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Design and Fabrication of a Multi-Grain Cleaning and Grading Machine

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ABSTRACT: The presence of foreign matter in grains increases the bulk weight and volume thereby increasing the cost of handling and transportation. Contaminants cause high losses during storage, lowers grain standards and market value. Agricultural processing operations such as cleaning (winnowing), grading, destoning and polishing are necessary for the provision of quality grains for consumption, storage, processing of food products and good quality exchange in the market. A grain cleaning and grading machine was designed and fabricated based detail engineering design for local use. The machine was tested and the data analyzed using ANOVA table to verify the effect of some variables on machines output capacity, cleaning efficiency and scatter loss. The grading efficiency was also determined and expressed using simple relationship graphs. The results of evaluation show that the performance parameters of the prototype machine ranged between; 620.83 and 1088.00 kg/hr. for the output capacity, 98.04 and 98.66 % for cleaning efficiency, and 1.11 and 2.89 % for grain scatter loss. The results for grading efficiency shows that the efficiency of grade A grains ranged between 70.19 and 78.68 %, while the grade B grains ranged between 69.09 and 77.04 %. The optimum performance of the machine in cleaning and grading SAMSORG 43 (Sorghum bicolor (L) Moench) grains was achieved at feed rate of 1200kg/hr., 4.5m/s air speed and 25mm crank amplitude.

Keywords: Design, fabrication, cleaning, grading, efficiency, SAMSORG 43 and scatter loss

I. INTRODUCTION

Nigeria's agriculture has not yet achieved the desired level of development, in spite of the laudable schemes and programmes of the Federal, States and Local Governments. Mechanized agriculture still depends on the massive importation of tractors and high-tech agricultural machines into the country for farming purposes. The application of modern or improved technologies have really not been appreciated by the smallholder farmers who occupies over 80 percent of the total farmer population and accounts for about 99 percent of produced grains (Mgbenka et al., 2015). The attitude of these majority of farmers may be attributed to either the technical nature, price tag or power source (electric) of the machines; or their regards for the traditional (manual) methods. The traditional method, however, require several man-hours, and it's usually physically demanding and energy sapping on the persons performing the operation.

Grain cleaning and grading are post-harvest operations that add value to agricultural crops. Grain cleaning is an operation that is performed to remove foreign and undesirable materials from threshed grains, while grading is the separation of grains into different grades, either according to size, shape, colour, weight or maturity. They are operations that aim at maximizing grains quality and minimizing quantitative deterioration after harvest.

Most existing mechanical cleaning and grading devices are somehow components of shellers, threshers, dehullers and combine harvesters. These machines are designed for specific crops and because of the various operations they perform; their power requirements are regularly high. The machines as such, are somehow expensive and above the reach of small scale farmers. Although, agricultural machines are expected to be optimal and reliable in design, having the capacity to resist failure and poor output quality, some of the locally fabricated ones operate with inappreciable efficiencies, low output capacities, high percentage scatter losses and inefficient power transmission and utilization.

The present administration in the Nigeria has embarked on accelerated food production campaign which is in turn yielding a significant result. This trend may bring about a high quest for processing machines such as the grain cleaners and grader to improve the post-harvest quality of the grains. Therefore, it is important to design and construct a simple and efficient, engine operated machine, which can at the same time clean and grade grains at cheap and affordable rates for the local farmers. This machine will relieve farmers and seed processors of the hard spent energy, time, labour and resources expended during manual operations. The objective of this research is to design and fabricate a multi-grain cleaning and grading machine for the major cereal grains base on detailed engineering design.

II. MATERIALS AND METHODS

2.1 Tools and Materials

The materials chosen for the construction work were selected to satisfy the requirement of strength, rigidity, durability, weight and the ability to withstand the effects of harsh environmental working conditions. Some of the devices used during the fabrication and testing of the machine include a weighing scale, measuring tape, punch, scriber, electric drilling machine, electric cutting and filling machine, guillotine, electric arc welding machine, digital anemometer, digital tachometer, and digital Vernier caliper (0.01mm sensitivity).

2.2 Machine Components Design

The components include the frame, hopper, shaft, belt, pulley, power unit, fan, fan housing and sieves. The design of some of the components is highlighted, thus;

2.2.1 Hopper:

The hopper is a trapezoidal-shaped component made with gauge 18 metal sheet and mounted on the frame to discharge over the top sieve at an angle of 30^o, for even and proper distribution.

