Evaluation of the Performance of a Rotary Screen Cowpea Cleaner- A Response Surface Approach

*Adewole A. Aderinlewo, Samuel A. Ayokambi, Olawale U. Dairo and Olayemi J. Adeosun

Department of Agricultural and Bioresources Engineering, Federal University of Agriculture, Abeokuta, Nigeria
{aderinlewoaa|dairoou|adeosunoj}@funaab.edu.ng| samuelayokambi@gmail.com

Abstract— The performance of a rotary screen cowpea cleaner was evaluated at angles of inclination of 5, 10, 15 and 20^o, screen speed of 115, 145 , 200 , 280 and 300 rpm with corresponding air velocity of 0.3, 1.3, 2.2, and 2.7 m/s using two varieties of cowpea namely Ife brown and IT90K-277-2. The results show that for Ife brown the highest cleaning efficiency of 71.12% was obtained at angle of inclination of 5^o, screen speed of 315 rpm and air velocity of 3.5 m/s. The highest cleaning efficiency for IT90K-277-2 of 68.89% was also obtained at the same angle of inclination, screen speed and air velocity. Response surface plots for both varieties showed that increase in air velocity produced more increase in the cleaning efficiency than increase in screen speed. Mathematical equations for predicting the cleaning efficiency for both varieties were also determined.

Keywords— Rotary screen, cowpea, cleaning efficiency

1 INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is an annual legume that is widely grown and consumed in Nigeria. It has been observed that freshly harvested and threshed cowpea in Nigeria contains between 27-33% impurities and this poses threat to human consumption and large scale agricultural processing (Adetunji, 2012). This has necessitated the development of cleaning machines such as rotary screen cleaner for removing these impurities from cowpea (Aderinlewo and Adetunji, 2013).

Cleaning is an important post harvest operation that is aimed at removing impurities or contaminants from harvested grains. It is an indispensable operation before drying, storage, marketing or further processing of the products. Clean and homogenous grains attract a high premium, resulting in high profit from sales to farmers. Thus several researchers have developed different cleaning machines for different grains such as air-screen cleaner for beniseed (Akinoso *et al*, 2010), continuous flow cowpea cleaner (Aguirre and Garay, 1999), reciprocating screen cereal cleaner (Okunola and Igbeka, 2009), Chickpea cleaner (Tabatabaeefar *et al*, 2003), air screen cleaner for rice (Pasikatan, 1996), rasp-bar sorghum thresher cum cleaner (Simonyan and Yiljep, 2008), rotary screen cleaner for cowpea (Aderinlewo and Adetunji, 2013). Most of these researchers reported that cleaning on these machines is influenced by factors such as air velocity, injection angle, amplitude and frequency of oscillation of sieves.

Response surface methodology is a collection of statistical and mathematical techniques that can be used for analyzing, modeling, developing, improving, and optimizing processes (Montgomery *et al*, 2001). This work was therefore carried out to evaluate the performance of a rotary screen cowpea cleaner using response surface methodology to analyse the effect of factors such as air velocity, screen speed and angle of inclination on cleaning efficiency.

* Corresponding Author

2 MATERIALS AND METHOD

The materials used for this work include two freshly harvested varieties of cowpea namely IT90K-277-2 and Ife brown and their impurities obtained from Institute of Agriculture research and Training, Ibadan and a rotary screen cowpea cleaner developed at the Department of Agricultural and Bio-resources Engineering, Federal University of Agriculture, Abeokuta. The moisture content of the cowpea varieties were determined by oven drying method and were found to be 12.4% wet basis (Aderinlewo *et al.* 2016).

2.1 DESCRIPTION OF THE ROTARY SCREEN CLEANER

The rotary screen cleaner consists of three main components namely a hopper, a centrifugal blower and a rotary screen. The hopper was fitted above the rotary screen. The centrifugal blower was positioned between the hopper and the rotary screen so that light weight impurities can be blown away before entering the rotary screen. The centrifugal blower was made of three plates attached to a bracket mounted on a shaft. It was driven by a 1 horse power, 960 rpm electric motor which also powers the rotary screen. The rotary screen is of diameter 300 mm and length 500 mm. The screen opening is circular and is of diameter 6 mm. Power transmission was by V-belt and pulley arrangement. The isometric view and picture are shown in Figures 1 and 2.

