PAT March, 2023 (Special Edition); 19(1): **81-86** *ISSN: 0794-5213*
Online copy available at www.patnsukjournal.net/currentissue
Publication of Nasarawa State University, Keffi

TEST-RUN OF PERFORMANCE EFFICIENCY OF A LOCALLY MADE GRAIN WINNOWER PROTOTYPE

B. B. Shani

Department of Crop and Soil Sciences, National Open University of Nigeria
Email: bshani@noun.edu.ng
GSM: +234-803-45745-44

Abstract
This study presents a novel device for cleaning threshed seeds of different crops using an air-blast fan and a reciprocating shaker with a replaceable sieve. The device was tested on sorghum, soybean, and millet, and the results showed that it achieved high cleaning efficiencies (95-98%) and low grain losses (0.63-0.81%) at optimal feed rates (2.5-6 kg) and fan speeds (415-582 rpm). The device is suitable for small-scale farmers who need a simple and effective way to process their harvested seeds.
Keywords: Mechanical design, performance efficiency, grain evaluation and winnower.

Introduction

Cleaning of grain or winnowing is an important process before preparing crop grains as food or industrial raw material. It involves the removal of chaff and other debris from the grain. There are quite a number of factors that affect the performance in terms of cleanliness and grain loss during the operation. Such factors include the amount of wind or air velocity, feed rate, and shaker frequency, dimension of sieve opening, sieve tilt angle, crop variety, and moisture content (Kirk et al., 1978; Nurul Islam, 1980; Sharma, 1976; Mohammed, 1984). Winnowing is the method of extracting grain from a mixture of grain and chaff in a naturally or artificially produced air stream. Separation is achieved by allowing the airstream to pass through the falling mixture vertically downwards. The grain being a heavier material is deposited nearly at the dropping place, whereas lighter material (chaff) is blown away to a greater distance. Winnowing operation in India is performed on a threshing floor, where all harvested crops are stacked in bundles. (Behera et al, 2020)

Traditionally, winnowing is carried out to separate the straw from the paddy by creating an air draft or natural wind by dropping the grain from a pan or scoop from a certain height in the blowing wind. This is a very simple and effective method, the but output is very low, that is, 40-45 kg/h (Singh and Gite, 2007). In Nigeria, particularly in the North, crop cleaning is part of women's contribution in the processing of grains. A woven circular tray of an average diameter of 500mm made from the back of a sorghum stalk is used. The cleaning operation is usually done in an open space when there is a free flow of natural wind. A batch of about one kilogram of threshed seeds is placed on the tray and then shaken to and fro, upwards and downwards in a systematic manner. Due to the tossing and reciprocating motion of the tray and with the aid of natural air current, the lighter material moves towards the front edge of the tray until it falls out and gets blown off from the winnower. Subsequently, only the clean seeds would remain on the tray. The time taken to clean a batch of one kilogram of unclean seeds ranges between seven to twelve minutes depending on the winnower's skill, the required cleanliness, grain/non-grain ratio, amount and stability of the natural air current, and other environmental factors (Gadu, 2000 and Ajoko, 2005). The long hours associated with the traditional method result in fatigue, loss of concentration, and consequently, reduction in separation quality. So often the natural wind condition may not be favorable for the operation and the result is increased time of operation and drudgery. The high cost of the thresher–cleaner machine is due to the additional cost of the thresher component which is not needed by an average farmer. The average farmer finds it more economical to thresh manually but is highly laborious and time-consuming to clean the grain using the manual method. A machine for cleaning grains is, therefore needed to satisfy both small and average farmer requirements.

Li et al. (2022) analyzed the rice grain collision behavior and monitoring mathematical model development for grain loss sensors4. They found that the fan speed has a significant impact on the grain sieve loss in the monitoring area, and with an increase in the fan speed, the corresponding grain sieve loss increases significantly. They also established a grain loss distribution function at the end of the sieve and a monitoring mathematical model with relevant variables based on the laboratory experiment results. The objective of this work was to develop a crop-grain cleaning machine and evaluate its performance using sorghum, soybean, and millet as the test crops.

