





Design and Performance Evaluation of Canola-Seed Cleaning Machine

Mohamed Ibrahim GHONIMY^{a,b*}, Mohamed Naguib ROSTOM^b

^aDepartment of Plant Production and Protection, College of Agriculture and Veterinary Medicine, Qassim University, Buraydah, SAUDIA ARABIA

^bAgricultural Engineering Dept., Faculty of Agriculture, Cairo University, Giza, EGYPT

(* Corresponding author. mohamed.ghonimy@agr.cu.edu.eg)

ABSTRACT

Canola cleaning machine was designed depending upon the mechanical and aerodynamic separation theories. The designed machine was tested at three levels of cylindrical sieve angle 4, 7, and 10 degree and three levels of flat sieve speed 0.62, 0.88, and 1.08 m s⁻¹. The evaluation criteria included machine productivity (*MP*), cleaning efficiency (*CE*), percentage of seed losses (*P_s*), specific consumed energy (*E_c*), and germination percentage (*G_p*). The results showed that the maximum values of *MP* and *CE* were 680.14 kg h⁻¹ and 99.85 % respectively. While the minimum value of *E_c* was 5.88 kW h ton⁻¹. These values were achieved at cylindrical sieve slope angle 7 degree and flat sieve speed 0.88 m s⁻¹. Under these working conditions, the values of *MP*, *E_c* and *CE* were 680.14 kg h⁻¹, 5.88 kWh ton⁻¹, and 99.85%, respectively. Thus, the designed machine can be used with enough confidence to clean the canola seeds at cylindrical sieve slope angle 7 degree and flat sieve speed 0.88 m s⁻¹.

RESEARCH ARTICLE

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INTRODUCTION

Canola is considered one of the most important oil production crops in the world. It comes after palms and soybean as a source of world oil production. The oil extracted from canola seed is second only to olive oil in proportion of mono-unsaturated fatty acids and can be used in cooking, salad oils, edible oil blends, or as margarine (Longwic *et al.*, 2021). Canola oil is free from cholesterol and contains about 6%



saturated fats and about 94% ([Statistical Year-Book, 2018](#)). The canola cake which is the by-product left after the oil extraction is a protein rich meal that can be used in livestock feeding. Canola gives a good seeds yield in the new lands, but in fact, the harvested seeds yield contains some strange materials components such as sands, straw, ... etc, which decrease the quality of extracted oil. [Jenks \(2000\)](#) stated that canola yields reduce by up to 77% if the weeds is not controlled. Rejection or serious price discounts may take place if the canola seeds were contaminated with wild mustard seeds. He added that the mechanical cultivation to remove weeds is not feasible, as canola is a shallow-seeded crop and tillage can injure canola seedling. [El-Sayed et al. \(2001\)](#) stated that canola crop which sowed by seed drill with a suitable row width of 400 mm gave the highest yield (3452 kg ha⁻¹) and the lowest consumed energy (9.45 kWh ha⁻¹) as compared with manual planting and planter. [Oladimeji et al. \(2020\)](#) considered Post-harvest losses (food lost from one stage to the other during handling) a major problem that faces the food production industry. Seed handling is a crucial piece of the complete innovation engaged with making accessible top notch seed. It guarantees the end clients, seeds of top notch with least defilement. In Agriculture, the term seed handling incorporates cleaning, drying, seed treatment, bundling and stockpiling ([Oladimeji et al., 2020](#)). [Simonyan and Yiljep \(2008\)](#) mentioned that the frequency of sieve oscillations, amplitude of oscillation, sieve slope, length of sieve, sieve width, sieve holes diameter, fan speed, and angle/direction of airflow from the fan are the machine parameters affecting the cleaning and separating process. While, the crop factors included crop variety, seed moisture content, seed size, maturity stage, seed bulk density, straw moisture content, straw bulk density, stalk length, and terminal velocities of seeds and other materials. [Serio et al. \(2019\)](#) defined the terminal velocity as the air velocity required for seed suspense or balance. They mentioned that when seeds are exposing to air current through a certain path begin to move then remain constant at a certain velocity, at this velocity the net gravitational acceleration force equals the resistance upward drag force. At this velocity the seed is remains constant and in this case this velocity called terminal velocity. [Binelo et al. \(2019\)](#) used image processing and fluidized bed methods to find the values of terminal velocity of soya seeds, oat and maize. [Gemedda \(2020\)](#) evaluated Delta 114 cleaning machine of Oromia Seed Enterprise at two locations and he found that the highest values of cleaning efficiency were 96.89%, and 95.65% for wheat and barley seed while the lowest cleaning efficiency was recorded during bean cleaning was 80.22%. In addition, the minimum value of cleaning loss, 3.22%, was performed for wheat process while the maximum cleaning loss, 24.76%, was found for bean seeds. [Alsharifi \(2018\)](#) tested three threshing cylinder rotating speed; 200, 250 and 300 rpm for two types of maize threshing machines (Local MTL and MGI-TY 60). He reported that the threshing efficiency, cracked grain percentage, broken maize, grain cleaning, machine productivity, and power consumption were 83.9%, 4.0%, 6.0%, 88.8%, 1.96 ton h⁻¹, and 11.4 kW, respectively for Local MTL, while there were 83.3%, 4.4%, 6.8, 87.5%, 1.14 ton h⁻¹, and 12.2 kW respectively under the same operating conditions for MGI-TY 60. From previous studies, it is clear that seeds cleaning in general depends on the dynamic and aerodynamic properties of the seeds. Therefore, this study aimed to design and evaluate the performance of canola-seed cleaning machine based on the mechanical and aerodynamic separation theories.

