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Research Article

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Performance Test of Grain Cleaner in Conjunction with Maize Sheller

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Abstract Grain cleaning is an important operation in a number of processes connected with the handling of maize after harvest. It is impossible to grow and harvest maize without getting undesirable intermixtures. These may comprise stone, chaff, dust as well as undeveloped, damaged and deteriorated grains.

A recent trend has seen the cleaning unit of Maize Sheller in cleaning grains. The cleaning unit of a Maize Sheller has the ability to remove both small and large foreign materials from a vast variety of grains and also to grade the grains into homogenous quality.

This began with the design, construction and performance test of the cleaning unit of a maize Sheller. The component part of the machine includes the blower, the vibrating screen, the clean grain outlet and the material other than grain (MOG) outlet. The threshed grain from the shelling unit was transferred into the cleaning unit which was cleaned and graded into homogenous quality.

The performance of the cleaning unit of the machine was evaluated using two varieties of maize (white and yellow). The result showed that the combination of fan speed in the blower with the vibrating screen affected significantly the total separation efficiency.

The average cleaning efficiency of the cleaner for white maize is 92.0% for separating maize grains, 67.0% for separating impurities, and 61.4% overall efficiency.

The average cleaning efficiency of the cleaner for yellow maize is 96.0% for separating maize grains, 37.67% for separating impurities, and 36.33% overall efficiency.

Keywords blower, vibrating screen, white maize, yellow maize, efficiency, impurities

1. Introduction

1.1 Background Study

Maize after wheat and rice is the most important and indispensable food that is consumed in great proportion all over the world. It provides nutrients for humans and animals and serves as raw material for oil, alcoholic beverages, food sweeteners, starch etc. Production of maize on a large scale is likely to continue to increase with the adoption of improved production technology and the availability of a wider market. This would mean a higher demand for labour for all farming operations particularly harvesting, threshing, cleaning and grading. Thresh grains require considerable additional cleaning before they can be used as food- whole or ground- and even as feed. The cleaning process presents more difficulties than the actual threshing process. Simonyan, K.J et al. (2006). For farmers to maximize profit from their maize, appropriate technology that suits their needs must be used.

1.2 Importance of Cleaning in Agriculture

Processing of agricultural materials is very important in agricultural production because the quality of the agricultural product is retained and improved. Enables reduction of losses during the stage of harvesting.

Harvested crops have foreign materials that may cause damage to the instrument used for further processing, and also reduce the quality of seeds by contaminating them and thereby constituting health hazards were used. These unwanted agents could be removed by cleaning.

Clean and homogenous seeds get a high premium, resulting in high profit gotten from sales by farmers. Also, planting clean seeds from which weeds or dirt have been removed will result in higher yields, lower cultivation costs and reduced control practices.

2. Methodology

Materials selected were based on availability, cost, durability, hardness, fatigue and environmental factor of operation. The material used the in construction and testing of the cleaner are:

Internal combustion engine (power source), 2mm thick mild steel, 2” by 2” Angle iron, 14,16,17mm, and 19mm bolts and nuts, yellow and white maize varieties, digital air flow meter, tachometer, oven, weighing scale, electrode, paint.

Maize cleaner components are blower and blower casing, pulley, vibrating screen, frame and frame support, and outlets.

2.1 Design consideration

The following were taken into consideration: Screen (vibrating) characteristics, geometrical and aerodynamic properties of maize–impurity mixture, fan size and capacity, and cost of construction.

2.1.1 Basic component designed

Actual Speed of the Blower

Adequate belt selection enhances the effective transmission of power from one shaft to another.

The relationship between the driven pulley speed and the speed of the prime mover is as

$N_1D_1 = N_2D_2$ Khurmi, R.S. and Gupta, J.K. (2005)

Where

N_1 is the speed of the driver,

N_2 is the speed of the driven,

D_1 is the diameter of the driver pulley, and,

D_2 is the diameter of the driven pulley

Velocity of the Belt

According to Khurmi, R.S. and Gupta, J.K. (2005) Velocity of the belt is given by V (velocity) $V= \frac{(\pi DN)}{60}$

Where,

D is the diameter of the driver pulley,

N_1 is the speed of the driver,

Length of Belt L

The length of belt L according to Khurmi, R.S. and Gupta, J.K. (2005) is given by

$\frac{\pi}{2}(D_1 + D_2)$

$L= \pi/2(D_1 + D_2) + 2C+(D_1 - D_2)^2 / 4C$

Where

D_1 is the diameter of the driver pulley and

D_2 is the diameter of the driven pulley,

C is the centre–to–the centre distance between the two pulleys.

Angle of Contact

The angle of contact $\theta = 180 - 2\alpha$

Where; $\sin\alpha = \frac{d_2 - d_1}{2C}$.

Groove angle of the pulley,2 β: $2\beta = 34^0$ Khurmi, R.S. and Gupta, J.K. (2005),

Maximum Permissible Tension in the Belt

Maximum permissible tension in the belt, T_{max}: $T_{max} = \sigma \times A$

Where;σ = stress for the belt material= 2MPa=2N/mm^2 ,

A=cross-sectional area = $^1/_2\,(a + b) \times t$.

Where: a is the inner face width of any cross-section of the belt,

b is the outer width of the belt, and
t is the thickness of the belt.
Tension in the tight side, $T_1 = T_{max} - T_C$
However, the centrifugal tension ($T_C = mv^2$, where m is the mass of the belt per unit length) in the belt can be neglected in this drive since its speed is low (that is, less than 10m/s) and hence, the tension in the tight side T_1 can be taken as the maximum permissible tension.
Mathematically: $T_1 = T_{max}$. Also, Tension in the slack side, T_2:The relationship between T_1 and T_2 – tensions in the tight and slack sides of the belts respectively – for the v-belt drive is obtained by the following equation:
$$log\left(\frac{T_1}{T_2}\right) = \mu\theta cosec\beta,$$
Where: µ= angle of friction between the belt and,
pulley material = 0.30 for rubber belt and mild steel pulley.

