

Development of an indigenous maize de-husking machine

Babajide Saheed Kosemani^{1*}, Ayoola Abiola Babalola¹, Titus Adeyinka Ilori²

(1. Agricultural Engineering Department, College of Engineering and Environmental Studies, Olabisi Onabanjo University, P.M.B 2002, Ago Iwoye, Ogun State, Nigeria ;

2. Federal College of Agriculture, School of Engineering, Department of Agricultural and Bio-Environmental Engineering, P.M.B 5029, Ibadan, Oyo State, Nigeria)

Abstract: Maize post-harvest operation most especially de-husking and shelling are still a challenge in low developing countries with more efforts required in advancing the operations. The development of a maize de-husking machine was undertaken for de-husking process in a farm settlement. The developed machine used shearing action developed by a rubberized roller to achieve the maize de-husking operation. The main feature of maize de-husking machine majorly consists of four (4) basic units including, feeding unit, de-husking unit, power transmission, discharge outlet. The de-husking unit includes the rubberized and conveyor rollers and the top cover. The rubberized rollers were made from 15mm thick rubber extracted from a used tyre. The experimental treatments included two level of maize moisture (14% and 16%), three level of roller speeds (400, 500 and 600 rpm) and three level of feeding rate (2, 4 and 6 kg). The measure variable in the evaluation of the machine included de-husking capacity, de-husking efficiency, and grain loss. The factors were selected to investigate the influence of the machine variables, crop parameters and their interaction on the machine performance. The result of the performance evaluation of the machine showed that the highest de-husking capacity, efficiency and losses were 340 kg hr⁻¹, 89.94% and 9.89%, respectively. The developed maize de-husking machine can be adopted for commercial processing of maize.

Keywords: de-husking, maize, post-harvest operation, appropriate technology.

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1 Introduction

Maize also known as corn is a staple largely produced and consumed globally. In 2021, maize annual world production including substantive areas in the sub-Saharan Africa stands at approximately 197 million hectares making it one of the leading crops

globally cultivated and second most cultivated cereal. The dry grain, production globally was 1,163 million tons (García-Lara and Serna-Saldivar, 2019; FAO, 2021). In Africa, the total maize harvested annually was 43 million hectares amounting to about 89.3 million. Currently, United States of America followed by China are the largest maize producer in the world, her production stands at 360,252 thousand tonnes that represent 34.28% of the total world production. South Africa followed by Nigeria are the largest producer in Africa. USDA and FAO published that Nigeria's annual production of maize stands between 11.6 and 12.6 million metric tons 2021 making Nigeria the

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***Corresponding author: Babajide Saheed Kosemani,** Agricultural Engineering Department, College of Engineering and Environmental Studies, Olabisi Onabanjo University, P.M.B 2002, Ago Iwoye, Ogun State, Nigeria. Email: indizjiddy.bk@gmail.com.

Africa's second largest maize producer and the world's 14th largest (FAO, 2021; Statista, 2022).

Maize contains high nutritional value like carbohydrates (72%), vitamins A, vitamins C, vitamins E, vital minerals, and has 10% protein (Mboya et al., 2011; Gwartz and Garcia-Casal, 2014; Ijarotimi, 2022). The fiber and calories content are also high, containing (8.5%) fiber, (4.8%) oil, (3.0%) sugar and (1.7%) ash which are excellent sources of energy (Mboya et al., 2011; Oyewole et al., 2020).

Due to its nutritional values and ease of production, maize has become an important grain globally and its consumption rate is increasing at a faster rate every day due to its roles in agri-food system and security (De Groote et al., 2020). The Federal Government of Nigeria restrictions on maize importation has resulted in rising demand for locally. In Nigeria between 2021 and 2023, the annual average consumption rate of maize for both human and animal is between 12 and 15 million metric tonnes (PwC, 2021). However, local production has for years lagged consumption, a situation that fuelled importation.

The produced maize was consumed by several families as staples and used as raw material in certain products in brewery, feeds mills, bakery, and pharmaceutical industries (Ogunniyi, 2011; Wossen et al., 2023). Majority of the maize produced in Nigeria is consumed primarily by livestock feed makers. Animal feeds, particularly aquaculture and feeds, account for roughly 45.5% of maize produced in the country. Nigerians consumed maize alone or combined as food or snacks with other food materials (Kosemani and Bamgboye, 2021). It is prepared as a fermented cereal porridge known as pap or ogi, corn meal (tuwo masara), corn drink (kunu or akamu), corn snack (nakia, elekute akple, ajepasi, aadun and donkwa) (Abdulrahman and Kolawole, 2006; Olaniyan, 2015). It is processed into variety of food products and raw materials, such as corn flour, corn syrup, sweeteners, maize oil, drinks, and ethanol

(Ranum et al., 2014). Corn is beneficial as a medicine in addition to being a key source of raw material in industries. It is a powerful anti-oxidant that protects the body from the harmful effects of free radicals, which cause cellular damage. It has the potential to ameliorate pain (Owoyele et al., 2010). Maize also aids in the production of excellent sex-related hormones particularly in males with erectile dysfunction. Potassium in corn ilk helps in increasing the rate of urine excretion (diuretic). In addition, corn silks are used in treating infected urinary tract and kidney stones (Lans, 2006; Sahib et al., 2012).