2.2.2 Determination of pulley diameter

The size of the driven pulley was determined using equation 1 as given by by Khurmi and Gupta (2007) as:

$$N_1D_1 = N_2D_2 \tag{1}$$

where:

N_1 = speed of driving pulley (rpm).
D_1 = diameter of driving pulley (m),
N_2 = required speed (speed of driven pulley) (rpm) and
D_2 = diameter of driven pulley (m).

2.2.3 Determination of belt length

The required belt length (L) was determined using equation 2 as given by Khurmi and Gupta (2007):

$$L = \frac{\pi}{2}(D + d) + 2C + \frac{(D-d)^2}{4C} \tag{2}$$

where:

C= distance between driving and driven pulleys (m)
D= diameter of driven pulley (m) and
d= diameter of the driving pulleys (m).

2.2.4 Determination of belt tensions

The belt tension was determined using the equations 3, 4 and 5 as used by Yayock (2016):

$$P = (T_1 - T_2)V \tag{3}$$

$$\frac{T_1}{T_2} = e^{\mu\theta Cosec\beta} \tag{4}$$

$$V = \frac{\pi dN}{60} \tag{5}$$

where:

P= Power, in watt, from the prime mover,
T_1 and T_2 are tensions (in Newton) on the tight and slack sides of the belt,
N= Speed of prime mover (rpm),
d= diameter of pulley in meter,
θ= angle of wrap in radian, and
μ= coefficient of friction between belt and pulley materials.
v= velocity of driven pulley (m/s)

2.2.5 Shaft design base on strength.

The shaft material of 35 mm diameter was selected from mild steel with code name (C1040) based on bending and torsion moment analysis. The shaft was suspended on two pillow bearings to provide support for easy rotation. The shaft diameter was obtained using equation 6 as used by Yayock et al. (2020).

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \tag{6}$$

where:

d=Shaft diameter, mm
K_b = Combine shock and fatigue factors for bending moment
K_t = Combine shock and fatigue factors for torsional moment
M_b = Maximum bending moment (Nm)
M_t = Torsional moments (Nm)
S_s = Maximum allowable shear stress for shafts with allowance for keyway (MPa).

2.2.6 Fan blade design

A radial or straight blade centrifugal fan with three (3) blades (impeller) was designed and constructed because of its suitability for generating large volume of air. The diameter of the fan blade was determined using equation 7 (Yayock, 2016).

$$D^2 = \frac{2.35 \times 10^8 P_s}{N^2 \varphi} \quad (7)$$

Where:
D = Impeller diameter for radial blade blower, inches (1inch = 25.4mm)
P_s = Static pressure (inches water gauge).
N = Speed of driving pulley (rpm).
φ = Pressure coefficient
The width of the fan blade (impeller) was determined by equation 8 as used by Yayock (2016) as:

$$W = \frac{175Q}{\emptyset N D^2} \quad (8)$$

Where:
W = Width of radial blade fan (impeller), inches
ϕ = flow coefficient
Q = Air flow rate (cfm),
N = Speed of driving pulley (rpm).

2.2.7 Fan housing
The fan blades were housed in a volute casing made with 1.5 mm thick mild steel sheet. The width of the housing unit was determined using equation 9 as reported by Sahay and Singh (2008).

$$M = 1.25W + 0.1d \quad (9)$$

where:
M = Width of housing unit, inches (1inch = 25.4mm)
W = Width of impeller (Fan blade), inches
d = Impeller diameter (inches).

2.2.8 Air discharge
The air discharge (Q) by the blower was determined using the relationship given by Joshi (1981) as:

$$Q = V \times D \times t \quad (10)$$

where:
Q = air discharge (m^3/s),
V = the air velocity (m/s),
D = the depth of flow in the conveying duct (m) and
t = the width of the conveying duct (m).

2.3 Selection of Sieves, Bearing, Bolts and Nuts
The axial dimensions of the test grain (SAMSORG 43 variety of Sorghum) were determined as important physical properties for the selection of suitable sieves. The maximum and minimum values of the grain length, width, thickness and geometric mean diameter were determined as 4.18 and 5.19 mm, 3.90 and 4.72 mm, 2.90 and 3.49 mm, and 3.70 and 4.34 mm, respectively, by taking a data of 100 randomly sampled grains. The average geometric mean diameter was obtained as 4.09mm at 7.89% moisture content, dry bases. Two round sieves (4 and 6 mm hole diameters) made from mild steel material were selected and used as the screen surfaces, based on the established properties. The machine is termed 'multi-grain' because it can be used to clean and separate different type and sizes of grains by simply, the replacement of sieves. The oscillatory/reciprocating motion of the shaker is created by a crank which involves the eccentric misalignment of two shafts to certain magnitude.
Two (2) radial (pillow) bearings with bearing number of 308 bore diameter of 40 mm, outside diameter of 90 mm and 18 mm width were selected and used to securely hold the shaft. Bolts and nuts were selected based on the required strength and available standards in the market.