Power Capacity of the Belt Drive

According to Nwakaire, J.N.et al., (2011)., the Power capacity of the belt drive, P: power is obtained by the following relationship:
$$P = (T_1 - T_2)v$$

Torque Transmitted by the Driven Shaft

According to Khurmi, R.S. and Gupta, J.K. (2005). Torque transmitted by the driven shaft, $M_T = \frac{P\times 60}{2\pi\times N_2}$.

Design of the Shaft Based on the Torsional Rigidity

The torsional deflection of the shaft was determined by using the torsion equation.
According to Khurmi, R.S. and Gupta, J.K. (2005)
$\theta = \frac{TL}{JG}$, and assuming an allowable angle of twist of 3*deg/meter*.
Where;
θ = angle of twist in radians = $3\pi/180$ *rad*,
T = torque or Twisting moment
G = modulus of rigidity for the shaft material (mild steel),
L = length of the shaft,
J = polar moment of inertia of the cross-sectional area about the axis of rotation.
For a solid shaft, $J = \frac{\pi}{32}D^4$.
the screen characteristics for the circular opening
$$C_O = 3\frac{\pi}{2} \times D^2/(D+d)^2$$
Where
D is the diameter of the hole and,
d is the distance between the successive holes.

Performance indices used in testing

According to Igbeka (1984), the Efficiency of separation of cleaned maize ξ_g, which was obtained as the ratio of cleaned maize grain coming out of the clean grain outlet to the total maize grain fed into the cleaner,
$$\xi_g = GP/GP+GR$$
where,
GP (Good Product) is the weight of clean grain in the clean grain outlet, kg, and,
GR (Good reject) is the weight of clean maize grain in the two reject outlets, kg.
The efficiency of separation of MOG,
$$\xi_{MOG} = BR/BR+BP$$
where:
BR is the weight of MOG (material other than grain e.g. pebbles, chaffs, broken and under-matured grain) collected from reject outlets, kg, and BP is the weight of MOG collected in the clean-grain outlet, kg.
The total cleaning efficiency of the machine,
ξ_T, $\xi_T = \xi_g \times \xi_{MOG}$.

3. Result and Discussion

The weight of different grades of products collected in the separate receptacles, the efficiency of separating clean maize, the efficiency of separating of impurities, and the total cleaning efficiency for white maize. The table below shows the weight collected at the product and reject receptacles at different blower speeds and corresponding efficiencies for maize (White maize).

Table 1: Data collected.

s/n	Weight of maize fed(kg/hr.)	Fan speed (rpm)	The volume of air (m^3)	Good product (kg/hr.)	Bad product (kg/hr.)	Good reject (kg/hr.)	Bad reject(kg/hr.)	The efficiency of separation of clean grain %	Efficiency of separation of impurities (MOG) %	Total cleaning efficiency %
1	68.4	1158	0.143	32.5	1.30	1.50	4.00	95.00	75.50	71.70
2	116.4	1164	0.155	68.80	5.01	4.93	12.86	92.80	71.90	66.70
3	172.8	1183	0.163	72.40	7.89	6.61	15.20	91.60	65.80	60.30
4	180	1213	0.172	85.70	10.32	10.10	18.88	89.50	64.70	57.90
Average		1179.5	0.1582	63.6	6.1	85.79	12.74	92.23	69.50	64.15