MATERIALS and METHODS

Cleaning operation is defined as the final operation for seeds separation from the other blemishes (empty pods, straw particles and sand). These different components are separated according to several separation theories.

Selection of cleaning theory

There are several theories for seeds cleaning from the other blemishes. These theories are aerodynamic cleaning by using air from fan, mechanical cleaning by using sieves, aeromechanical cleaning and surface textures cleaning (Giyevskiy *et al.*, 2018).

The cleaning of canola-seeds from other blemishes (empty pods, straw particles and sand) could be achieved using mechanical and aerodynamic theories.

Mechanical cleaning

In this theory, the cleaning of canola-seeds from other blemishes depends upon the differences of the component's dimensions. Different scales sieves are used for cleaning operations. So, for this task, the mechanical cleaning unit was designed. It's consisting of three sieves one of them is cylindrical shape, moving in rotational movement to separate empty pods. The others are flat sieves moving in reciprocating movement for separating straw and some other blemishes. The function of these sieves is to accelerate the materials (empty pods and straw particles) to the exit hole. During this operation canola-seeds and fine sand moving to the aerodynamic separation unit through seed receiver.

Aerodynamic cleaning

The principle of aerodynamic theory depends upon the differences of terminal velocity and differences of drag coefficient of the different components. In this theory the cleaning is proceeding by pushing air current using a fan to separate canola-seeds from fine sand and any remain blemishes. Determination of drag coefficient and terminal velocity for canola-seeds are considered the most important factors for aerodynamic cleaning unit design.

Design of canola cleaning machine

The designed machine consists of the following main components, Figure 1.

Mechanical cleaning unit

The mechanical cleaning unit, Figure 2, consists of three sieves for the cleaning of canola-seeds from the other blemishes.

One of these sieves is cylindrical shape has a length of 1360 mm, 500 mm diameter and 5 mm holes diameter used for the separation of empty pods. The hole diameters were selected after the experimental determination of empty pods lengths and diameters which were 17 and 8 mm respectively. The empty pods and the other blemishes separation based on centrifugal force that generated from the rotational movement of the sieve besides the slope angle on the longitudinal axis of sieve. The optimum peripheral speed of the cylindrical sieve is 23 m s^{-1} equivalent to 878 rpm (Kepner *et al.*, 2005). The cylindrical sieve is connected with ball bearings fixed U-beam

(100 x 45 x 6 mm) at its end. This beam can be adjusted up and down for controlling sieve slope angle.

The other two sieves (flat type) were placed below the cylindrical sieve. The higher one has a length of 1500 mm, 700 mm width and 3 mm holes diameter. This sieve is used for completely separation of straw and empty pods. This sieve permits canola-seeds and fine sand to fall to the lower sieve. Receiver was fabricated to receive the empty pods and straw particles from the cylindrical and first flat sieve. This receiver has a reciprocating movement by crankshaft receiving movement from 100 mm diameter pulley fixed the end of the cylindrical sieve axis. This crankshaft was designed to give a stroke of 50 mm and rotating speed 820 rpm.

The lower sieve was designed with a total length of 2000 mm and total width of 700 mm. This sieve was divided into two sections. The first section has a length of 1500 mm and 0.5 mm holes diameter to keep canola-seeds above the sieve. The second section has a length of 500 mm and 5 mm holes diameter to permit for canola-seeds to go to the next cleaning unit. It has to be mentioned here that the two sieves are reciprocally moving by the reversible reciprocating arm. The flat sieves take the harmonic reciprocating motion by transmission shaft and eccentric crank in order to facilitate the transmission of canola-seeds to the seed's receiver then to the second separation unit (aerodynamic separation unit). The rotating speed of the transmission shaft to flat sieve could be determined from equation (1) according to (RNAM, 1995).

$$\omega = \left(\frac{2g}{r}\right)^{0.5} \times 60 \quad (1)$$

Where:

- ω = Transmission shaft rotating speed, rad min⁻¹;
- r = Eccentric crank radius, m.
- r = Eccentric crank radius, m.

Three values of r (50, 100 and 150 mm) were selected in order to determine the suitable transmission shaft rotating speed.

The flat sieve has a reciprocating harmonic motion with eccentric crank radius (50, 100 and 150 mm). This harmonic motion is represented in Figure 3. The flat sieve starts its reciprocating motion at point (a) the sieve forward velocity increased gradually to reach its maximum at the middle of the curve (point b), then its decreases gradually until it stops completely at point (c). This harmonic motion of the sieve occurs during 180 degree of eccentric crank. The average sieve speed was calculated from equation (2).

$$F_{ss} = \frac{S}{T} \quad (2)$$

Where:

- F_{ss} = Average speed of flat sieve, m s⁻¹;
- S = Sieve reciprocating stroke, m;
- T = Time required for sieve reciprocating stroke = $30/\omega$, s.