2.4 Machine Construction
The machine was fabricated and assembled, based on detailed design in the Department of Agricultural and Bio-Resource Engineering, Ahmadu Bello University, Zaria, Nigeria as shown in figures 1.0, and 2.0. Table 1.0 shows the materials, tools and method used in coupling the components. The side view of the constructed machine is shown in figure 3.0. The machine was constructed to be within the reach of small and medium scale farmers.

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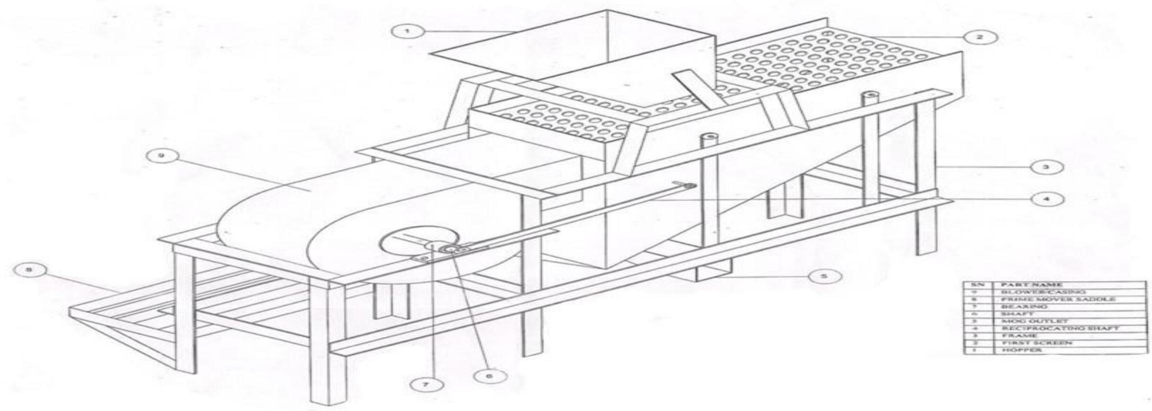