Despite the economic importance of maize as a human food, animal feed, and raw materials, ineffective management of its post-harvest operation has reduced the quality and quantity of the produce/products, which resulted to losses of income and among producers, processors, and marketers. In Nigeria, post-harvest losses in maize grain production was found to be around 15%-20%. Badly executed maize harvesting and post-harvest operations, in addition to lack of sufficient processing and marketing facilities, were the reasons of post-harvest losses in maize (Atanda et al., 2011; Kumar and Kalita, 2017).

The maize processing majorly involved harvesting, drying de-husking, shelling, storage and milling.

Maize post-harvest operation most especially de-husking and shelling are still a challenge in low developing countries with more efforts required in advancing the operations (Uttam et al., 2018). De-husking is the removal of the outer sheath from ear heads without seed damage is mostly performed by farm women (Singh and Singh, 2010; Oriaku et al., 2014). It is carried out after harvesting on the farm field or within the storage environment before storage in silos or grain barns (Mali et al., 2015).

Using appropriate mechanization technologies to process maize into quality form would not only prolong the useful life of the products but also increase the net profit of the farmers. Farmers would

be able to enjoy their financial benefits from maize production (Nwakaire et al., 2011). Many indigenous maize shellers are currently available for maize shelling, but there are no locally developed de-husking machine that can be adopted by the maize farmers. Many farmers continue to de-husk maize manually using locally fabricated small hand tool by the local artisans. Using these tools are strenuous, time consuming and resulted to low output. A worker can only de-husk 8 to 15 kg of maize an hour (Patil, et.al, 2014). Few farmers de-husked their maize using imported de-husking machine, which is costly to purchase, difficult to operate and maintain. Many large-scale commercial farmers who could not afford to buy the de-husking machine resulted to hiring from those who could afford to buy the imported machine (Takawira-Nyakuchena and Mushiri, 2020). In addition, other farmers prefer hand maize dehusking, which is arduous, time-consuming, and only suitable for small-scale maize production.

Previous researchers, such as Mudgal et al. (1998), Singh (2013), Takawira-Nyakuchena and Mushiri (2020) and worked on developing designs to solve maize de-husking concerns. Mudgal et al. (1998) developed a pedal operated maize husker-sheller in an attempt to mechanize the process. Singh (2013) revealed that, while hand-operated maize dehusker-shellers are suitable for farm women, they are difficult to use, gives very low efficiency and low output. Adesokan et al. (2019) constructed design, construction and carried out performance evaluation of low-cost maize dehusker-sheller in Nigeria, the de-husking efficiency obtained after the performance evaluation was low. The de-husking efficiency obtained when operating the machine at at speed 49.1, 32.2 and 30.2 m s⁻¹ were 58.67%, 57.00% and 54.16%, respectively.

Therefore, there is need for appropriate indigenous technology to solve the problem of de-husking in post-harvest maize production process. The main

objective of this study was to develop an indigenous maize de-husking machine.

2 Materials and methods

2.1 Development of maize de-husking machine

The maize de-husking machine was developed for removing the sheath of maize using locally available materials during 2022 planting season. The machine was designed and fabricated between August 2022 and March 2023 at Agricultural and Bio-environmental Engineering workshop, Federal College of Agriculture, in Ibadan southwest, Nigeria at latitude 7.3792° N, and longitude 3.8444° E. Important physical and mechanical properties of matured maize were measured in order to design various components of the machine de-husking machine.

2.1.1 Design Considerations and Calculations

Parameters which include roller speed, length of de-husking area, feeding rate and maize grains moisture content which affect the performance of the de-husking machine were established after knowing the physical properties of the maize grains and review of literatures (Alonge and Kosemani, 2011). General design considerations include low cost of machinery, simplicity of design high productivity, portability and safety and convenience of control.

