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RESEARCH TITLE

Design, Fabrication and Performance Evaluation of Wheat Grain Cleaner for Small-Scale Farmers

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Abstract

Wheat cleaner had been designed, manufactured and tested in the workshop of the department of agricultural engineering, faculty of agricultural sciences, university of Dongola, northern state of Sudan under collaboration of Alshamaliya for Agricultural Services Company, for the purpose of enhancing productivity for small-scale farmers who used to plant their saved wheat grains every season with all risk of weed infestation and low viability.

The prototype of wheat cleaner consists of; the hopper, the high capacity fan, the flat screen (which is the major cleaning unit), the clean grain pan and the trash pan. The gauge of the screen is 2 mm and it is inclined 20° by jackscrew to facilitate the ease of flow of materials in the screen. The machine is operated by a 0.6 hp electric motor using a v-belt drive. The cleaning efficiencies of the machine were evaluated at two speeds of operation namely; 208 and 300 rpm.

The shape and diameter of screen holes which designated according to the geometric mean diameter for tested wheat has given a very good results based on efficiency of separating clean wheat grains (ξG), efficiency of separating materials other than grains (ξMOG), total cleaning efficiency (ξT) and percentage of product purity (%Pp) which were 99.8%, 88.89%, 88.68% and 99.43% respectively, at crank speed of 208 rpm.

Key Words: Wheat cleaner, Geometric mean diameter, Small-scale farmers.

1. Introduction:

Wheat is a strategic field crop in Sudan, since it constitutes the main staple food for most of the urban population. Its cultivation along the Nile banks in the Northern region, between latitudes 16° and 22°N dates back to 3000 B.C. Wheat cultivation in Sudan expanded recently to latitudes lower than 15° N as a winter crop, occupying the largest area in Sudanese irrigated schemes, and it is the second most important cereal crop after sorghum in the country (Ishag, 1994). The demand for wheat increased due to urbanization, but there is a large deficit of production compared to consumption. Average wheat yields in Sudan are very low, due to climatical and production factors. Nowadays, many different fertilizer forms are introduced in Sudan to raise wheat yields.

Up to date farmers in the northern state of Sudan tend to use their saved wheat seed instead of cleaned seeds provided by Ministry of Production and Economic Resources, on the one hand because of its high cost, and to guarantee free feed for their animals on the other hand. without considering the serious impact of weeds in reducing productivity, farmers believed that weeds which grow along with the main crop is a free supply for animal feeding and can save money that should be spent on commercial forage.

Many types of processing equipment have been developed and used in many parts of the world for grain threshing; however, most of these machines are expensive and require high power to operate, which are therefore beyond the reach of majority of small scale farmers. Hence, there is need to design, fabricate and evaluate wheat grain cleaner which is portable, low cost and can operate with electric motor or diesel engine in rural areas.

2. Literature reviews:

Weeds are one of the major constraints in potential yield of wheat. The losses caused by weeds vary depending on the weed species, their density, and environmental factors. Because of higher economic cost of labour for manual weeding and its lower efficacy, farmers are relying heavily on herbicides for effective weed control in different crops including wheat. Lack of labors and ignorance about the critical period of weeds removal are the limiting factors for early weeding and high yield. Until recently weeds did not constitute a threat to wheat production in northern Sudan. However, the use of uncertified seeds and grazing by animals of infested fields helped dissemination of seeds of some serious annual weeds viz., *Sorghum arundinaceum*. *Malva parviflora*. and *Sinapsis arvensis* throughout the regions (Mohamed and Mohamed, 1992-93). Today weeds present a serious problem to production of wheat in northern Sudan and that because most of the farmers use unclean wheat grains. Moreover, some farmers delay weeds control or don't control weed, thus leading to an increase in weed seed bank. The yield losses are mainly due to delayed weeding or insufficient weed control (Babiker *et al.*, 1995).

The primary method of seed cleaning is the air-screen separator. It uses a combination of air, gravity, and screens to separate seed based on size, shape, and density. These widely-use units come in a variety of models with two to eight vibrating screens. In all cases, the cleaning principles are the same. The seed mass drops onto the top screen which scalps and removes large trash and impurities. Seed and smaller trash pass through to the next screen which retains the seed and allows the trash to pass through. Multiple screens provide seed size and density separation. Air streams remove the trash and impurities and the seed moves to bagging or collection units. Numerous types and sizes of screen are available. The rate of feed, airflow, oscillation of the screens, and screen pitch are adjustable. With experience, an operator can set all the variables and achieve excellent results (Adewumi, 2012).