Materials and Methods

The Physical and Engineering properties of the grain and non-grain material were considered in the determination of the design parameters of the cleaning device. These properties include size, shape, and angle of repose of the grain. Also considered were moisture content, density, and terminal velocity of the grain and non-grain material. The parameters established include: Fan size and speed, Sieve mesh, Shaker frequency, and amplitude Shaker size and tilt angle and Power requirement

Description of the Prototype

The machine comprises mainly the hopper, the fan, the shaker, and the supporting frame. The hopper is made of a gauge 18 metal sheet with a trapezoidal cross-section. The sides slant inwards to form the hopper outlet situated above the shaker.

Table 1: Description of Materials of the components of Winnower Machine

S/N	Description and specification	Qty	Material
1.	Prime mover (Electro motor) (2 hp 2000rpm)	1	
2.	Pulley (Ø100 x 25mm)	1	M.S
3.	Pulley (Ø180 x 25mm)	1	M.S
4.	Pulley (Ø160 x 25mm)	1	M.S
5.	Belt (v- type, 1200 x10x9mm)	1	Leather
6.	Belt (v- type, 1100 x10x9mm)	1	Leather
7.	Flopper (400 x 300 x 300mm)	1	M.S. sheet (Gauge 18)
8.	Shaker (680 x 400 x 530mm)	1	M.S. sheet (Gauge 16)
9.	Bolt (Ø14mm)	1	M.S
10.	Fan Housing (Ø500mm x 430mm)	1	M.S. sheet (Gauge 18)
11.	Frame (25 x 25mm angle iron)	1	M.S Angle iron
12.	Connecting rod (Ø25mm iron rod)	1	M.S Rod
13.	Fan shaft (Ø25 x 460mm)	1	M.S Rod
14.	Grain outlet (280 x 150 x100mm)	1	M.S. sheet (Gauge 18)
	Scale 1:5 Dimension in mm		

The fan has blades enclosed in the casing whose outlet is located to deliver a current of air over the shaker along the reciprocation direction of the shaker. The shaker assembly consists of three a sieve, a grain collecting pan, and a clean grain outlet. It is suspended from the frame on four bearings each attached to a 12mm x 100mm bolt and nut to facilitate adjustment in the tilt angle ranging from 1 to 30o. A crank mechanism with an adjustable crank and connecting rod to achieve various levels of reciprocating amplitudes was used to drive the shaker. A 2.24 kW prime-mover was mounted on the frame to power the fan and the crank mechanism using a belt and pulley drive. The frame which holds all the components together at their relative positions was constructed using a 3mm x 38 mm x 38 mm angle iron. The major components of the prototype are shown in the assembly drawing (Figure 1) and Description of materials as shown in Table 1.