2.1.2 De-husking rollers

The de-husking speed of the de-husking rollers were determined using Equation 1 (Olaoye and Ayelade, 2019).

$$s_d = \frac{V \times 60}{\pi D} \quad (1)$$

where,

s_d = De-husking speed of the de-hulling rollers (rps)

D = Diameter of de-husking rollers (m); and

V = Peripheral speed of the de-husking rollers (m s⁻¹).

The diameter of the de-husking roller was chosen as 65 mm.

The speed obtained for the de-husking rollers was 542 mm.

2.1.3 Length of de-husking rollers

The length of de-husking rollers was determined using Winkler equation as shown in Equation 2 (Dange et al., 2021).

$$F_r = \frac{0.05 \times N_p \times n \times L_s \times R}{1 + \delta} \quad (2)$$

where,

F^R = Feed rate (kg s⁻¹);

N_p = Pitch number;

n = Speed of shaft (ms⁻¹);

L_s = Shaft length (m);

k = 0.17-0.32 Newton per meter length of shaft;

and

$$\delta = 1/\delta = (0.67).$$

Let $k=0.25$ N m⁻¹, the calculated de-husking roller length after rearranging the parameters and considering 1.5 times of factor of safety was 900 m.

2.1.4 Power requirement of the machine

The power requirement (P) by the de-husking section include power required to de-husking the maize and power for driving the rollers. The equation used to calculate the power requirement is as shown in Equation 3 (Olaoye and Ayelade, 2019).

$$P_d = F \times n \quad (3)$$

where,

P_d = Power required for de-husking (W);

F = De-husking force (N) = 23.26 N;

n = Peripheral speed of the de-husking rollers (m s⁻¹).

The power required obtained from the calculation was 39.77 W.

To determine the power needed to drive the rollers, Weight of the roller was calculated using Equation 4.

$$W_r = V \times \rho \times d \quad (4)$$

Where,

W_r = Weight of the roller (kg);

V = Volume of the roller (m³);

ρ = density of mild steel (kg m⁻³).

Acceleration to gravity = 9.91 m s⁻¹, the weight obtained for the roller was 526.44 N.

The torque was calculated using Equation 5 (Alonge and Kosemani, 2011).

$$T = W_r \times R \quad (5)$$

where,

R = Radius of the roller (m);

T =Torque (N m).

The calculated value of the toque on the de-husking rollers was 14.25 N m. Consequently, the power required for driving the rollers was calculated as 404.26 W for one roller and 1617.06 W for the four rollers in the de-husking section of machine.

The total power required to drive the machine was 1657.37 Kw. Considering factor of safety and availability, 2.24 kW electric motor was used (Chilur and Kumar, 2018).

2.1.5 The hopper design

The selected shape for the de-husking machine's hopper was trapezoidal shape. The top wide of the hopper was calculated using Equation 6 (Adedeji et al., 2020).

$$H_{tw} = 2X + B \quad (6)$$

Where, H_{tw} =Width of the top section (mm);

B =Width of the bottom section (mm); and

X =Side length of the top section of the hopper (mm).

Side length of the top section of the hopper was obtained using a coefficient of sliding friction of 30° for maize grains. The coefficient of sliding friction (μ_s) was determined using expression shown in Equation 7 (Altuntas and Yildiz, 2007).

$$\mu_s = \tan\phi = \frac{h}{b} \quad (7)$$

where,

h =Height of inclination (m);

b = Base of inclination (m);

ϕ =Angle of inclination.

The value obtained for width of the top section

was 357 mm.

2.1.6 Volumetric capacity of the hopper

The volumetric capacity of the hopper was obtained using Equation 8 (Olaoye, 2011)

$$V_v = \frac{G_c}{\rho_v} = A_b \times L \quad (8)$$

where,

G_c = Gravimetric capacity (kg);

ρ_v = Nominal density of the plant material in the de-husking chamber (kg mm⁻³);

A_b = Base area (mm²);

L = Length of hopper (mm).

The calculated volumetric capacity obtained was 14,126700 mm³.

2.1.7 Design of the main shaft.

The shaft was designed using the combined twisting moment and bending moment. The diameter of the shaft was calculated using Equation 9 given by Khurmi and Gupta (2005).

$$T_m = (M^2 + T^2) = \pi \times S_s \times d^3 / 16 \quad (9)$$

T_m = Shaft twisting moment;

M = Maximum bending moment;

S_s = Allowable shear stress;

T = Torque transmitted by the shaft.

The calculated diameter for the main shaft was 28.99 m but a shaft of diameter 30mm was selected due to availability.