Igbeka (1984) designed and constructed a machine to sieve rice and beans. The machine had sieve angle of 4-5º with a specific angular velocity of 300-350 rpm. The sieving efficiency was from 20-61% for different moisture content and varieties.

Tabatabaeefar *et al.*, (2003) also designed and developed a machine to sieve and grade chick pea. The machine's fan speed, sieve slope and opening sizes of the sieves can all be adjusted, making it suitable for cleaning other crops. They found that the proper slope for sieve sizes 8, 7, and 6 mm was about 5º, and about 2º for the 10 mm sieve. The proper sieve (or screen) frequency was also determined to be 200 Hz. The separation efficiency of cleaned chickpea was determined to be 93% while the separation efficiency of MOP was 91%. The overall machine separating efficiency was 84% at 5.7 % moisture content, which is higher than reported by Igbeka (1984).

Okunola and Igbeka (2009) developed a portable cereal cleaning machine. Their machine used forced air from a rotary fan and reciprocating sieve driven by an eccentric shaft for separation of grain from grain-impurity mixture. The machine optimum performance was 98% product purity at a total separation efficiency of 71% for Paddy rice at 30º tilt angle.

Adetunji (2012) development a rotary-screen cleaner for Cowpea consists of; the hopper, the blower, the rotary screen (which is the major cleaning unit), the clean grain outlet and the impurity outlet. The machine optimum performance was 96.96% product purity at a total separation efficiency of 65.28% for Cowpea at 10º tilt angle.

3. Materials and methods:

3.1. Determination of geometric mean diameter:

A vernier caliper was used to measure three perpendicular diameters for wheat grains with 0.05 mm accuracy. In the case of seeds and grains, length, width, and thickness are often used, respectively, to designate the maximum, average, and minimum diameters (Edison and Brogan, 1972). From these axial dimensions, Dp for the seeds were determined as the geometric mean of the three dimensions given as (Mohsenin, 1970).

$$D_p = (abc)^{\frac{1}{3}} \tag{1}$$

Where: a = length, b = width and c = thickness

3.2. Determination of angle of repose for wheat:

Our experiment observed that angle of repose for wheat was 28° which was in accordance with the findings of Lorenzen (1957), Clover (1998) and Yasir *et al.*, (2012) (Table 1). The leg opposite and average of four values for leg adjacent were measured. The test was repeated three times and the average was measured.

$$\theta = arctan\frac{leg\ opposite}{leg\ adjacent} \tag{2}$$

Where: θ is the angle of repose.

Table 1: determination of angle of repose

No. of tests	Leg opposite (cm)	Leg adjacent cm				av. Leg adjacent (cm)	Angle (degrees)
		1	2	3	4		
1	4.50	9.50	9.30	9.30	8.80	9.23	26.00
2	4.60	9.10	8.50	8.40	8.10	8.53	28.35
3	4.70	8.20	7.20	8.60	8.20	8.05	30.28
average			**28.21°**				

3.3. Determination of the grains mass:

A digital (electronic) scale was used to measure grain weights for mass with 0.05 g accuracy. The average maximum, and minimum weight for each wheat grains were determined.

3.4. Physical properties of tested wheat:

One hundred samples of randomly selected wheat grains of a local Sudanese variety Imam, were measured for length, width, thickness, mass (n=1000 grains) and geometric mean diameter as given in Table 2;

Table 2: Physical properties of tested wheat

Physical properties	min	max	mean
Length l, mm	5.7	7.4	7.05
Width w, mm	2.9	3.7	3.8
Thickness t, mm	2.4	3.6	3.5
1000 grain mass, g	37.09	38.4	38.245
Geometric mean diameter mm	3.17	4.40	3.78

3.5. Screen characteristics:

Screens are characterized by parameters such as shape of opening, effective size of opening and the coefficient of opening, C_o.

For circular opening;

$$C_o = \frac{Opean\ \ Area}{Total\ \ Area} = \frac{3\pi}{2} \times \frac{D^2}{(D+d)^2} \quad (3)$$

Where;

D = diameter of hole = 2 mm

d = distance between the successive holes = 4.5 mm

For efficient screening, C_o is taken as 40% (Igbeka, 1984).

Screen size selection for this wheat cleaner is such that the screen retains whole grains until channeled into the good receptacle, broken grain and other undersize contaminant passes through it. Screen diameter of 2 mm was chosen.