Figure 1.0: Isometric design of the machine

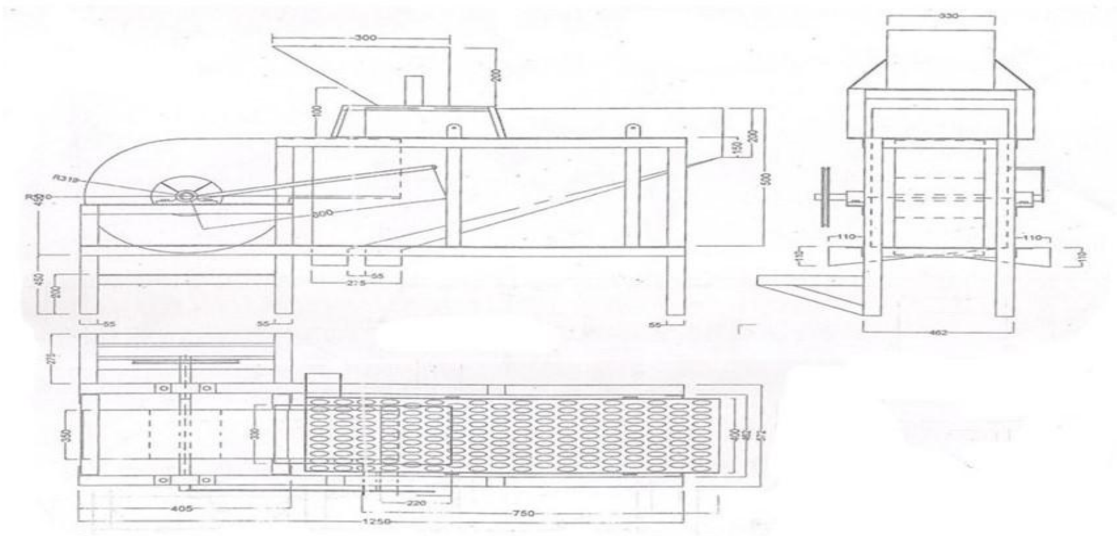

Figure 2.0: Orthographic design of the machine

Table 1.0: Machine Construction Processes

S/N	Components	Construction Material	Construction Tool (s)	Construction Method
1.	Frame	2” × 2” Angle iron (3 & 5 mm thick)	Cutting disc, Cutting machine, Measuring tape, Engineer's square, Welding machine	Welding
2.	Hopper	Mild steel sheet (1.5mm)	Scriber, Guillotine, Electrodes, Welding machine	Welding
3.	Oscillating Unit	Mild steel sheet (1.5 & 3mm) 1.5" x 1.5" Angle iron Flat bar (3 & 5mm) Nut and bolts	Grinding disc, Cutting disc, Cutting machine, Drilling machine, Guillotine, Welding machine	Drilling Welding
4.	Fan	Mild steel sheet (3mm) Shaft (35mm diam.)	Cutting machine, Guillotine, Electrodes, Welding machine	Welding
5.	Fan housing	Mild steel sheet (1.5mm)	Cutting machine, Guillotine, Electrodes, Welding machine	Welding
6.	Prime mover seat	2” × 2” Angle iron (3 & 5mm)	Cutting disc, Cutting machine, Measuring tape, Welding machine	Welding

2.5 Working Principle of the Machine

A batch of uncleaned, threshed grains is fed through the hopper to flow by gravity over the first sieve. The cleaning and grading chamber consists of two sieves of different size openings and a centrifugal blower. The first sieves, 6mm holes diameter, is inclined at an angle of 8^0 while the second sieve, with 4mm holes diameter, is inclined at 12^0 in a reverse direction, for easy discharging of the cleaned and graded grains through the outlet chutes. The two sieves could be adjusted between 8^0 and 15^0 tilt angle. A deflector is placed between the two sieves to control and convey undersized material from the top sieve for thorough action by the second sieve. The sieve chamber oscillates at amplitudes created by the crank. The grains and small chaff particles, less than 6mm mean diameter passes through the first sieve and move across an air blast from the blower which performs the separation (cleaning) based on aerodynamic properties and density of the materials. The chaff and lighter particles are separated and discharged by the air stream. The cleaned grains, afterward, roll over the second sieve to be separated by the sieve into two grades (grains larger than 4mm mean diameter and those less than). The machine is powered by a 2.24kW petrol engine.

2.6 Machine Evaluation

2.6.1 Selection of experimental grains

SAMSORG 43 variety of sorghum (Sorghum bicolor (L) Moench) was sourced, being a dominant local variety of sorghum and used as the experimental crops. The grain sample was analyzed manually before the experiment and the result showed that the sample consist of 87 % pure grains and 13 % impurities (chaff, straw, dust, small immature seeds).

2.6.2 Performance parameters

Machine output capacity, cleaning efficiency, grain scatter loss and grading efficiency were determined as the machine performance indices;

i. Output capacity: The output capacity is the quantity of the grain cleaned by the machine per unit time. It was obtained using equation 11 as used by Ndirika (1994).

$$T_c = \frac{Q_s}{T} \quad (11)$$

Where:
T_c = output capacity in kg/hr,
Q_s = quantity of grains collected at the grain outlet in kg, and
T = time taken for the operation in hour.

ii. Cleaning efficiency: The cleaning efficiency was obtained using equation 12 as reported by Simonyan (2006).

$$\eta = \frac{G_o}{G_o + C_{cg}} . 100 \quad (12)$$

where:
η =cleaning efficiency, %
G_o = weight of pure grain at the outlet, kg
C_{cg} = weight of contaminant, kg

iii. Percentage of scatter loss: This refers to all the grains that got scattered around the machine during operation. The scatter loss was determined using equation 13 as given by Ndirika (1994).

$$S_c = \frac{Q_l}{Q_t} \quad (13)$$

Where:
S_c = percentage of scatter loss (%),
Q_l = quantity of grains scattered around the machine (kg), and
Q_t = quantity of grains fed into the machine (kg).

iv. Grading efficiency: The grading efficiency was obtained by manual re-sieving of the grains retained over the screen surfaces and the pan, using the same screen sizes. The efficiency was obtained using equation 14 as used by Yayock and Ishaya (2020).