2.1.8 Design of frame

A rectangular shaped frame was designed to support both the de-husking chamber and power transmission unit of the machine using Equation 10. If the beam is simply supported and under a uniformly distributed load, the maximum bending deflection Δ , is given by Equation 10 (Khurmi and Gupta, 2005).

$$\Delta = \frac{5wl^4}{384EI} \quad (10)$$

where,

W = Load per unit (N mm⁻¹) = 1706.05 N mm⁻¹;

l = Span (mm) = 1200 mm;

E = Modulus of elasticity (N mm⁻²) = 206,000 N

mm⁻².

The deflection is usually limited to $\frac{l}{360}$.

The young modulus for mild steel is 206,000 N mm⁻².

$$\Delta = \frac{l}{360} \quad (11)$$

The preferred size of the frame on the BS 4848 part: 1972 after the design was 50 × 50 × 4 mm M S angle iron selected. The frame was made with a beam length and breadth of 1200 mm and 465 mm, respectively and column length of 600 mm. The squareness of the frame members was ascertained during assembly before it was welded. The machine's whole surface was painted to avoid corrosion and rust.

2.2 Maize de-husking machine components

The maize de-husking machine consists of four basic units.

- (1) The feeding unit;
- (2) Dusking unit;
- (3) Transmission;
- (4) Discharge outlet.

2.2.1 The feeding unit

This is the component of de-husking machine where the cob is felled into the machine. It is trapezoidal in shape and made from 3 mm thick mild steel sheet. The height of this unit is 230 mm with a top opening of 525 mm by 360 mm and bottom opening of 360 mm by 360 mm. it is made from 2 mm mild steel plate.

2.2.2 De-husking unit

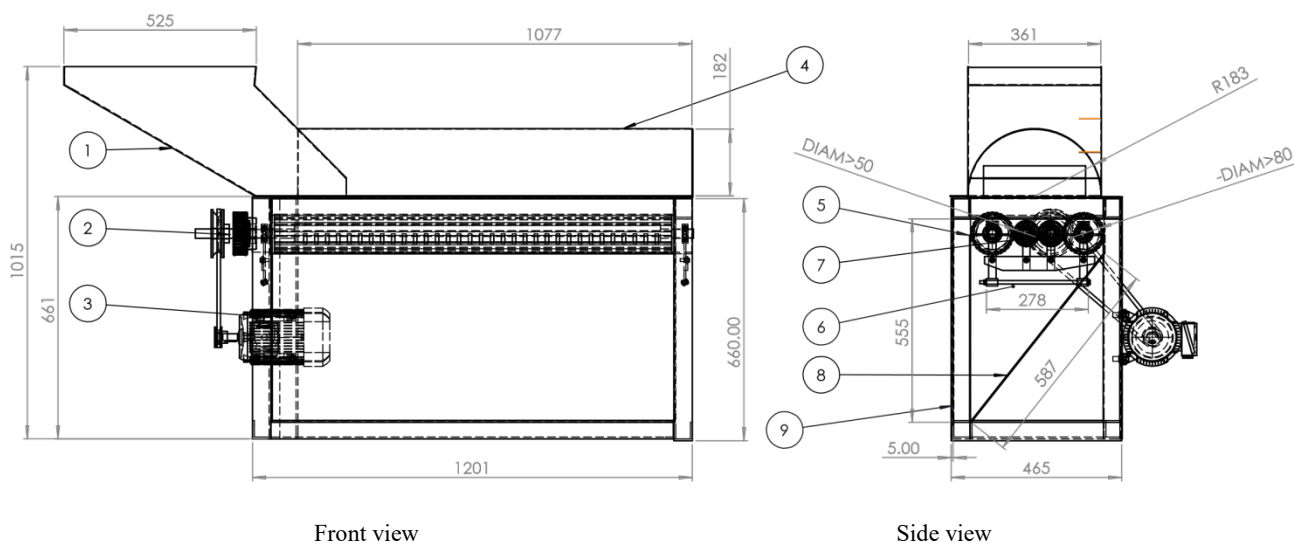
The de-husking unit consist of two sets of rubberized rollers with spine, two sets of screw rollers and a top cover. The top cover was a semi- cylindrical component made form 2 mm mild steel which cover the rollers and where the de-husking take place. The rubberized rollers were 80 mm diameter and 1020 mm in length. The rollers were made from 50 mm, 3 mm thick galvanised pipe rapped with 15 mm thick rubber and mounted on a 30 mm diameter sold shaft which

was flanged at both ends. The rubberized rollers were made from 15 mm thick rubber extracted from a used tyre. The rubberised rollers were designed to rotate in anti-clockwise against the screw shaft. The screw shafts are made from diameter of 50 mm and is 1020 mm length. The worm was made from 10 mm diameter rod are welded to the shaft in a spiral form at

pitch of 65 mm across the length of the shaft.

