in contact with the rotary spikes which breaks the pod and allows the kernel out after which it falls by action of gravity through the sieve. The castor kernel and shell then comes in contact with the stream of air from the blower which separates the kernel from the shell by the difference in terminal velocity. The shell is blown out via the chaff outlet while the castor drops down and is collected at the seed outlet. The different samples collected were then sorted into the categories of whole seed, broken seeds and chaff mixed with seed. They were later weighed and recorded accordingly.

2.8.4. Output Parameters

The output parameters were determined using the following expressions as given below;

Shelling capacity (kg/h) = $S_c = \frac{m_s}{T} \times 3.6$

Breakage (%) = $B = \frac{W_b}{m_s} \times 100$

Shelling Efficiency (%) = $S_e = 100 - B$

Where;
m_s is mass of castor seeds collected
W_b is mass of broken seeds collecte
T is time taken for the sample to be sieved

2.8.5. Instrumentation

The following materials and instruments were used in the course of this study.

- Digital weighing scale: A digital weighing scale with an accuracy ±0/01g was used to measure the samples for the experiment.
- Digital tachometer: A contact/non-contact digital tachometer with accuracy ± (0.05% + 1 digits) was used to measure the speed of the machine during operation.
- Laboratory Oven: It is used for drying of groundnut in other to determine the moisture content. An electric digital laboratory oven NL-9023A was used for the study.

2.9. Statistical Analysis

The statistical analysis used for this study is analysis of variance (ANOVA) using Design Expert Software version 6.08. A 3D plot is also used to describe the dependent variables with respect to the independent variables.

3. Results

The summary of the result from the test of the motorized castor decorticator were presented in Table 2

Table 2 Summary of Result Obtained from the Motorized Castor Decorticator

Run	Feed Rate	Machine speed	Moisture content	Shelling capacity	Breakage	Shelling efficiency
	(Kg)	(rpm)	(%)	(Kg/h)	(%)	(%)
1	1	900	6	247.8	7.5	92.5
2	1	800	7	231.7	5.6	94.4
3	1.5	900	7	276.4	9.8	90.2
4	1	1000	7	230.6	7.1	92.9
5	1	900	8	183.8	20.8	79.2
6	1.5	800	6	330.2	9	91
7	1.5	900	7	276.4	9.8	90.2
8	1.5	800	8	296.6	30.8	69.2
9	2	900	8	267.1	27.2	72.8
10	1.5	1000	8	271.4	22.1	77
11	1.5	900	7	276.4	9.8	90.2
12	1.5	900	7	276.4	9.8	90.2
13	2	800	7	310.8	11	89

14	2	900	6	500.1	7.4	92.6
15	1.5	1000	6	268	5.5	94.5
16	1.5	900	7	276.4	9.8	90.2
17	1.5	900	7	276.4	9.8	90.2
18	2	1000	7	317	8.5	91.5

4. Discussion

The result obtained from the experimental runs of the machine shows that maximum shelling capacity of 500.1Kg/h was obtained at a feed rate, machine speed and moisture content of 2Kg, 900rpm and 6%$_{wb}$ respectively and minimum shelling capacity of 183.8Kg/h was obtained at a feed rate, machine speed and moisture content of 1Kg, 900rpm and 8%$_{wb}$ respectively. A maximum shelling efficiency of 94.5% was obtained at a corresponding feed rate, machine speed and moisture content of 1.5Kg, 1000rpm and 6%$_{wb}$ respectively. While the minimum shelling efficiency of 69.2% was obtained at a corresponding feed rate, machine speed and moisture content of 1.5Kg, 800 and 8%$_{wb}$ respectively. The result showed that the three factors considered were relevant to the performance of the machine.

4.1. The Effect of Variables on the Shelling Capacity of the Machine

Table 3 shows the analysis of variance (ANOVA) for the Shelling Capacity of the Motorized Castor Decorticator

Table 3 Analysis of Variance (ANOVA) for the Shelling Capacity of the Motorized Castor Decorticator

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	55199.72	9	6133.303	3.612058	0.0422	Significant
A-Feedrate	31387.65	1	31387.65	18.48499	0.0026	
B-Machine speed	846.6613	1	846.6613	0.49862	0.5002	
C-Moisture content	13382.48	1	13382.48	7.881283	0.0229	
AB	13.3225	1	13.3225	0.007846	0.9316	
AC	7140.25	1	7140.25	4.205075	0.0744	
BC	342.25	1	342.25	0.20156	0.6654	
A^2	19.93705	1	19.93705	0.011741	0.9164	
B^2	157.7461	1	157.7461	0.092901	0.7683	
C^2	1954.261	1	1954.261	1.150914	0.3146	
Residual	13584.06	8	1698.008			
Lack of Fit	13584.06	3	4528.021			
Pure Error	0	5	0			
Cor Total	68783.79	17				