$$\eta_g = \frac{G_o}{G_o + G_{cg}} 100 \quad (14)$$

where:
η_g =grading efficiency, %;
G_o = weight of grains retained over screen by manual sieving with same screen size (kg), and
G_{cg} = weight of grains that passed through screen by sieving manually (kg)

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Figure 3.0: Photograph Showing Side View of the Machine

2.6.3 Design of Experiment

A Complete Randomized Block Design experiment with three factors and four/three levels was used as the experiment for testing the machine. The factors are; feed rate, air speed and crank amplitude. Four levels of the feed-rate (F_1 = 800Kg/hr., F_2 = 1000Kg/hr., F_3 = 1200Kg/hr. and F_4 = 1400Kg/hr.) was considered, four levels of air speed (S_1 = 2.5 m/s, S_2 = 4.5 m/s, S_3 = 6.0 m/s, and S_3 = 8.0 m/s) and three levels of crank amplitude (C_1 = 10 mm, C_2 = 25 mm and C_3 = 40 mm). The experimental factors were combined randomly in a layout of 48 treatment units and replicated three times to give a total of 144 experimental units.

Statistical Analysis Software (SAS) was used to analyze the data obtained from the performance analysis of the machine. The effect of variation of the variables and their interactions was verified at 5% level of significance and significant factors were further analyzed using the least significant difference (LSD).

III. RESULTS AND DISCUSSION

3.1 Grain Cleaning

3.1.1 Output capacity

The analysis of variance (ANOVA) results for output capacity of the developed machine is shown in Table 2.0. The table shows that the effects of the main factors (feed rates, air speeds and crank amplitudes) on the machine output capacity is highly significant at both 1 % and 5 % probability levels. The first and second order interactions of the variables are also highly significant at the same probability levels. The high significant differences between the variables, their interactions and the effect on machines output capacity is an indicate that the output results can be altered by any slight change in value of the variables.

Further analysis was carried out using the least significances difference (LSD) as shown in Table 3.0. The LSD reveals that the mean output capacity at 1400kg/hr. feed rate is statistically higher than the values produced by 800, 1000 and 1200kg/hr. feed rates, although the optimum output was achieved at 1200kg/hr. The output capacity of the machine showed a progressive pattern of an increasing value with increase in feed rate, from the lowest feed rate (800kg/hr.) to the highest (1400kg/hr.).

The effect of air speeds on output capacity was also found to be highly significant. The LSD reveals that the best performance was produced by the 4.5 m/s air speed followed by 2.5 m/s, then the 8.0 and 6.0 m/s air speeds. The output capacity followed a polynomial pattern, where it progressed from the 2.5 m/s air speed to a peak value at 4.5 m/s, and thus, decreased to the minimum value at 6.0 m/s and rising up again.

The mean output value at 25 mm crank amplitude was the best output. It was statistically higher in value than the result from the 40 and 10 mm crank amplitudes.

Table 2.0 Analysis of Variance (ANOVA) Results for Output Capacity

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Pr > F
Replication, R	2	180.50	90.25	0.25	0.7769
Air speed, S	3	428280.75	142760.25	400.40**	<0.0001
Feed rate, F	3	4273388.75	1424462.92	3995.15**	<0.0001
Crank Amplitude, C	2	93840.50	46920.25	131.60**	<0.0001
S x F	9	187596.25	20844.03	58.46**	<0.0001
S x C	6	63727.50	10621.25	29.79**	<0.0001
C x F	6	102485.50	17080.92	47.91**	<0.0001
S x F x C	18	121626.50	6757.03	18.95**	<0.0001
Error	94	33515.50	356.55		
Total	143	5304641.75			

** --- Highly significant

Table 3.0 LSD of variables for output capacity of machine

FEED RATE		**AIR SPEED**		**CRANK AMPLITUDE**	
Levels (kg/hr.)	**Mean (kg/hr)**	**Levels (m/s)**	**Mean (kg/hr)**	**Levels (mm)**	**Mean (kg/hr)**
1400	1088.50a	4.5	912.83a	25	866.63a
1200	865.67b	2.5	841.83b	40	813.50b
1000	747.17c	8.0	801.83c	10	811.50b
800	620.83d	6.0	766.17d		
Critical value = 0.1473		**Critical value = 0.1473**		**Critical value = 0.1275**	

3.1.2 Cleaning efficiency

The analysis of variance (ANOVA) results for grain cleaning efficiency is shown in Table 4.0. The result shows that the effects of feed rate, air speed and crank amplitude on cleaning efficiency of the grains is highly significant. The first and second order interactions of the variables are also highly significant with cleaning efficiency.