2.2.3 Power transmission.

The machine is powered by 2.25 kW, 1450 rpm electric motor through a pulley- belt transmission, the diameter of the driver pulley was 76 mm while the diameter of the driven was 204 mm. The driven pulley was mounted on of the rubberized roller.



No/off	Component
1.	Hopper
2.	Gear
3.	Electric motor
4.	Top cylinder
5.	Rubberized roller
6.	Adjuster
7.	Conveyor roller
8.	Sheath outlet
9.	Frame

Figure 1 Developed maize de-husking machine

2.2.4 Discharge outlet

There are two outlets on the de-husking machine including the outlet for the maize and the sheath. The sheath outlet was made from 2 mm mild steel sheet slanted at angle 28° to the horizontal. It was 1100 mm length and the slanted breath was 587 mm. The de-husked maize outlet was equally made for a 2 mm mild steel sheet metal. It is 300 by 150 mm opening on the top cover where the maize de-husked are collected.

2.3 Performance evaluation of the maize de-husking machine

Partially dried maize was collected from the

Federal College of Agriculture research farm. The collected maize was subjected to two level of dryness, 14% and 16%. Three roller speeds including 41.8, 52.3 and 62.8 m s⁻¹ were selected for the purpose of testing the performance of the machine and confirmed using a sensitivity tachometer. The three level of feed rate was used by feed the hopper at 2, 4, 6 kg min⁻¹. The maize de-husking machine was evaluated using standard procedure for combining various treatments and the parameters were determined following PAE Standard 221 (2005). Performance indices including de-husking capacity, de-husking efficiency, grain loss as presented in

Equations 12 to 14 were used in evaluating the performance of the maize de-husking machine (PAE, 2005).

$$De-husking\ capacity\ (kg\ hr^{-1}) = \frac{M_1}{T_1} \quad (12)$$

Where,

M_1 = mass of the maize (kg); and

T_1 = time taken to de-husk (hr).

$$De-husking\ Efficiency\ (\%) = \frac{M_2}{M_3} \times 100 \quad (13)$$

Where,

M_2 = total mass of husks removed by the machine (kg); and

M_3 =total mass of the husk fed into the machine (kg).

$$Grain\ losses\ (\%) = \frac{M_4}{M_5} \times 100 \quad (14)$$

Where,

M_4 = mass collected at the husk outlet (kg); and

M_5 = mass of maize collected at the husk outlet + mass of de-husked maize (M_1)(kg).

2.4 Experimental design

The experimental design used in evaluating the performance of the maize de-husking machine was three factors at three level for rollers speed and feeding rate, and two level of maize grains moisture content which was $3 \times 3 \times 2$ factorial experiment with three replicates as shown in Table 1.

Table 1 Experimental design

Independent Parameters	Levels	Dependent parameters	Replicates
Moisture content	MO_1 (14%)	Efficiency	3
	MO_2 (16%)	Grain loss	
Feed rate	Fr_1 (2 kg)	De-husking capacity	
	Fr_2 (4 kg)		
	Fr_3 (6 kg)		
Speed	S_1 (400 rpm)		
	S_2 (500 rpm)		
	S_3 (600 rpm)		

2.5 Statistical analysis

The data collected was subjected to descriptive

analysis and analysis of variance was done. The Duncan Multiple Range Test (DMRT) was used to determine the means difference between significant factors.

3 Results and discussion

The developed maize de-husking machine using local sources materials is as shown in Figure 2. The mean for the different measured parameter including machine capacity, de-husking efficiency and seed losses is as shown in Table 2. The summary of the results obtained for the performance evaluation of the de-husking are as shown Table 3.

3.1 De-husking capacity

The results obtained from the measured samples for de-husking capacity during the performance evaluation of the machine showed that the highest de-husking capacity was $340\ kg\ hr^{-1}$ while the minimum was $250\ kg\ hr^{-1}$. It can be deduced from Table 3 for machine capacity that $F_r, M_o, S_p, F_r \times S_p, F_r \times M_o, S_p \times M_o$ and $F_r \times M_o \times S_p$ are significant at 5% level. The results obtained using DMRT as shown in Table 4 showed that feeding rate and roller speed at various levels of operation are statistically different from one another. The trend of the de-husking capacity versus roller speed is presented in Figure 3. It can be deduced Figure 3 that de-husking capacity increases with increase in roller speed. The pattern of the de-husking capacity versus feeding rate is presented in Figure 4. It can be deduced from Figure 4 that de-husking capacity increases with increase in feeding rate.