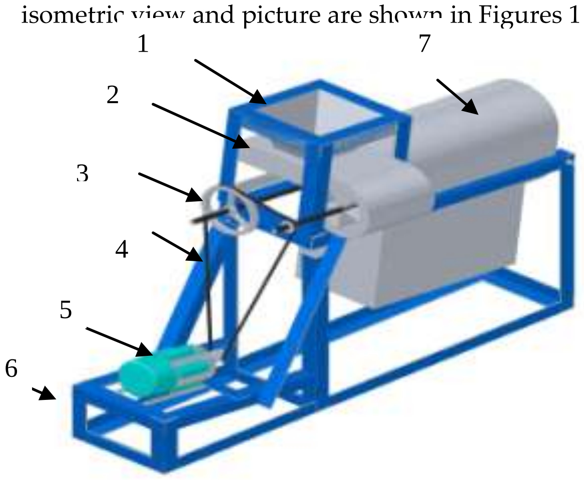

Fig. 1: Isometric view of the cleaner
1: Hopper ,2: Blower, 3: Pulley, 4: V-belt,
5: Electric motor, 6: Motor stand,7: Screen Case

Fig. 2: Picture of the cleaner

2.2 Determination of Cleaning Efficiency

Each of the two varieties of cowpea was contaminated with the impurities to a level of 10 %. 240g each of the mixture of sound grain and impurities were injected into the rotary cleaner at different angles of inclination of the screen namely 5, 10, 15 and 20° and screen speed of 115, 145 , 200 , 280 and 300 rpm. The air velocities at these screen speeds were measured with a digital anemometer and were found to be 0.3m/s, 1.3m/s, 2.2m/s, and 2.7m/s. This was replicated three times. On each occasion the cleaning efficiency of the machine were evaluated using the relation (Panasiewicz, 1999: Aderinlewo and Raji, 2013):

$$n = \frac{W_1}{W_0}.100 \qquad (1)$$

Where n = cleaning efficiency, %

W_0 = total mass of impurities in initial material, g

W_1 = mass of impurities separated from initial material, g

Central composite rotatable design of response surface methodology was used to generate surface plots to show the response of the cleaning efficiency to input variables namely angle of inclination, air velocity and screen speed and also to develop a regression model for predicting the cleaning efficiency using Design Expert 8.

3 Results and Discussion

The results of the cleaning efficiency obtained at different angles of inclination, screen speed and air velocities for the two varieties are presented in Tables 1 and 2. The highest values of the cleaning efficiencies for Ife brown were obtained at angle of inclination of 5° and it increased with increase in screen speed and air velocity. The cleaning efficiency also increased with increase in screen speed and air velocity at angle of inclination of 10° but at angles of 15° and 20° it tend to decrease with increase in screen speed and air velocity.

The highest cleaning efficiency of 71.12% for Ife brown was obtained at angle of inclination of 5°, screen speed of 315 rpm and air velocity of 3.5 m/s while the lowest was 25.73% at the same screen speed and air velocity but at angle of inclination of 15°. The surface plot at angle of inclination of 5° shows that increase in air velocity produces more increase in the cleaning efficiency than increase in screen speed as shown in Fig.3. Similar observations were made at other angles of inclination.

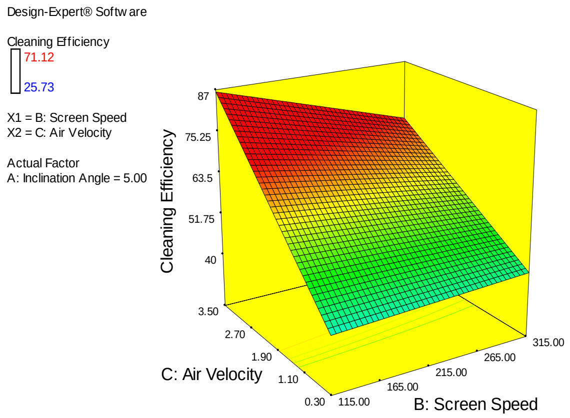

Fig. 3: Surface plots of cleaning efficiency of Ife brown.

The mathematical model for predicting the cleaning efficiency from the dependent variables for Ife brown is as expressed below:

Cleaning Efficiency = 28.88 + 0.97*A + 8.94E-003*B + 24.94*C + 2.37E-003*A*B – 1.44*A*C – 0.029*B*C (2)

Where A = inclination angle; B = screen speed

C = air velocity; (R^2 = 0.89)

For IT90K-277-2, the highest values of the cleaning efficiencies were also obtained at angle of 5° and it also increased with increase in screen speed and air velocity. The cleaning efficiency also increased with increase in screen speed and air velocity at angle of 10° but decreased at angles of 15° and 20°. The highest cleaning efficiency of 68.89% was obtained at angle of inclination of 5° and screen speed of 315 rpm and air velocity of 3.5 m/s (Table 2). The lowest was 21.64% obtained and same screen speed and air velocity but at angle of inclination of 20°. The surface plot at angle of inclination of 5° also shows that increase in air velocity produces more increase in the cleaning efficiency than increase in screen speed as shown in Fig. 4. This was also observed in the surface plots at other angles of inclination.