3.6. Machine specifications:

The specification of the wheat cleaner as at the time of construction is shown in Table 3 below;

Table 3: Machine Specification

Component	Description
Overall length	2650mm
Overall width	1400mm
Overall height	1550mm
Machine capacity	42 kg/h
Power requirement	0.6hp with 1390rpm
Power transmission	V-belts drive with pulley diameters 285mm, 45mm and 45mm
Fan	Radial fan with 8 blades
Fan blade size	800mm by 130mm
Fan Housing	Ø450mm by 850mm
Airflow channel inlet size	630mm by 15mm
Fan shaft	Ø22mm by 1000mm
Number of screens (flat)	1; 1200mm by 730mm
hole diameters (round)	Ø2mm
Connecting rod length	300mm
Crank speed	208rpm

3.7. Operating principle:

The operation of the wheat cleaner can be described as follow:

The materials from farmer-saved wheat grains are fed in to the grains box to flow down freely and directly to the screen supported by gravity and control gate. while shaking, small materials other than healthy wheat grains (including broken grains and half-matured grains) drop down to the trash pan.

Air from the high capacity fan is directed to get rid of lighter trashes, whereas clean wheat grains is forwarded to the clean grain pan supported by gravity and inclination which is controlled manually by jackscrew in front of the machine (Figure 1 and Figure 2).

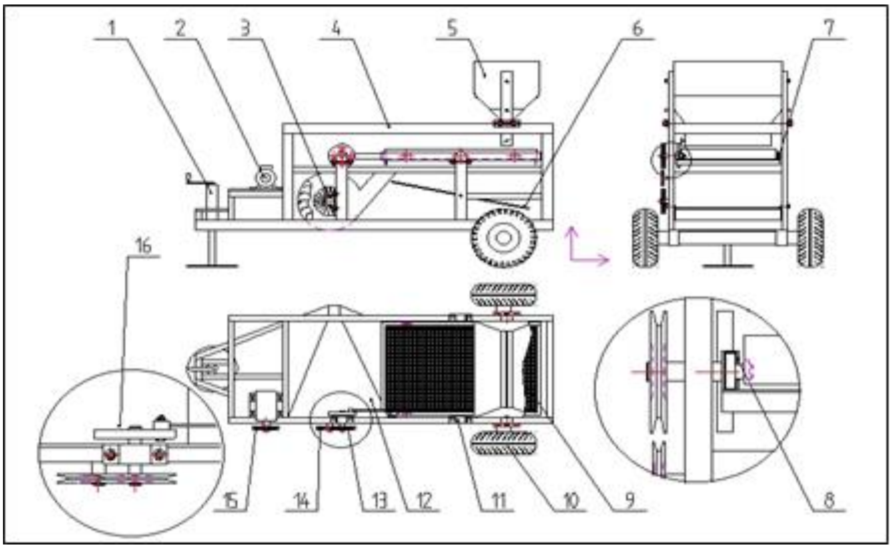

Figure 1: The major components of the prototype of wheat cleaner

1- jackscrew, 2- electric motor, 3- high capacity fan, 4- frame, 5- grains box, 6- trashes pan, 7-shaker, 8- bearing, 9- screen, 10- driving wheel, 11- bearing, 12- clean grains pan, 13- crank pulley, 14- fan pulley, 15- driving pulley, 16- crank.

Figure 2: (a) the prototype of wheat cleaner, (b) undesirable materials, (c) clean grain pan

3.8. Testing for the wheat cleaner efficiencies:

Figure 3: The prototype of wheat cleaner

The indices used in testing the performance of this wheat cleaner as shown in the equations below by Igbeka (1984):

3.8.1. Efficiency of separation of cleaned grains, ξG:

This efficiency was obtained as the ratio of cleaned wheat grain coming out of the clean- grain outlet to the total clean wheat grain fed into the machine. Mathematically:

$$\xi G = \frac{GP}{GP + GR} \times 100\% \quad (4)$$

Where;

GP is the weight of clean wheat grain in the clean- grain outlet, kg.

GR is the weight of clean wheat grain in the two reject outlets, kg.

3.8.2. Efficiency of separation of MOG (materials other than grains), ξMOG:

This efficiency was obtained as the ratio of the weight of MOG (which includes broken grains, half-matured grains and weed seeds) to the total weight of the MOG fed into the machine. This efficiency is represented mathematically as follows:

$$\xi MOG = \frac{BR}{BR + BP} \times 100\% \quad (5)$$

Where;

BR is the weight of MOG collected from two reject outlets, kg.