*Significant at p≤0.05. A=feed rate, B= machine speed, C= moisture content

The p-values of the terms A (0.0026), C (0.0229) show that the models are significant at $p \leq 0.05$ while B, A^2, B^2, C^2, AB, AC, BC are not significant with p-value above 0.05. Among all the terms in table 3, it was observed that A (feed rate) has the highest influence on the regression model with f-value 18.48499 followed by C (moisture content) with f-value 7.881283. This is an indicator that the feed rate greatly affects the shelling capacity of the machine followed by the moisture content of the sample.

Figure 3, 4 and 5 shows the interactive effect of machine speed and feed rate; moisture content and feed rate; moisture content and machine speed respectively on the shelling capacity of the machine.

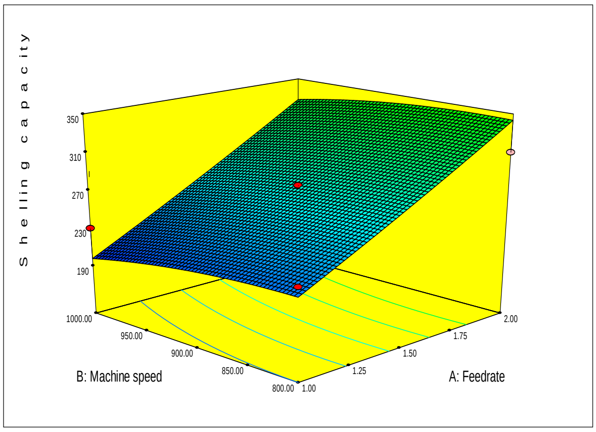

Figure 3 3D Surface plots showing the effect of machine speed and feed rate and their interactive effect on the shelling capacity of the machine

The 3D surface plot in figure 3 depicts the interaction between machine speed and feed rate which in turn is used to study the effect on the shelling capacity of the machine. It could be seen from the graph that an increase in the machine speed leads to a slight increase in the shelling capacity of the machine while an increase in feed rate leads to a sharp increment of the shelling capacity of the machine. This indicates the feed rate has a great influence on the output capacity of the machine.

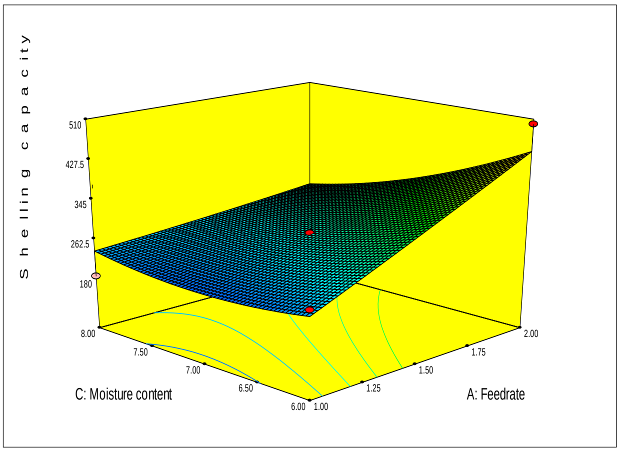

Figure 4 3D surface plots showing the effect of moisture content and feed rate and their interactive effect on the shelling capacity of the machine

The 3D surface plot in figure 4 depicts the interaction between moisture content and feed rate which in turn is used to study the effect on the shelling capacity of the machine. It could be seen from the graph that an increase in the moisture content from 6%$_{wb}$ to 8%$_{wb}$ leads to a slight increase in the shelling capacity of the machine while an increase in feed rate from 1kg to 2kg leads to a sharp increment of the shelling capacity of the machine.

The 3D surface plot in figure 5 depicts the interaction between moisture content and the machine speed which in turn is used to study the effect on the shelling capacity of the machine. It is observed that an increase in the moisture content from 6%$_{wb}$ upward continue to increase the output capacity until it reaches 7%$_{wb}$ where a continuous increase in the moisture content leads to a decrease in the output capacity while a continuous increase in the machine speed from 800rpm to 1000rpm increased the output capacity. This is an indication that the machine speed has a great effect on the output capacity of the machine.