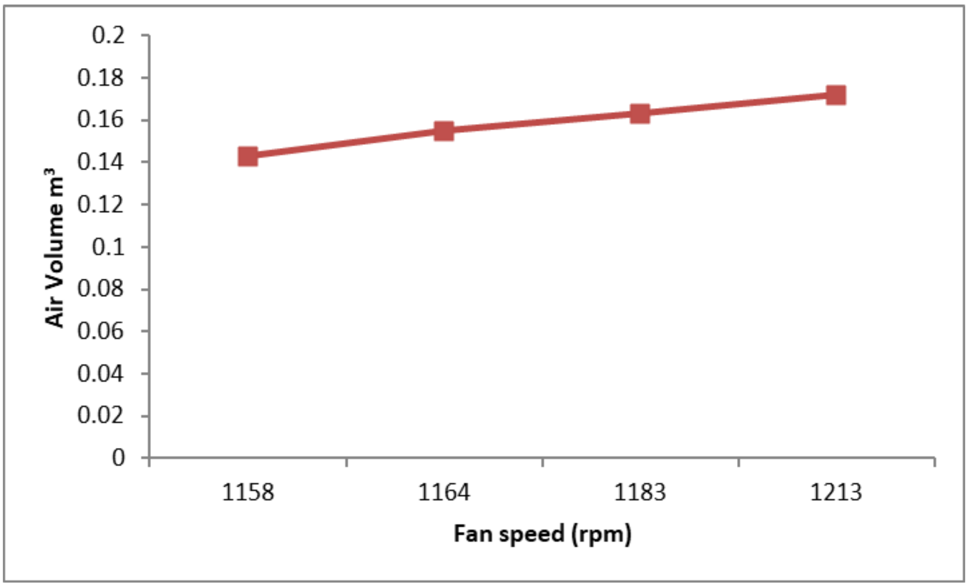


Figure 1: Effect of fan speed on the volume of air

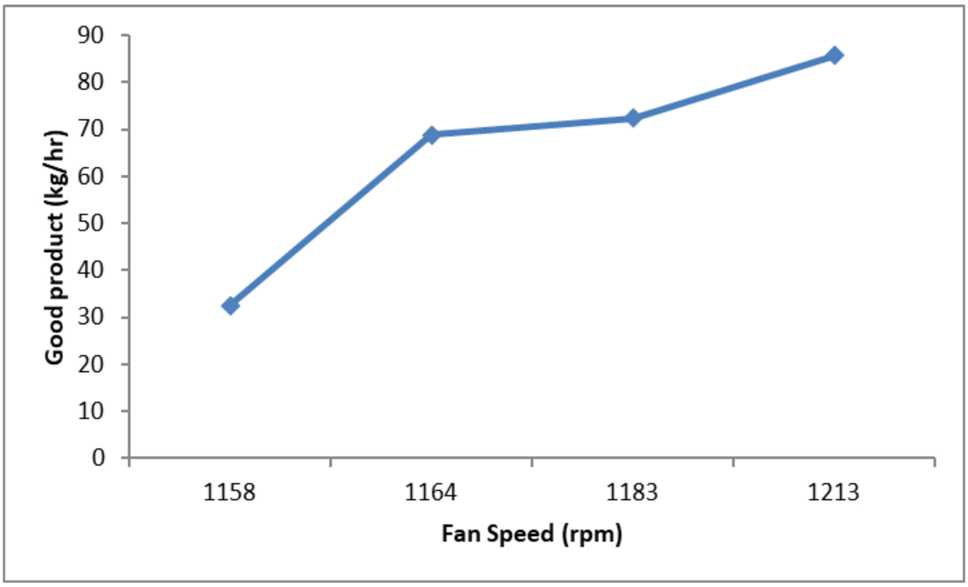


Figure 2: Effect of fan speed on Good product

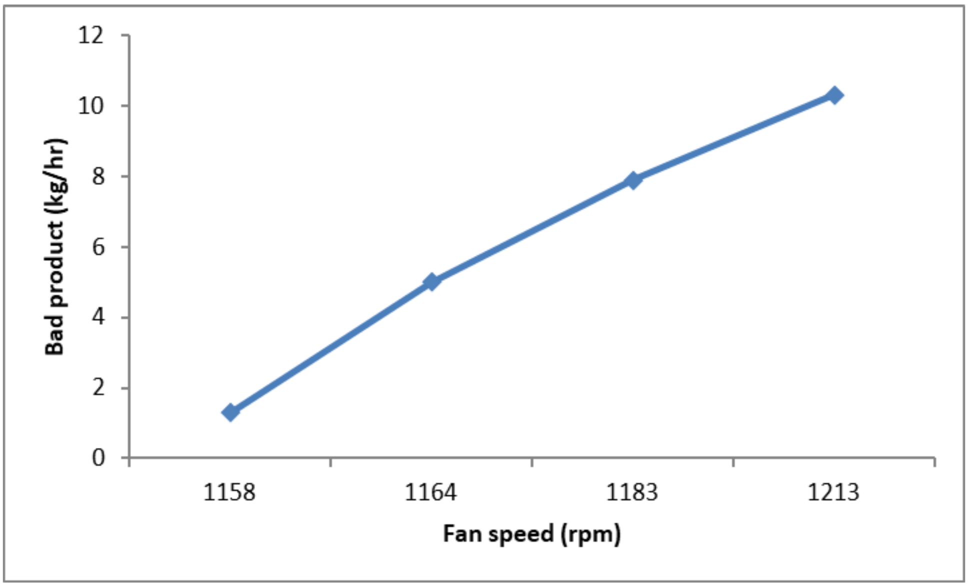


Figure 3: Effect of fan speed on Bad product

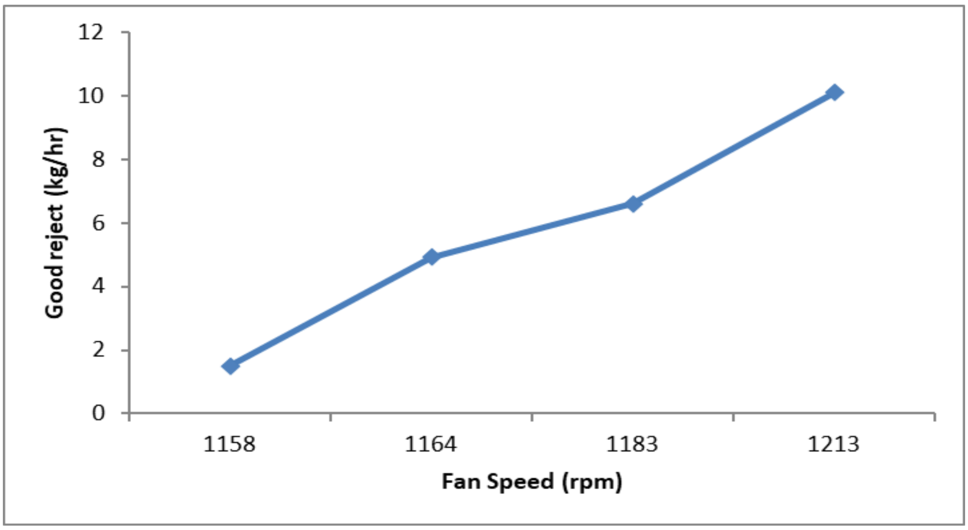


Figure 4: Effect of fan speed on Good reject