Further analysis using the LSD shows that the 800kg/hr. feed rate produced the best efficiency. The LSD result is shown in figure 5.0. The cleaning efficiency decreased with increase in feed rate in the order of 800, 1000, 1200 and 1400 kg/hr. The phenomena may be attributed to the fact that at high feed rates, there are more materials at the cleaning chamber to be cleaned than at lower feed rates. As the feed rate continuously increase, the material flowing across the air current forms a thicker blanket which makes it more difficult for the air current to penetrate and flush out the unwanted material, therefore, more of the foreign materials move along with the grains. The finding agrees with the works of Simonyan et al. (2007) and Muhammad et al. (2013) who both reported decreasing cleaning efficiency with increasing feed rates for sorghum grain. The increasing load intensity of materials may also be the reason for the decrease in cleaning efficiency.

The LSD for the effect of air speed on cleaning efficiency indicate that the best result was achieved at air speed of 4.5 m/s. The mean cleaning efficiency for 6.0 m/s was the second best followed by 8.0 m/s and then 2.5 m/s. This behaviour of the cleaning efficiency with increase in air speed may be due to the increasing load across the air stream. Air speeds below and above the range of the grains terminal velocity yielded poor results, while the observed best performance was within the range of the velocity of SAMSORG 43 grains.

Table 4.0 Analysis of Variance (ANOVA) Results for Percentage Cleaning efficiency

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Pr > F
Replication, R	2	0.228	0.114	1.55**	0.2175
Air speed, S	3	5.910	1.970	26.79**	<0.0001
Feed rate, F	3	7.070	2.357	32.05**	<0.0001
Crank Amplitude, C	2	3.573	1.786	24.30**	<0.0001
S x F	9	15.339	1.704	23.18**	<0.0001
S x C	6	2.118	0.353	4.80**	0.0003
C x F	6	3.381	0.564	7.66**	<0.0001
S x F x C	18	12.465	0.692	9.42**	<0.0001
Error	94	6.911	0.074		
Total	143	56.996			

** --- Highly significant

Table 5.0 LSD of the variables for cleaning efficiency of machine

FEED RATE		**AIR SPEED**		**CRANK AMPLITUDE**	
Levels (kg/hr.)	**Mean (%)**	**Levels (m/s)**	**Mean (%)**	**Levels (mm)**	**Mean (%)**
800	98.64a	4.5	98.66a	25	98.60a
1000	98.50b	6.0	98.50b	40	98.32b
1200	98.37c	8.0	98.27c	10	98.24b
1400	98.04d	2.5	98.13d		
Critical value = 0.1269		Critical value = 0.1269		Critical value = 0.1099	

An increase in the quantity of grains and foreign materials across the air flow causes turbulence, while a decrease will lower the free stream turbulence intensity which causes the drag coefficient to decrease. Simonyan et al. (2007) reported a decrease in cleaning efficiency for sorghum as a result of increasing air speed and they attributed it to the reduction in the resident time of flight of the materials to be cleaned within the air stream. They also reported that when the resident time is longer, the efficiency of separation is affected positively and there are greater likelihoods for the lighter particles to be displaced by the air stream.

The results for the effect of crank amplitudes on cleaning efficiency as shown by the LSD reveals that the 25 mm, crank amplitude produced the highest mean cleaning efficiency. The result shows a polynomial relationship within the range of amplitude considered. The cleaning efficiency increased from the 10mm crank amplitude to a peak value at 25mm and decreased afterward to the 40mm amplitude. The rising and falling trends observed on the cleaning efficiency with increasing sieve oscillations may be due to less resident time of the materials to be separated on the sieve.

3.1.3 Scatter loss

The analysis of variance (ANOVA) results for percentage scatter loss of the prototype cleaning machine is presented on Table 6.0. The results show that the effect of feed rates and air speeds on the scatter loss of the machine are highly significant while that of the crank amplitudes is significantly different, but the results for a combination of any two or more variables is not significant.