3.2 De-husking efficiency

The results obtained from the measured samples for de-husking efficiency during the performance evaluation of the machine showed that the highest de-husking efficiency was 89.94% while the minimum was 67%. It can be deduced from Table 3 for machine capacity that $F_r, M_o, S_p, F_r \times S_p, F_r \times M_o, S_p \times M_o$ and $F_r \times M_o \times S_p$ were significant at 5% level. The results obtained using DMRT as shown in Tale 4 showed that

feeding rate and roller speed at various levels of operation are statistically different from one another. The trend of the de-husking efficiency versus roller speed is presented in Figure 5. It can be deduced from Figure 5 that de-husking efficiency decreases with increase in roller speed. The pattern of the de-husking efficiency versus roller speed is presented in Figure 6. It can be deduced from Figure 6 that de-husking efficiency decreases with increase in feeding rate.

3.3 Grain losses

The results obtained from the measured samples for grain losses during the performance evaluation of the machine showed that the highest grain loss was 9.89% while the minimum was 3.00%. It can be deduced from Table 3 for grain losses that F_r , M_o , S_p , $F_r \times S_p$, $F_r \times M_o$, $S_p \times M_o$ and $F_r \times M_o \times S_p$ are significant at 5% level. The trend of the grain losses

versus roller speed is presented in Figure 7. It can be deduced from Figure 7 that grain losses increases with increase in roller speed. The pattern of the grain losses versus roller speed is presented in Figure 8. It can be deduced from Figure 8 that grain losses increases with increase in feeding rate.

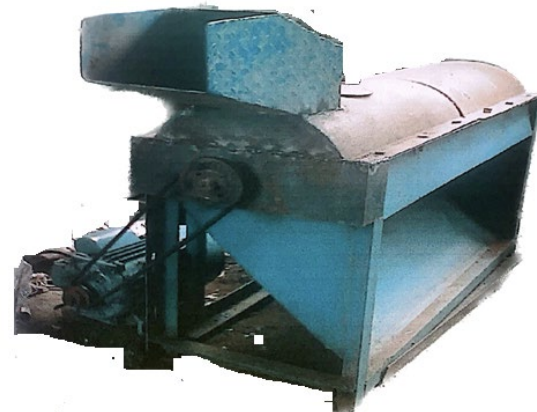


Figure 2 The developed maize de-husking machine

Table 2 Results of means for different measured parameters

Moisture (%)	Feeding rate (kg)	Speed (rpm)	Capacity (kg hr ⁻¹)	De-husking efficiency (%)	Seed losses (%)
<i>M_{o1}</i>	<i>Fr₁</i>	<i>Sp1</i>	250.33	83.34	5.63
		<i>Sp2</i>	270.33	87.28	6.64
		<i>Sp3</i>	305.66	88.48	8.64
	<i>Fr₂</i>	<i>Sp1</i>	255.33	88.34	4.03
		<i>Sp2</i>	280	82.41	7.03
		<i>Sp3</i>	319.33	81.4	9.12
	<i>Fr₃</i>	<i>Sp1</i>	260.66	76.4	6.8
		<i>Sp2</i>	300.66	80.98	9.55
		<i>Sp3</i>	324.33	73.5	8.18
<i>M_{o2}</i>	<i>Fr₁</i>	<i>Sp1</i>	257.66	87.55	4.64
		<i>Sp2</i>	296	69.67	3.84
		<i>Sp3</i>	332.33	73.33	3.03
	<i>Fr₂</i>	<i>Sp1</i>	252.34	78.35	4.71
		<i>Sp2</i>	280.32	78.66	6.79
		<i>Sp3</i>	335.66	82.96	5.87
	<i>Fr₃</i>	<i>Sp1</i>	254.67	84.58	4.15
		<i>Sp2</i>	287.3	70.63	3.44
		<i>Sp3</i>	319	72.01	5.57

Table 3 Summary of analysis of variance F- values for different factors (main and interaction factors) for different measured parameters

Factors (main and interaction factors)	Capacity (kg h ⁻¹)	De-husking efficiency (%)	Grain losses (%)
Model	132.63*	28.04*	612.90*
Intercept	224372.28*	82721.26*	98745.37*
Feed rate	132.63*	43.05*	229.85*
Speed	224372.28*	31.20*	735.22*
Moisture	7.68*	78.56*	4736.07*
Feed rate × speed	1031.46*	5.73*	157.30*
Feed rate × moisture	19.79*	19.16*	515.54*
Speed × moisture	7.61*	34.87*	494.28*
Feed rate × speed × moisture	44.59*	29.64*	276.07*

Table 4 Results of DMRT showing the mean at various level of feeding rate and roller speed for different measured parameters

Measured parameters	Feeding rate (kg)			Roller speed (rpm)		
	Fr_1	Fr_2	Fr_3	S_1	S_2	S_3
De-husking capacity	285.39 ^a	287.18 ^a	291.09 ^a	255.19 ^a	285.76 ^b	322.71 ^c
De-husking efficiency	81.61 ^a	82.02 ^b	76.35 ^b	83.09 ^a	78.27 ^a	78.61 ^b
Grain losses	5.40 ^a	6.26 ^a	6.28 ^a	4.99 ^a	6.21 ^{a,b}	6.73 ^b

Note: Mean with different letters along the same row are statistically different from each other at $p < 0.05$.