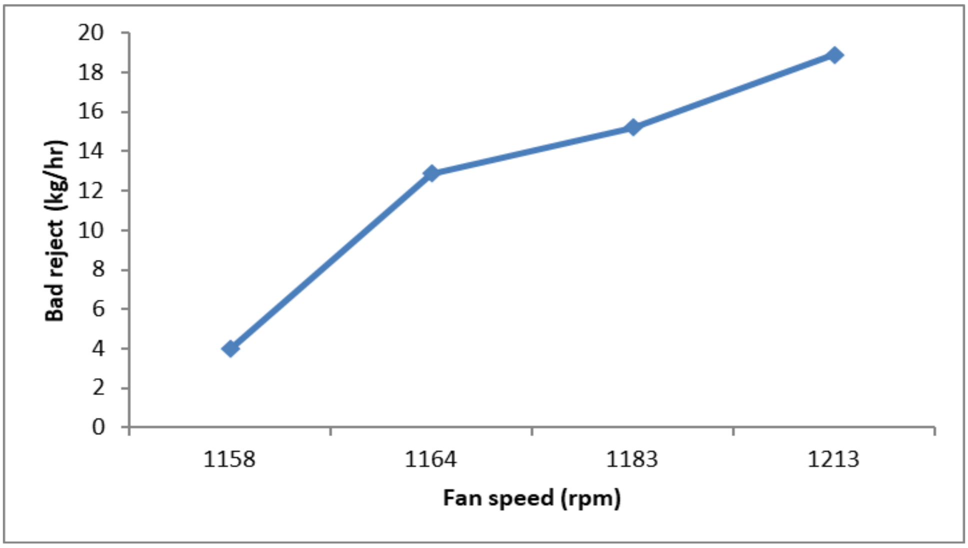


Figure 5: Effect of fan speed on Bad reject

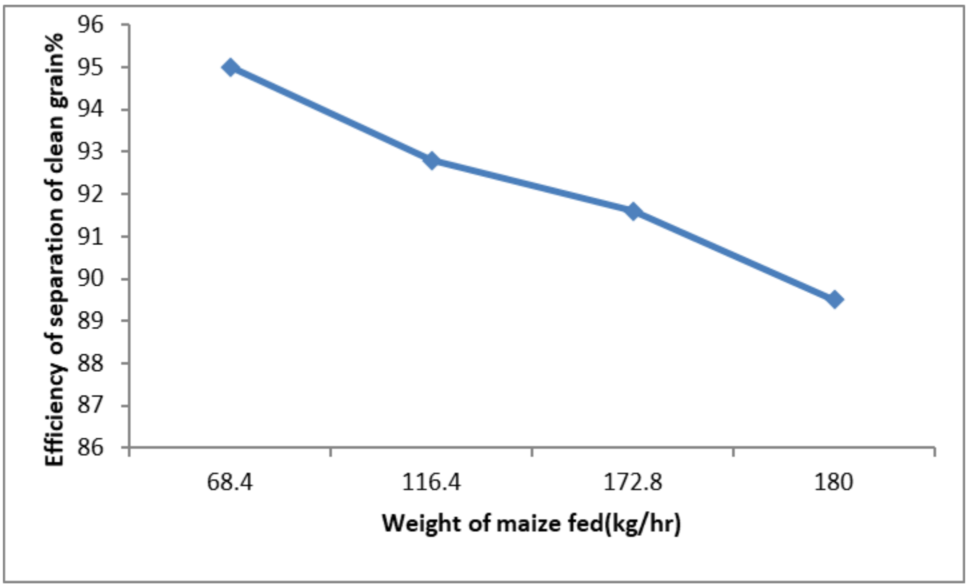


Figure 6: Effect of weight of maize fed on efficiency of separation of clean grain

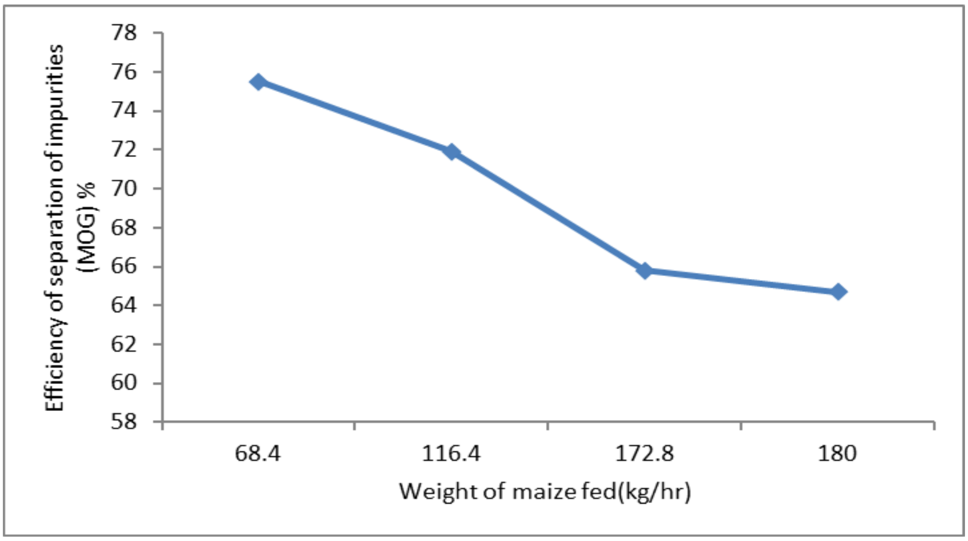


Figure 7: Effect of the weight of maize fed (kg/hr.) on the efficiency of separation of impurities (MOG) %