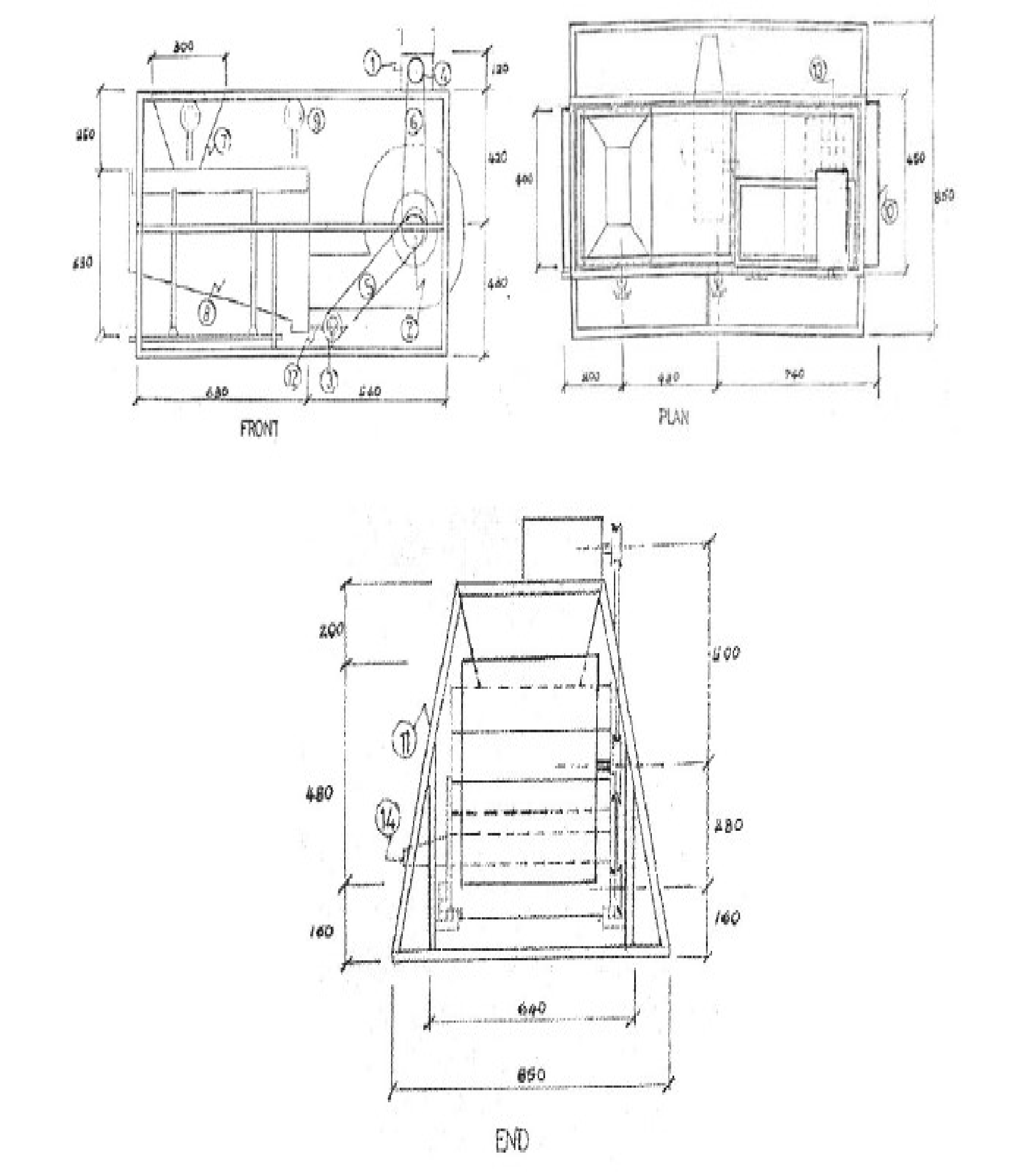

Figure 1. Detailed Assembly Drawing of the Winnower Machine

Operation of the Prototype

The machine is operated by starting the prime mover which drives the fan and the shaker assembly simultaneously. A batch, at a time, of threshed grain containing both grain and non-grain material is then fed into the machine through the hopper. It flows down by gravity and passes through the hopper outlet and drops across the fan air current onto the shaker sieve. The non-grain material being lighter is blown out of the machine through the outer end of the shaker. The grain material passes through the sieve mesh onto the grain collecting pan and subsequently, flows down the slope of the pan and the grain outlet where it is collected. The broken stalks and other debris that reach the surface of the sieve are moved by the air current and discharged at the outer end of the shaker.

Test Procedure

The test involves taking a pair of samples which were at the grain outlet and at the non-grain (unwanted material) outlet. The weights of grain and other material in each sample was recorded. The procedure was repeated for each throughput. The amount of debris in clean grain outlet samples determined the cleanliness (cleaning efficiency) while the amount of grain found in non-grain outlet samples determines the grain loss. The expressions used for calculating the percent cleaning efficiency and percent grain loss were as follows:

$$(i)\ E_C = \frac{W_G}{W_{TG}} x\ 100$$

$$(ii)\ G_L = \left[\frac{W_{GN}}{W_G + W_{GN}}\right] 100$$

Where,
EC = Percent cleaning efficiency
GL = Percent grain loss
WG = Weight of grain material in clean-grain sample
WTG = Weight of total material in clean-grain sample
WGN = Weight of grain material in non-grain sample
WTN = Weight of total material in non-grain sample

The data was recorded at four levels each, of feed capacity, shaker frequency, shaker amplitude, and fan speed while each experimental unit was replicated three times.