Table 6.0: ANOVA Results for Scatter loss

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Pr > F
Replication, R	2	904.780	452.390	1.02	0.3663
Air speed, S	3	9806.523	3268.841	7.33**	0.0002
Feed rate, F	3	8623.707	2874.569	6.45**	0.0005
Crank Amplitude, C	2	3007.815	1503.907	3.37*	0.0384
S x F	9	6217.150	690.794	1.55NS	0.1420
S x C	6	2361.799	393.633	0.88NS	0.5105
C x F	6	3564.602	594.100	1.33NS	0.2503
S x F x C	18	12256.809	680.933	1.53NS	0.0975
Error	94	41893.811	445.679		
Total	143	88636.996			

NS - Not significant
* - Significant
** - Highly significant

Table 7.0: LSD of variables for percentage scatter loss

FEED RATE		**AIR SPEED**		**CRANK AMPLITUDE**	
Levels (Kg/min)	**Mean (%)**	**Levels (m/s)**	**Mean (%)**	**Levels (mm)**	**Mean (%)**
1400	2.25a	8.0	2.89a	40	2.52a
1200	2.57a	6.0	2.76ab	10	2.73ab
1000	2.09a	4.5	1.11bc	25	1.33b
800	1.52b	2.5	1.68c		
Critical value = 9.89		Critical value = 9.89		Critical value = 8.56	

Table 7.0 shows the LSD for the effect of the variable on machine scatter loss. The result shows that scatter loss increased with increase in feed rate form the lowest value at 800kg/hr. to the highest at 23.3kg/hr. feed rate. Muhammad et al. (2013) reported a polynomial relationship between grain scatter loss and feed rate for sorghum grains.

The LSD results further reveals that the air speed of 8.0m/s produced the highest mean scatter loss and the value is statistically different from the mean value for the other air speed levels considered, although it does not significantly differ in effect with the result for 6.0 m/s. The 2.5m/s air speed produced the least scatter loss. At higher air speeds, the grains and some of the particles are then blown away together with the chaff. A reduction in air speed which enhances the separation process causes more of the grains to move along with the unwanted material and be collected at the outlet. Muhammad et al. (2013) reported a polynomial relationship between fan speed and grain scatter loss for sorghum. The LSD reveals that the 40 mm crank amplitude produced the highest loss.

3.2 Grain Grading

3.2.1 Effects of the feed rate on grading efficiency

The effects of feed rate on grading efficiency of the machine is shown in Figures 4.0. The result showed a linear negative correlation between grading efficiency and feed rate. Grading efficiency decreased with increase in feed rate. The grading efficiencies of grade A grains decreased from 78.68 to 70.19 % (10 % decrease), while grade B decreased from 75.32 to 69.09 % (8.27%, decrease). The effect of feed rate on grading efficiency of SAMSORG 43 shows a similar trend to that of feed rate and cleaning efficiency, where the efficiencies decreases with increase in the feed values. The coefficient of determination (R^2) for the relationship between feed rate and grading efficiency are; 0.9951 and 0.9909 for grades A and B, respectively. Salwa et al., (2010) reported that high feed rates create a thick layer of the material on the screen, and causes a considerable deterioration of the conditions required for the grains to penetrate through the sieve perforations. Simonyan et al. (2007), Salwa et al., (2010), Muhammad et al. (2013), and Yayock and Ishaya

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(2020) all reported that efficiency decreases with increasing feed rates. It can therefore be deducted that, at higher feed rates the grading performance of grading machines often results to poor graded grains.

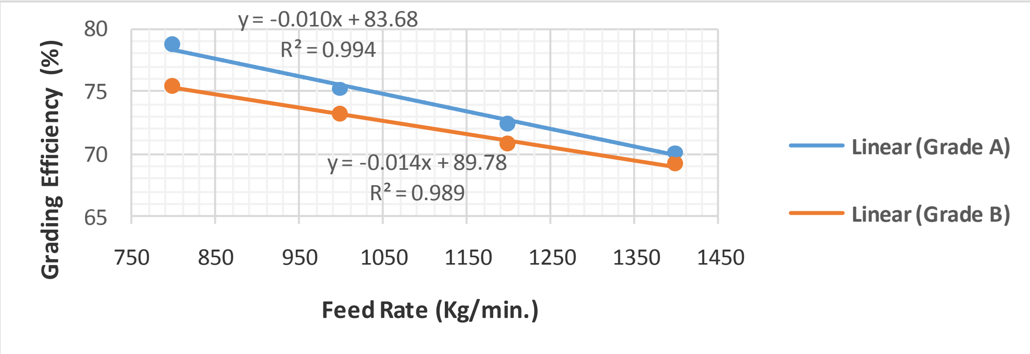

Figure 4.0: Effects of the crank amplitude on grading efficiency

3.2.2 Effects of air speed on grading efficiency

Figures 5.0 shows the effects of air speed on the grading performance of the machine. The grading efficiencies for the two grades, A and B showed an initial increase from the air speed of 2.5m/s to a peak value at 4.5m/s before decreasing with further increase in air speed. The best efficiency was observed at 45m/s for both grades. Simonyan et al. (2007) attributed the relationship between air speed and grain efficiency to the reduction in the resident time of flight of materials to be cleaned/graded within the air stream, which when the time is longer, will positively affect the outcome.