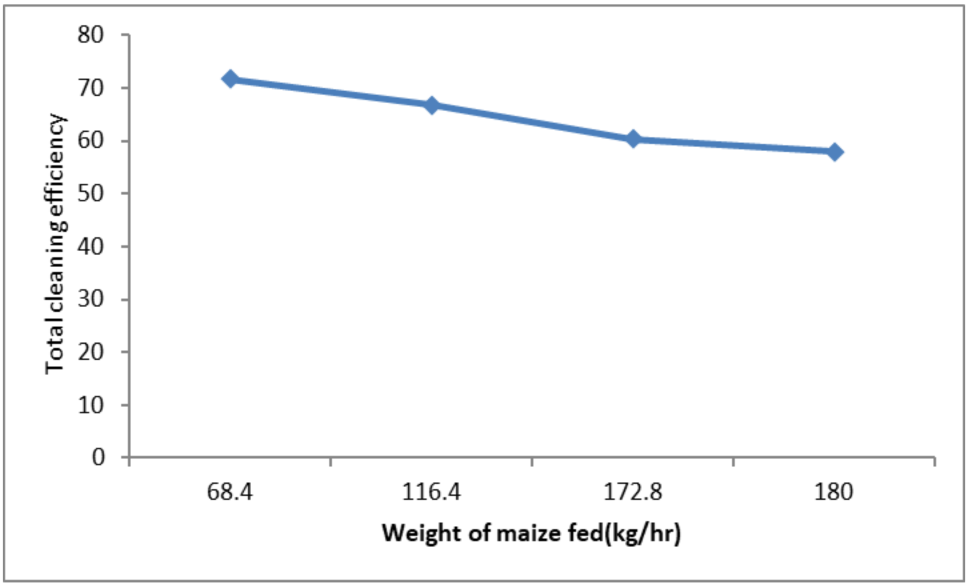


Figure 8: Effect of Weight of maize fed(kg/hr.) on total cleaning efficiency

The table below shows the weight collected at the product and reject receptacles at different blower speeds and corresponding efficiencies for maize (Yellow maize).

Table 2:

S/N	Weight of maize fed(kg/hr.)	The volume of air (m^3)	Fan speed (rpm)	The volume of air (m^3)	Good product (kg/hr.)	Bad product (kg/hr.)	Good reject (kg/hr.)	Bad reject(kg/hr.)	The efficiency of separation of clean grain %	Efficiency of separation of impurities (MOG) %	Total cleaning efficiency
1	90	4.2	1058	4.2	51.18	1.89	1.50	1.62	97.00	46.00	45.00
2	100	4.4	1060	4.4	52.08	4.75	1.68	2.94	96.00	38.00	36.00
3	120	4.65	1158	4.65	55.50	7.38	2.1	3.15	95.00	29.00	28.00
Average		4.42	1092	4.42	63.6	6.1	85.79	12.74	92.23	69.50	64.15

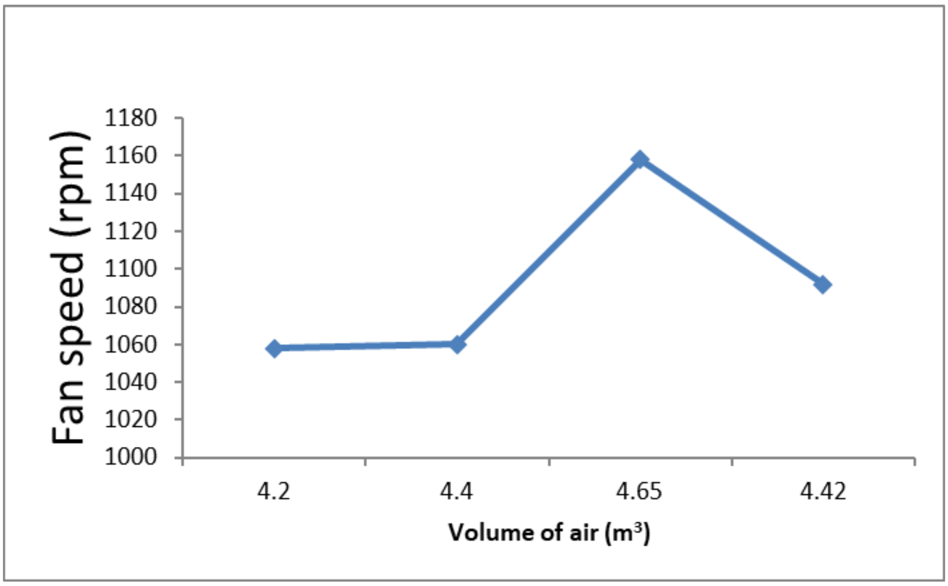


Figure 9: Effect of fan speed (rpm) on volume of air (m^3).