Results and Discussion

Table 1: Presentation of Test Results of Machine parameters

Replication	Fan speed	% Feed rate Kg/s	Cleaning efficiency%	% Grain loss
1	850	0.25	100	2.5
2	800	0.43	98	3.2
3	750	0.49	90	4.0
4	650	0.51	89	5.4
5	550	0.65	84	6.3
6	450	0.72	80	7.5
7	350	079	78	8.4
8	250	0.88	77	8.9
9	150	0.92	74	9.2
10	100	1.02	69	10.2

Effect of Feed Rate on the Machine Performance

Figure 1 and Table 1 show the effect of feed rate on cleaning efficiency and grain loss. The regression analysis showed a high linear correlation of feed rate with cleaning efficiency for each of the test crops with a coefficient of determination of 0.97. The attainment of 100% cleanliness was at feed rates of 0.25 kg. However, the cleaning efficiency decreased with an increase in feed rate at the rate of 6.0% per kg/s. This shows an indirect relationship between changes in feed rate and cleaning efficiency. The figure also presents the regression curves of percentage grain loss against feed rate for the test crop. The relationship shows minimum percentage grain losses of 2.5 corresponding to feed rates of 0.25kg/s. The percentage of grain loss for the crop increased either with another increase or decrease of feed rate from the minimum points.

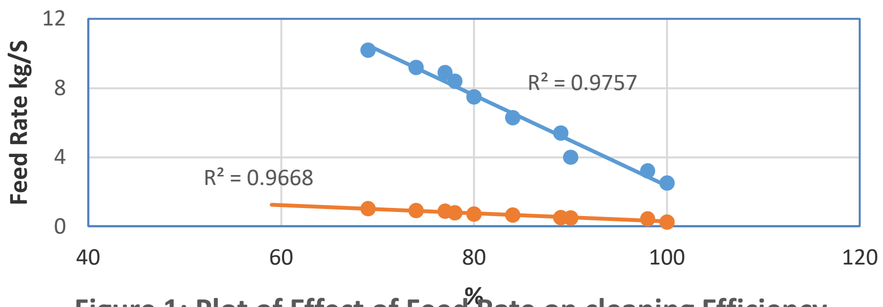

Figure 1: Plot of Effect of Feed Rate on cleaning Efficiency and Grain Loss

The optimum cleaning efficiencies of the crop was considered as those corresponding to minimum percentage grain losses which was 98%.

Effect of Fan Speed on the Machine Performance

Fan speed exhibited positive linear relationship with cleaning efficiency with coefficient of determination of 0.94 as shown in Figure 2. The rates of percentage increase in cleanliness with increase in fan speeds were 0.06%per rpm and attained 100% cleanliness at fan speed corresponding to 850rpm.

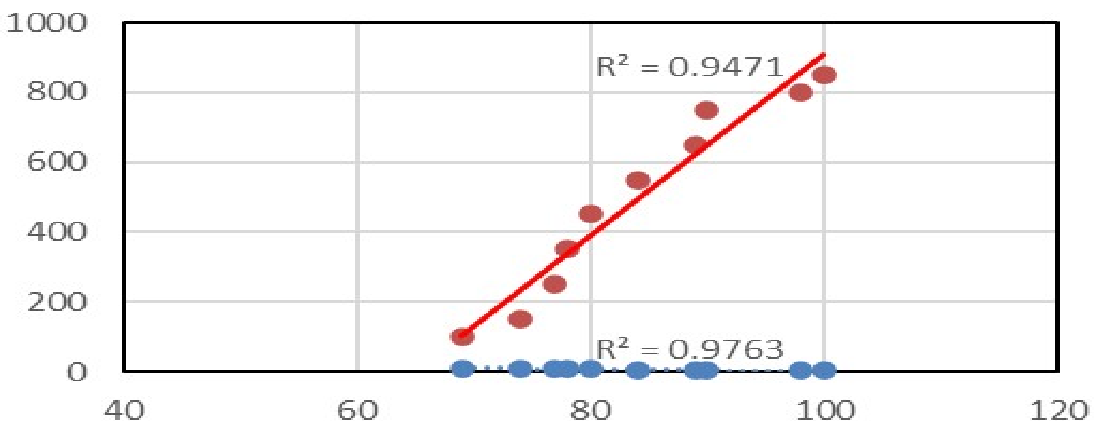

Figure 2: Plot of Effect of Feed Rate on cleaning Efficiency and Grain Loss

Relationship between fan speed and percentage grain loss - shown in Figure 2 were there was polynomial relationship with minimum values of grain loss for the respective crops as 105, 1.3 and 4.8% corresponding to fan speeds of 350, 400 and 250 rpm. The grain loss for each of the crops increased with either further decrease or increase of fan speed from the value corresponding to minimum grain loss.