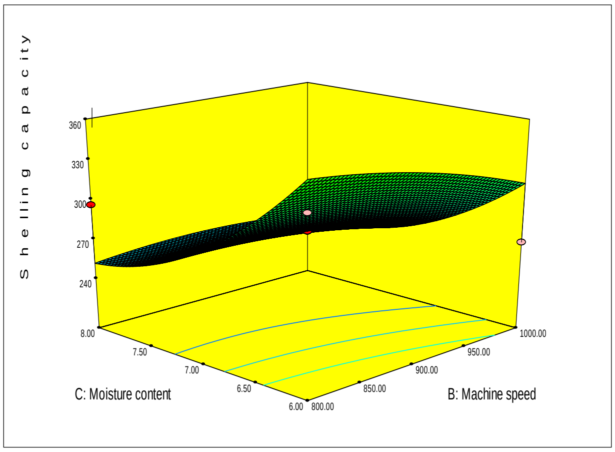

Figure 5 3D surface plots showing the effect of moisture content and speed and their interactive effect on the shelling capacity of the machine

4.2. The Effect of Variables on the Shelling Efficiency of the Machine

Table 4: shows the analysis of variance (ANOVA) for the shelling efficiency of the Motorized Castor Decorticator

Table 4 Analysis of Variance (ANOVA) for the Shelling Efficiency of the Motorized Castor Decorticator

	Sum of		Mean	F	p-value	
Source	**Squares**	**df**	**Square**	**Value**	**Prob > F**	
Model	962.6069	9	106.9563	47.28005	< 0.0001	significant
A-Feedrate	21.45125	1	21.45125	9.482525	0.0151	
B-Machine speed	18.91125	1	18.91125	8.359718	0.0202	
C-Moisture content	655.22	1	655.22	289.64	< 0.0001	
AB	4	1	4	1.7682	0.2203	
AC	10.5625	1	10.5625	4.669153	0.0627	
BC	4.6225	1	4.6225	2.043376	0.1907	
A^2	10.48364	1	10.48364	4.634292	0.0635	
B^2	0.174545	1	0.174545	0.077158	0.7882	
C^2	243.8209	1	243.8209	107.781	< 0.0001	
Residual	18.0975	8	2.262188			
Lack of Fit	18.0975	3	6.0325			
Pure Error	0	5	0			
Cor Total	980.7044	17				

*Significant at p≤0.05. A=feed rate, B= machine speed, C= moisture content

The p-values of the term A (0.0151), B (0.0202), C (< 0.0001), C ^{2}(< 0.0001) show that the models are significant at $p \leq 0.05$ while AB, AC, BC, A^2, B^2 are not significant with p-value above 0.05. Among all the terms in table 4, it was observed that A (feed rate) has the highest influence on the regression model with f-value 9.482525. This is an indicator that the feed rate greatly affects the shelling efficiency of the machine.

Figure 6, 7 and 8 shows the interactive effect of machine speed and feed rate; moisture content and feed rate; moisture content and machine speed respectively on the shelling efficiency of the machine.

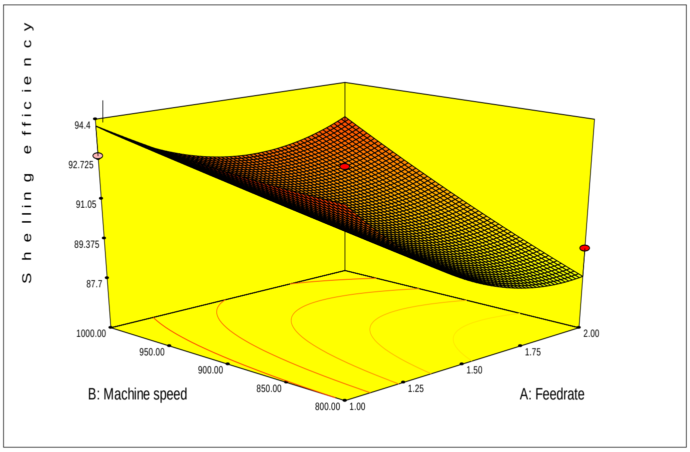

Figure 6 3D surface plots showing the effect of machine speed and feed rate and their interactive effect on the shelling efficiency of the machine

The 3D surface plot in figure 6 depicts the interaction between machine speed and feed rate which in turn is used to study the effect on the shelling efficiency of the machine. It was observed that an increase in the machine speed from 800rpm to 1000rpm resulted in a sharp increase in the shelling efficiency of the machine which could be attributed to the rate at which the seeds are being shelled while an increase in the feed rate from 1 Kg to 1.5Kg reduced the shelling efficiency which could be due to the fact that more seeds are damaged under this condition.