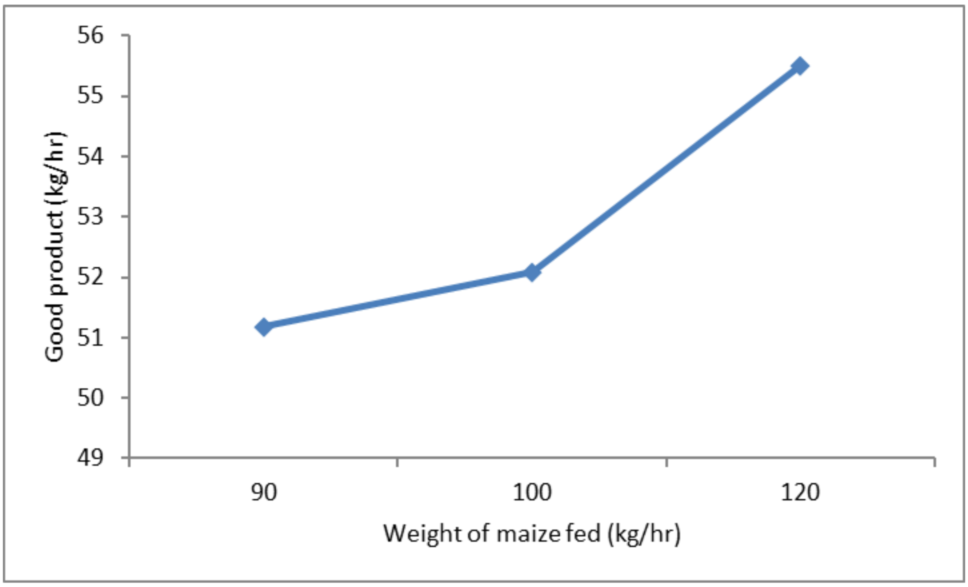


Figure 10: Effect of weight of maize fed (kg/hr.) on good product (kg/hr.)

Figure 11: Effect of the weight of maize fed (kg/hr.) on the bad product (kg/hr.)

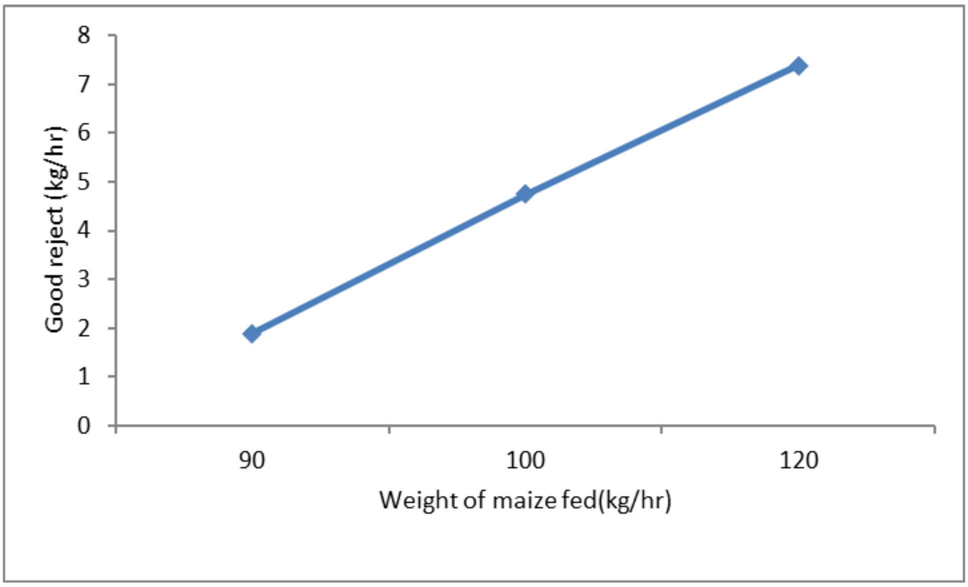


Figure 12: Effect of weight of maize fed (kg/hr.) on good reject (kg/hr.)

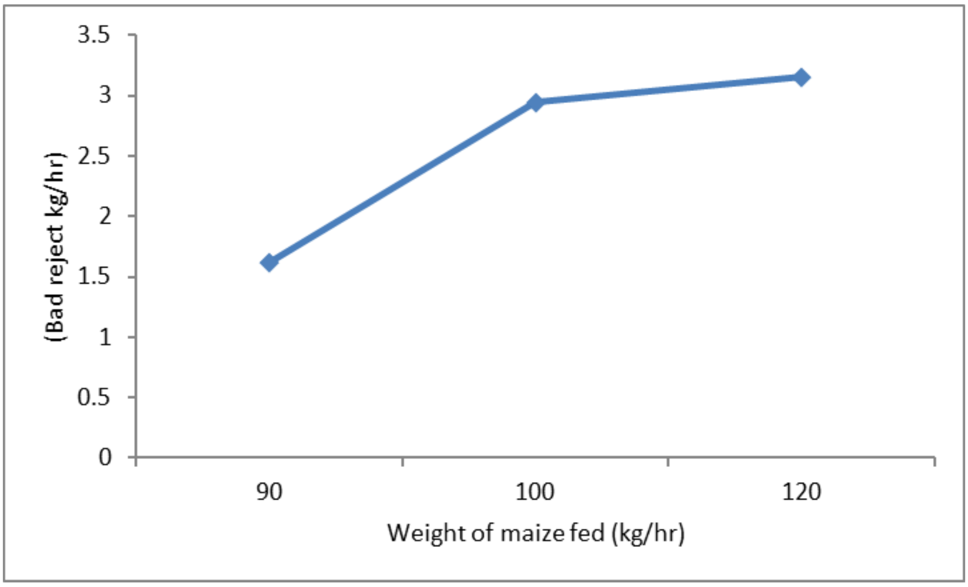


Figure 13: Effect of weight of maize fed (kg/hr.) on bad reject (kg/hr.)