The percentage cleaning efficiency for the three crops corresponding to the minimum percentage grain loss were 82, 85 and 72% for sorghum, soyabean and millet respectively. These values do not indicate satisfactory cleanliness and cannot represent the optimum values. The results align with the findings of Liang et al., (2019) who developed a grain sieve loss fuzzy control system in rice combine harvesters. They investigated the effects of fan speed, guide plate angle, and sieve opening on the grain sieve loss and grain impurity ratio through a large number of bench tests. They also designed a fuzzy control model for the cleaning system that can control the fan speed and guide plate angle automatically, and reduce the grain sieve loss to some extent.

Concession should be made to consider fan speeds that give better cleanliness at the expense of more grain loss for each of the crops. Average fan speed of that corresponding to minimum grain loss and that at 100% cleanliness for each of the crops should be considered as the optimum fan speed, together with its corresponding grain loss and cleanliness. These optimum values of percentage grain losses were 4.0, 3.5 and 5.5% corresponding percentage cleaning efficiencies were 92, 93 and 86% respectively for sorghum, soybean and millet.

Conclusion

This paper presents a novel cleaning machine for crop seeds that uses an air-blast fan and a reciprocating shaker with a replaceable sieve. The machine was tested on three crops: sorghum, soybean, and millet. The results showed that the cleaning efficiency and the grain loss of the machine were influenced by the feed rate and the fan speed. The optimal values of these parameters were determined by balancing the trade-off between cleanliness and grain loss. The optimal feed rates were 0.23, 0.30, and 0.27 kg/s, and the optimal fan speeds were 505, 582, and 415 rpm for sorghum, soybean, and millet, respectively. These values resulted in cleaning efficiencies of 92, 93, and 86%, and grain losses of 4.0, 3.5, and 5.5%, respectively. The maximum outputs of the machine for the three crops were 414, 540, and 486 kg/h. The machine is suitable for small-scale farmers who need a simple and effective way to process their harvested seeds.

References

Behera, A., Sahoo, A. U., Swain, J. R., Kar, S., & Mahapatra, M. (2020). Development and evaluation of a hand operated double chain-sprocket winnower for cereal crops. International Journal of Current Microbiology and Applied Sciences, 9(3), 2319-7706.

Kashayap, M. M., & Pandya, A. C. (1966). A qualitative theoretical approach to the problem of winnowing. Journal of Agricultural Engineering Research, 11(1), 40.

Kirk, T. G., Campbell, D. W., Pickering, W. D., Stanley, G. W., Scheenan, G. J., & Wilson, J. N. (1978). Evaluation of a simulation model of combine harvester. In Proceedings of the International of Grain and Forage Harvesting Conference (pp. 1-10). ASAE.

Li, D.; Wang, Z.; Liang, Z.; Zhu, F.; Xu, T.; Cui, X.; Zhao, P. Analyzing Rice Grain Collision Behavior and Monitoring Mathematical Model Development for Grain Loss Sensors. Agriculture 2022, 12, 839

Liang, Z., Li, Y., & Xu, L. (2019). Grain sieve loss fuzzy control system in rice combine harvesters. Applied Sciences, 9(1), 114.

Nurul Islam. (1980). Design and construction of manually operated seed cleaning and grading machine. Agricultural Mechanization in Asia, Africa and Latin America, 11(1), 56.

Singh, S. P., & Gite, L. P. (2007). Ergonomic evaluation of a hand operated paddy winnower by women workers. Journal of Agricultural Engineering, 44, 67-71.

Sharma, A. P. (1976). Design and development of winnowing machine. Agricultural Mechanization in Asia, Africa and Latin America, 12(24), 25.