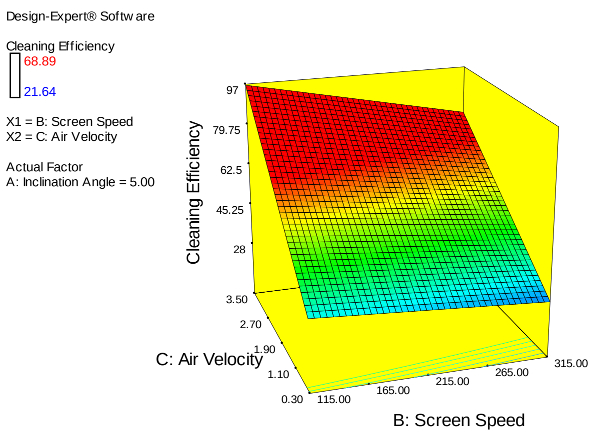

Fig.4: Surface plot of cleaning efficiencies of IT90K-277-2

Table 1. Cleaning efficiencies of **Ife brown** at different screen inclination, speed and air velocities

Angle of inclination, (°)	Screen Speed, (rpm)	Air Velocity, m/s	Cleaning Efficiency, %
5	115	0.3	39.39
5	145	1.3	57.94
5	200	2.2	61.92
5	280	2.7	66.73
5	315	3.5	71.12
10	115	0.3	39.36
10	145	1.3	50.10
10	200	2.2	54.56
10	280	2.7	55.98
10	315	3.5	55.81
15	115	0.3	56.11
15	145	1.3	51.57
15	200	2.2	46.24
15	280	2.7	39.66
15	315	3.5	25.73
20	115	0.3	50.38
20	145	1.3	42.47
20	200	2.2	40.03
20	280	2.7	31.40
20	315	3.5	27.69

Table 2. Cleaning efficiencies of **IT90K-277-2** at different screen inclination ,speed and air velocities

Angle of Inclination, (°)	Screen Speed (rpm)	Air velocity, m/s	Cleaning Efficiency ,%
5	115	0.3	27.59
5	145	1.3	50.16
5	200	2.2	57.64
5	280	2.7	65.20
5	315	3.5	68.89
10	115	0.3	39.84
10	145	1.3	56.22
10	200	2.2	58.96
10	280	2.7	64.66
10	315	3.5	67.05
15	115	0.3	52.66
15	145	1.3	54.92
15	200	2.2	47.49
15	280	2.7	44.77
15	315	3.5	41.37
20	115	0.3	40.30
20	145	1.3	34.01
20	200	2.2	26.99
20	280	2.7	25.60
20	315	3.5	21.64

The mathematical model for predicting the cleaning efficiency from the dependent variables for IT90K-277-7 is as expressed below:

Cleaning Efficiency = +29.55 + 0.53 * A -0.063* B+30.87 *C +7.31E-003 * A *B -1.85*A * C -0.020 * B * C (3)
($R^2 = 0.82$)

The predicted and the actual cleaning efficiencies for both Ife brown and IT90K-277-2 are presented in Table 3. With R^2 of 0.89 for the predicting equation for Ife brown and R^2 of 0.82 for that of IT90K-277-2, the equations predict well the cleaning efficiencies for the two varieties of cowpea.

Table 3. Predicted and actual cleaning efficiencies for Ife brown and IT90K-277-2

	Ife brown		**IT90K-277-2**	
Angle of inclination (°)	Actual Cleaning Efficiency (%)	Predicted cleaning Efficiency (%)	Actual Cleaning Efficiency (%)	Predicted cleaning Efficiency (%)
5	39.39	40.42	27.59	24.90
5	57.94	54.26	50.16	52.58
5	61.92	63.98	57.64	65.46
5	66.73	65.22	65.20	67.73
5	71.12	69.95	68.89	77.07
10	39.36	44.46	39.84	38.99
10	50.10	51.47	56.22	48.49
10	54.56	55.37	58.96	55.04
10	55.98	53.97	64.66	55.59
10	55.81	53.37	67.05	58.79
15	56.11	48.51	52.66	43.07
15	51.57	48.68	54.92	44.40
15	46.24	46.77	47.49	44.61
15	39.66	42.72	44.77	43.46
15	25.73	36.78	41.37	40.52
20	50.38	52.55	40.30	47.16
20	42.47	45.89	34.01	40.31
20	40.03	38.16	26.99	34.19
20	31.40	31.47	25.60	31.33
20	27.69	20.19	21.64	22.25

4 Conclusions

1. For Ife brown the highest cleaning efficiency of 71.12% was obtained at angle of inclination of 5°, screen speed of 315 rpm and air velocity of 3.5 m/s.
2. The highest cleaning efficiency for IT90K-277-2 of 68.89% was obtained at angle of inclination of 5°, screen speed of 315 rpm and air velocity of 3.5 m/s.
3. Response surface plot at each angle of inclination showed that increase in air velocity produced more increase in the cleaning efficiency than increase in screen speed.

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