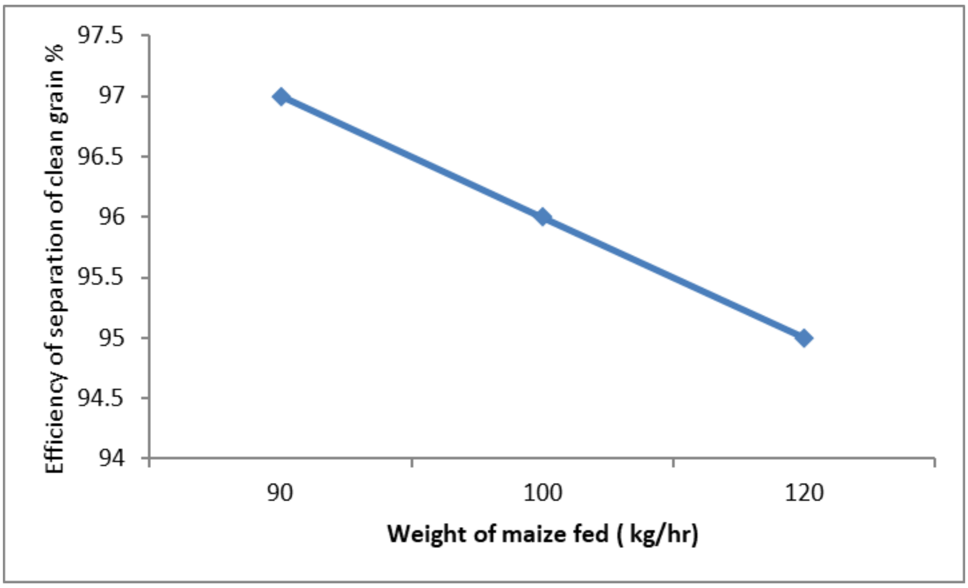


Figure 14: Effect of the weight of maize fed (kg/hr.) on Efficiency of separation of clean grain %

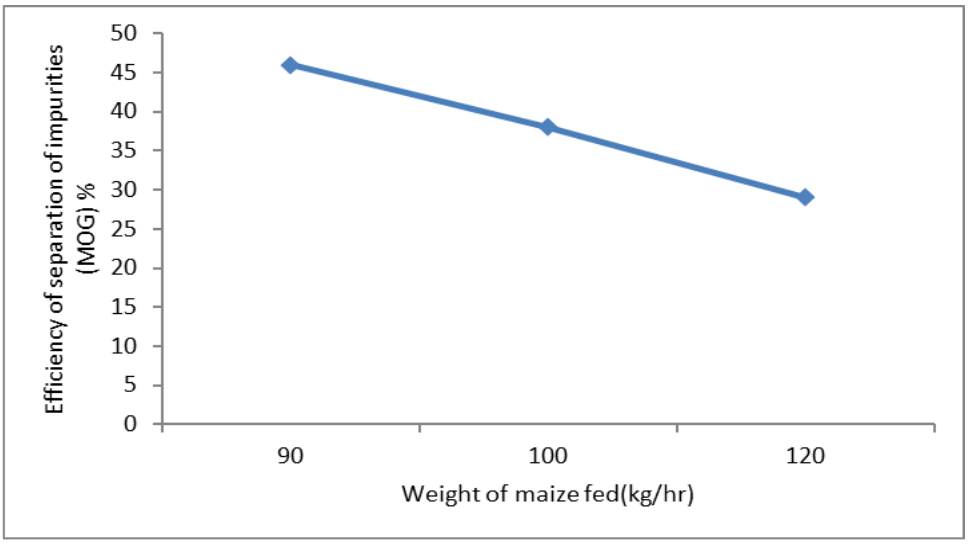


Figure 15: Effect of the weight of maize fed (kg/hr.) on Efficiency of separation of impurities (MOG) %

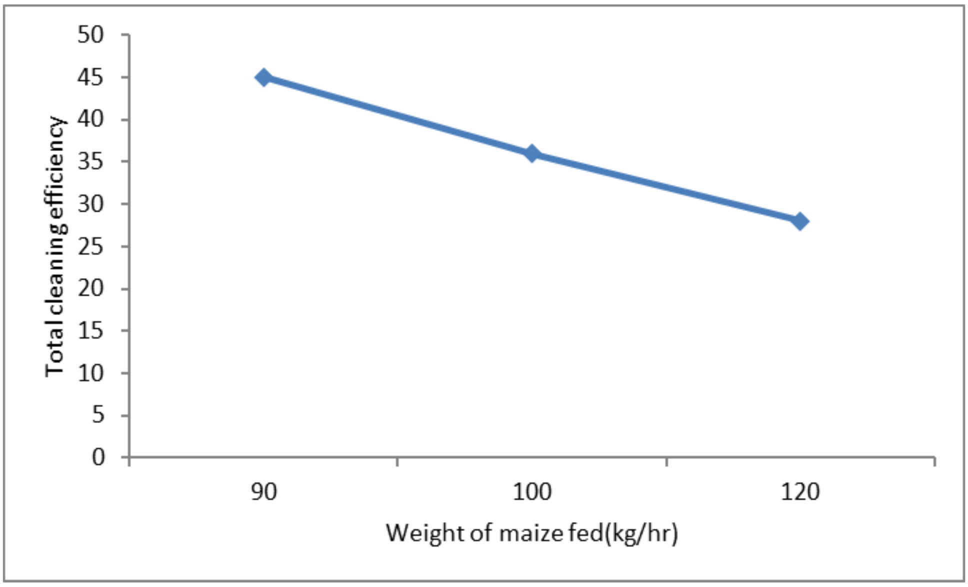


Figure 16: Effect of the weight of maize fed (kg/hr.) on total cleaning efficiency

4. Discussion and Result

White Maize

From the test carried out as presented in Table 1.0, the efficiencies were obtained for four trials which were determined by the weight of maize fed (kg/hr.). the efficiency of separation of clean maize grain, ξ_g ranged between 89.50 and 95.00 %, giving an average value of 92.23%; the efficiency of separation of impurities, ξ_b ranged between 64.70 and 75.50%, giving an average value of 69.50% and total cleaning efficiency, ξ_T ranging from 57.90 to 71.70% averaging 64.15%. Also, Table 1.0 shows values of the speed of the blower in rpm for the four trials, and the volume of air blown for cleaning for the trials.