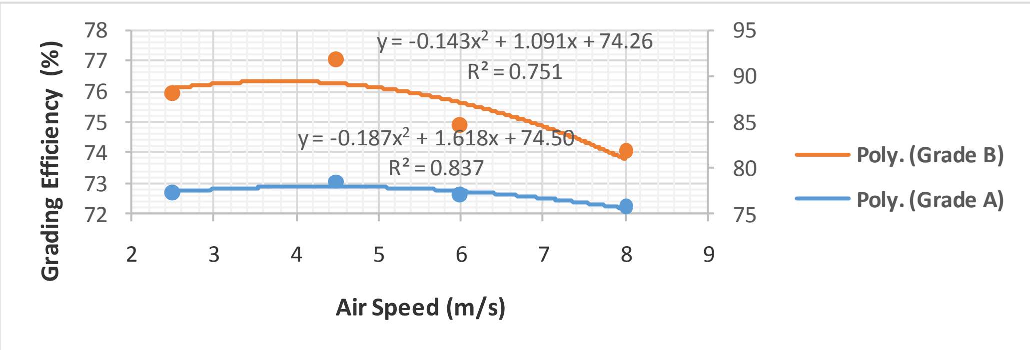

Figure 5.0: Effects of Feed Rate on Grading Efficiency

3.2.3 Effects of crank amplitude on grading efficiency

The effect of crank amplitude on grading efficiency is expressed in Figure 6.0. The relationship followed a polynomial pattern for both grades A and B. Both grades showed an increase in grading efficiency from the lowest crank amplitude of 10mm to a peak value at 25mm and then decreased to 40mm amplitude. The coefficient of determination (R^2) is 1 for both grades A and B.

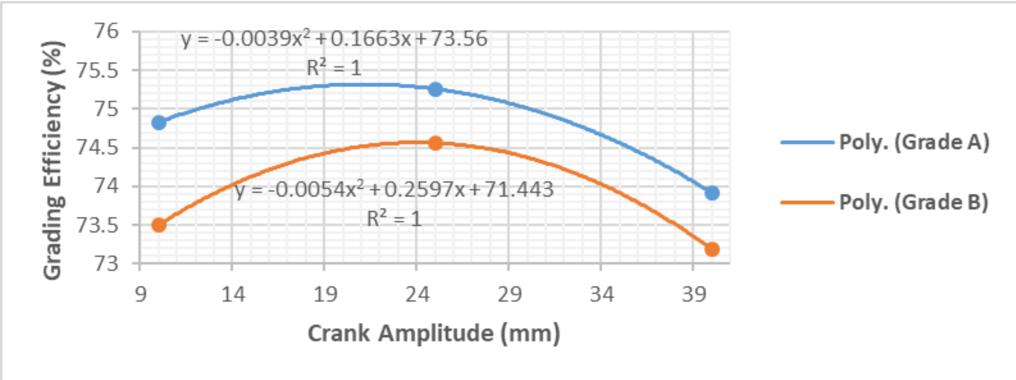

Figure 6.0: Effects of screen tilt angle on grading efficiency

IV. CONCLUSION

A multi-grain cleaning and grading machine was design and fabricated to meet the quality requirements of small farm holder and small scale seed processor in the post-harvest processing of their grains. The results of evaluation show that the performance parameters of the prototype machine ranged between; 620.83 and 1088.00 kg/hr. for the output capacity, 98.04 and 98.66 % for cleaning efficiency, and 1.11 and 2.89 % for grain scatter loss. The results for grading efficiency shows that the efficiency of grade A grains ranged between 70.19 and 78.68 %, while the grade B grains ranged between 69.09 and 77.04 %. The optimum performance of the machine in cleaning and grading was achieved at feed rate of 1200kg/hr., 4.5m/s air speed and 25mm crank amplitude.

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