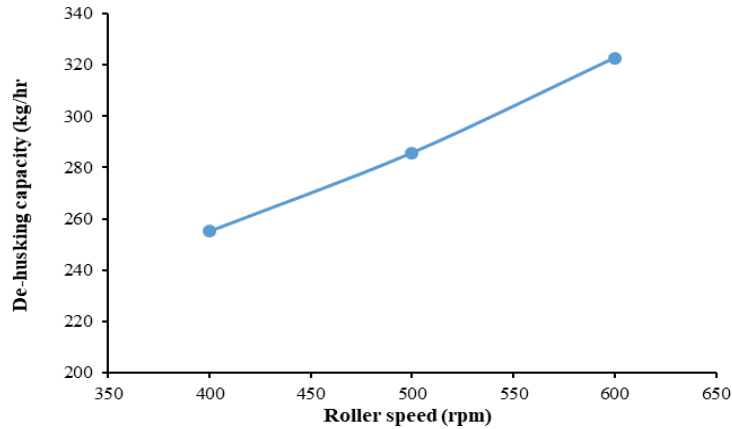


Figure 3 Graph of mean de-husking capacity versus speed of roller

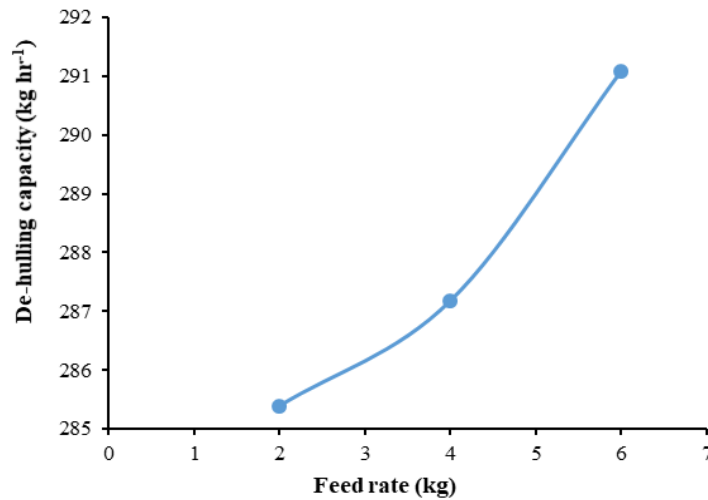


Figure 4 Graph of mean de-hulling capacity versus feeding rate

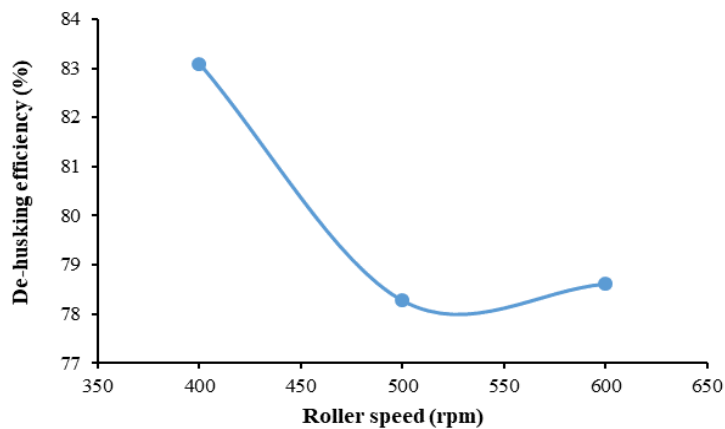


Figure 5 Graph of mean de-husking efficiency versus speed of roller

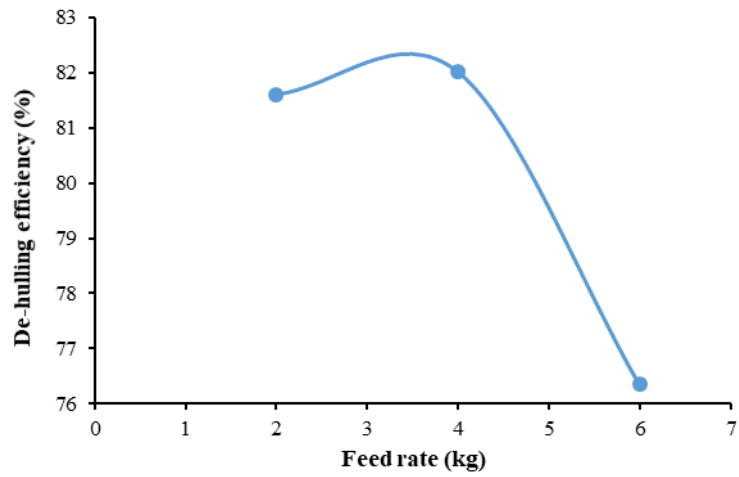


Figure 6 Graph of mean de-husking efficiency versus feeding rate

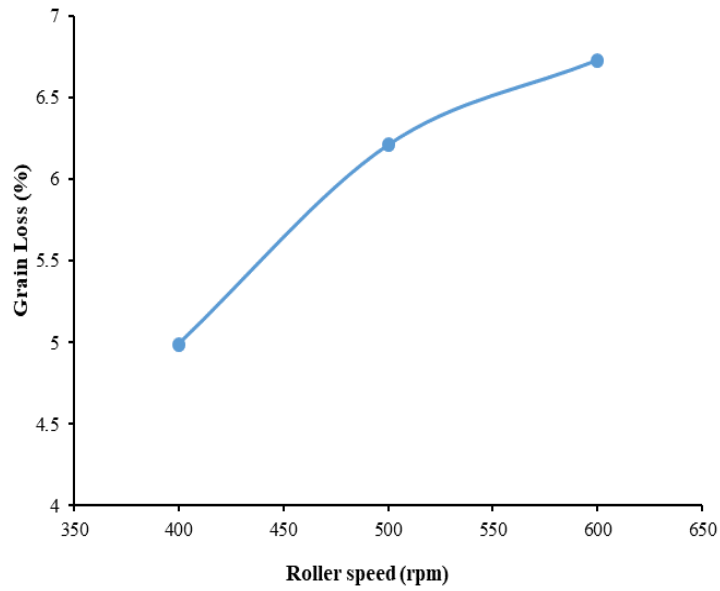


Figure 7 Graph of mean grain loss versus speed of roller

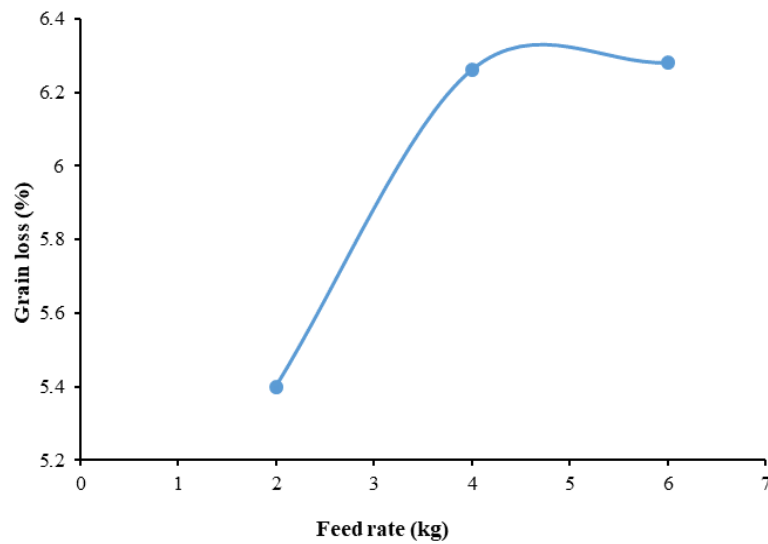


Figure 8 Graph of mean grain losses versus feeding rate

4 Conclusion

The maize de-husking machine was developed using available local materials for de-husking maize. The average de-husking capacity, de-husking efficiency and grain loss were 287 kg hr⁻¹, 79.99% and 5.98%, respectively. The result of the performance evaluation of the maize de-husker revealed that moisture content, speed of rollers and feeding rate at various levels of operation affects the de-husking efficiency of the machine. Machine de-husking capacity increases with increase in feeding rate and roller speed and grain loss also increases with increase in roller speed and the moisture content. The interaction between feed rate, roller speed, moisture content, (feed rate and roller speed), (feed rate and moisture content), (roller speed and moisture content) and (feed rate, roller speed and moisture content) at various level of operation affected de-husking capacity, de-husking efficiency and grain loss

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