According to figure 1.0, the volume of air in the blower increases as fan speed increases and vice versa. For cleaning to be more efficient, the volume of air blown in the blower must be sufficient. According to figure 2.0, the values of a good product (grain) separated from the material increase as fan speed increases. According to figure 3.0, the values of the bad product (impurities) separated from the material increase as fan speed increases. According to figure 4.0, the values of good reject (grain) from below increases as fan speed increases. According to figure 5.0, the values of bad reject (impurities) from the blower increase as fan speed increases. According to figure 6.0, the efficiency of separation of clean grain decreases as the weight of maize fed increases. According to figure 7.0, the efficiency of separation of impurities decreases as the weight of maize fed increases. According to figure 8.0, total cleaning efficiency decreases as the weight of maize fed increases.

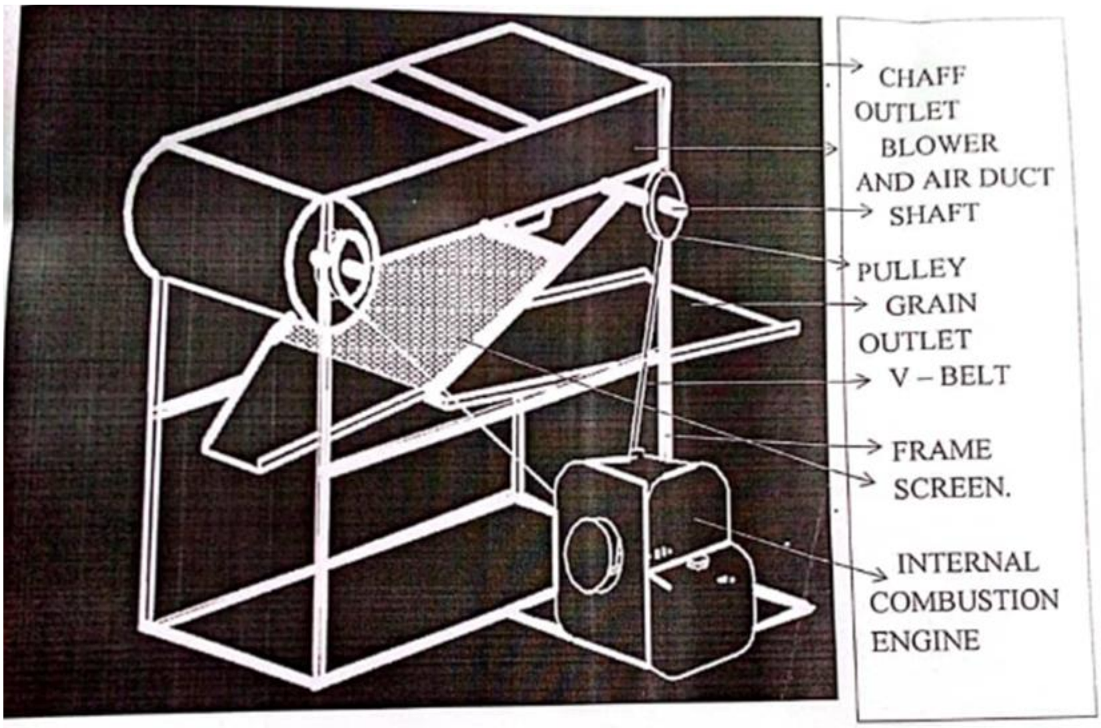
Yellow Maize

From the test carried out as presented in Table 2.0, the efficiencies were obtained for three trials which were determined by the weight of maize fed (kg/hr.). The efficiency of separation of clean maize grain, ξg ranged between 95.00 and 97.00 %, giving an average value of 96.00%; the efficiency of separation of impurities, ξ_b ranged between 29.00 and 46.00%, giving an average value of 37.67% and total cleaning efficiency, ξ_T ranging from 28.00 to 45.0 % averaging 36.33%.

According to figure 9, the volume of air in the blower increases as fan speed increases and vice versa. For cleaning to be more efficient, the volume of air blown in the blower must be sufficient. According to figure 10, the values of a good product (grain) separated from the material increases as the weight of maize increases. According to figure 11, the values of the bad product (impurities) separated from the material increase as the weight of maize increases. According to figure 12, the values of good reject (grain) increases as the weight of maize increases. According to figure 13, the values of bad reject (impurities) from the blower increase as the weight of maize increases. According to figure 14 efficiency of separation of clean grain decreases as the weight of maize fed increases. According to figure 15, the efficiency of the separation of impurities decreases as the weight of maize fed increases. According to figure 16, total cleaning efficiency decreases as the weight of maize fed increases.

5. Conclusion

The result clearly shows the machine was successfully designed. The average cleaning efficiency of the cleaner for white maize is 92.0% for separating maize grains, 67.0% for separating impurities, and 61.4% overall efficiency The average cleaning efficiency of the cleaner for yellow maize is: 96.0% for separating maize grains, 37.67% for separating impurities, 36.33% overall efficiency. Maize that is free from dirt looks attractive and justifies its cost. The net present value of Maize cleaner is close to N 100,000 while this cleaner was fabricated for around N50,000. The price difference shows a drastic reduction in the purchase price of Maize cleaner. More research should be done to identify the many needs of the farmers so that new machines can be designed to meet their needs.



Isometric View of the Maize Cleaner

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