BP is the weight of MOG collected in the clean- grain outlet, kg.

3.8.3. Total cleaning efficiency of the machine, ξT:

This was obtained as the product of the efficiency of separation of good product and the efficiency of separation of MOG. This is also expressed mathematically as:

$$\xi T = \xi G \times \xi MOG \times 100\% \quad (6)$$

Where; ξG and ξMOG are as described earlier.

3.8.4. Percentage purity of whole wheat grains in products, %Pp:

This was obtained as the ratio of weight of whole wheat grains in the products to the total weight of products. This is expressed mathematically as:

$$\%Pp = \frac{GP}{GP + BP} \times 100\% \quad (7)$$

4. Results and discussion:

The prototype of wheat cleaner had been used for cleaning farmer-saved seeds obtained from a local farmer around. From the test carried out as presented in Table 4 and Table 5, the efficiencies and percentage purity were obtained for three (3) trials at crank speed of 208 rpm. The efficiency of separating clean wheat grain, ξG ranged between 99.85 and 99.90%, giving an average value of 99.87%; the efficiency of separating MOG (impurities), ξMOG ranged between 84.59 and 92.66%, giving an average value of 88.79 % and total cleaning efficiency, ξT ranging from 84.46 to 92.56% averaging 88.68 %. The product percentage purity of whole wheat grains also ranged from 99.28 to 99.58% and averaging 99.43%.

At 300 rpm however, the efficiency of separating clean wheat grain, ξG ranged between 86.10 and 89.23%, giving an average value of 88.03%; the efficiency of separating MOG (impurities), ξMOG ranged between 50.99 and 51%, giving an average value of 51% and total cleaning efficiency, ξT ranging from 43.91 to 45.49% averaging 44.98%. The product percentage purity of whole wheat grains also ranged from 96.95 to 97.39% and averaging 97.20%.

Table 4: Summary showing weights collected at product and reject receptacles at 208 rpm crank speed and the corresponding separation efficiencies for wheat variety Imam.

	Stopwatch	Feed, g	GP, g	BP, g	GR, g	BR, g	ξG, %	ξMOG, %	ξT, %	%Pp
Trial 1	00:14:20	10000	9503.59	52.69	11.24	432.48	99.88	89.13	89.02	99.44
Trial 2	00:13:57	10000	9536.72	69.16	14.26	379.86	99.85	84.59	84.46	99.28
Trial 3	00:14:18	10000	9452.09	39.52	08.78	499.61	99.90	92.66	92.56	99.58
Average	**00:14:12**	**10000**	**9497.46**	**53.79**	**11.42**	**437.31**	**99.87**	**88.79**	**88.68**	**99.43**

Table 5: Summary showing weights collected at product and reject receptacles at 300 rpm crank speed and the corresponding separation efficiencies for wheat variety Imam.

	Stopwatch	Feed, g	GP, g	BP, g	GR, g	BR, g	ξG, %	ξMOG, %	ξT, %	%Pp
Trial 1	00:09:33	10000	8490.28	237.73	1024.56	247.43	89.23	50.99	45.49	97.27
Trial 2	00:10:24	10000	8223.99	220.01	1327.00	229.00	86.10	51.00	43.91	97.39
Trial 3	00:09:55	10000	8398.65	264.17	1062.23	274.95	88.77	50.99	45.26	96.95
Average	**00:09:57**	**10000**	**8370.97**	**240.63**	**1137.93**	**250.46**	**88.03**	**51.00**	**44.89**	**97.20**

5. Conclusions:

The prototype of wheat cleaner had been designed, manufactured and tested under laboratory in order to work on farmer-saved seeds to increase productivity for small-scale farmers reducing weed infestation, improving seed quality, encouraging mechanized farming, decreasing cost, easy maintenance and usage, and can operate in rural areas.

The separation efficiency for wheat grains was 99.87 %, efficiency of separation of MOG was 88.79 %, total cleaning efficiency was 88.68 % and percentage purity was 99.43 % at crank speed of 208 rpm.

At 300 rpm however, the separation efficiency for wheat grains was 88.03 %, efficiency of separation of MOG was 51 %, total cleaning efficiency was 44.49 % and percentage purity was 97.20 %. The results indicated that higher efficiencies were obtained at lower screen speeds.

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