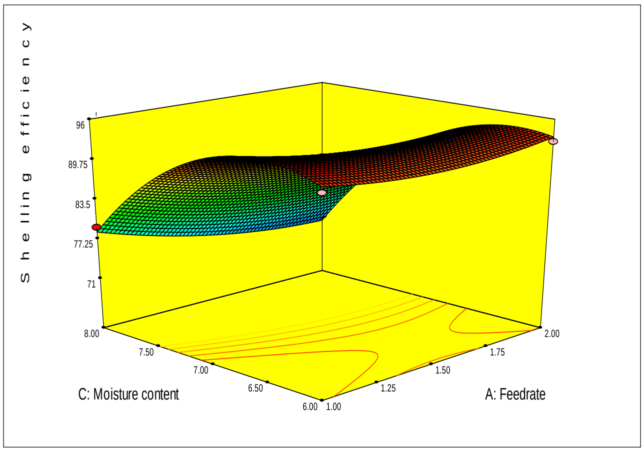

Figure 7 3D surface plots showing the effect of moisture content and feed rate and their interactive effect on the shelling efficiency of the machine

The 3D surface plot in figure 7 depicts the interaction between moisture content and feed rate which in turn is used to study the effect on the shelling efficiency of the machine. It was observed that an increase in the feed rate from 1 Kg to 2Kg has a slightly linear effect on the shelling efficiency while an increase in the moisture content of the sample from 6%$_{wb}$ to 7%$_{wb}$ resulted in a sharp increase in the shelling efficiency of the machine and later reduced at a moisture content above this level.

The 3D surface plot in figure 8 depicts the interaction between moisture content and machine speed which in turn is used to study the effect on the shelling efficiency of the machine. It was observed that an increase in the moisture content of the sample from 6%$_{wb}$ to 7%$_{wb}$ resulted in a sharp increase in the shelling efficiency of the machine and later reduces it at a higher moisture content. This indicates that the moisture content should not exceed 7%$_{wb}$ for optimum performance of the machine. Also, an increase in the machine speed from 800rpm to 1000rpm lead to a slight increase in the shelling efficiency of the machine.

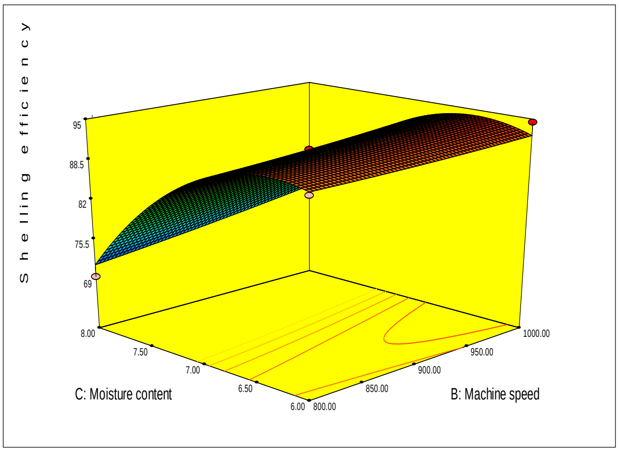

Figure 8 3D surface plots showing the effect of moisture content and speed and their interactive effect on the shelling efficiency of the machine

5. Conclusion

A motorized Castor (*Ricinus communis L.*) seed decorticator was designed, fabricated and evaluated for performance. Based on the results obtained from the tests, the following conclusions can be drawn, the machine has a maximum shelling efficiency and minimum breakage of 94.5% and 5.5% respectively at a feed rate, machine speed and moisture content of 1.5Kg, 1000rpm and $6\%_{wb}$ respectively. The maximum shelling capacity of 500.1kg/h at a feed rate, machine speed and moisture content of 2Kg, 900rpm and $6\%_{wb}$ respectively. Finally, the machine is therefore observed to perform best at a feed rate, speed and moisture content of 2Kg, 900rpm and $6\%_{wb}$ respectively with a shelling capacity, breakage and shelling efficiency of 500.1Kg/h, 7.4% and 92.6% respectively.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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