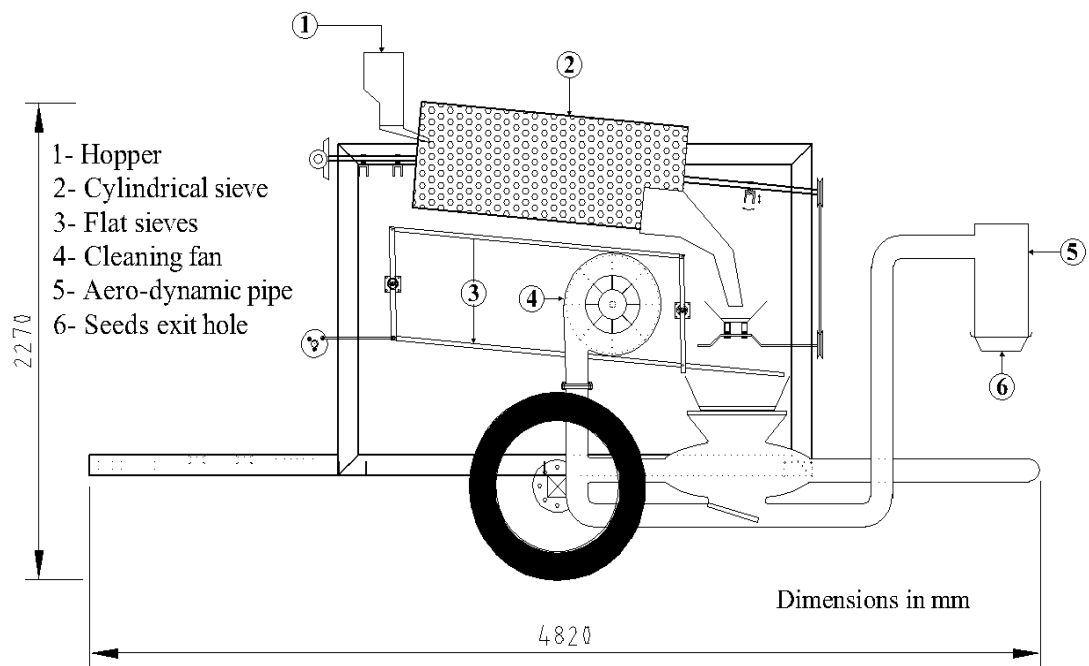


Figure 1. Canola-seeds cleaning machine.

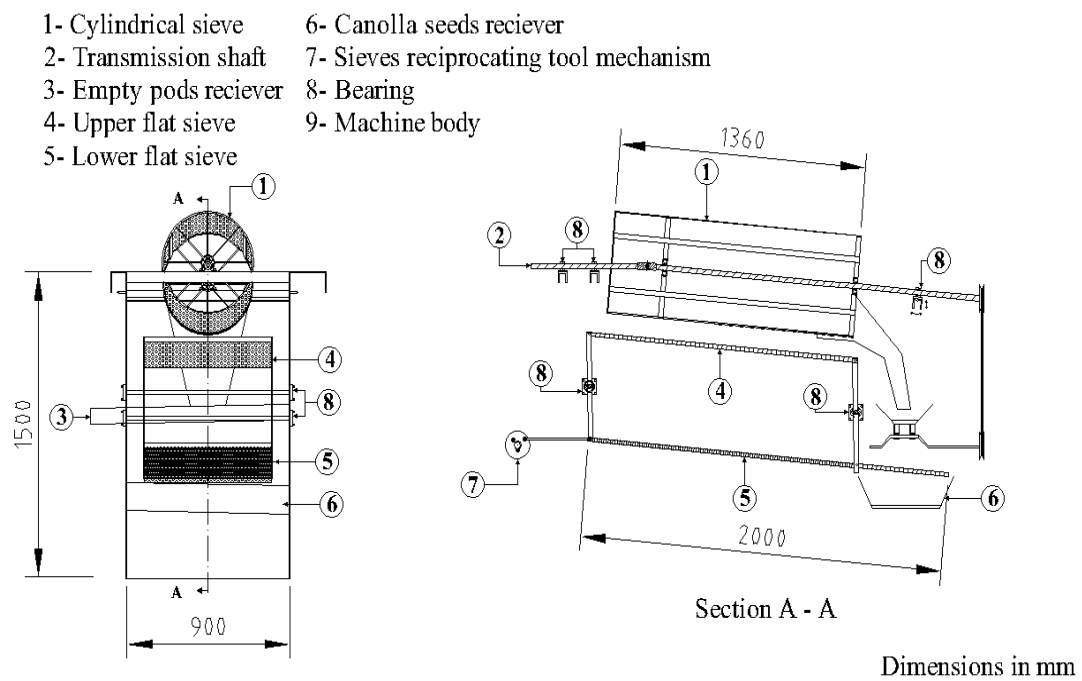


Figure 2. Mechanical cleaning unit.

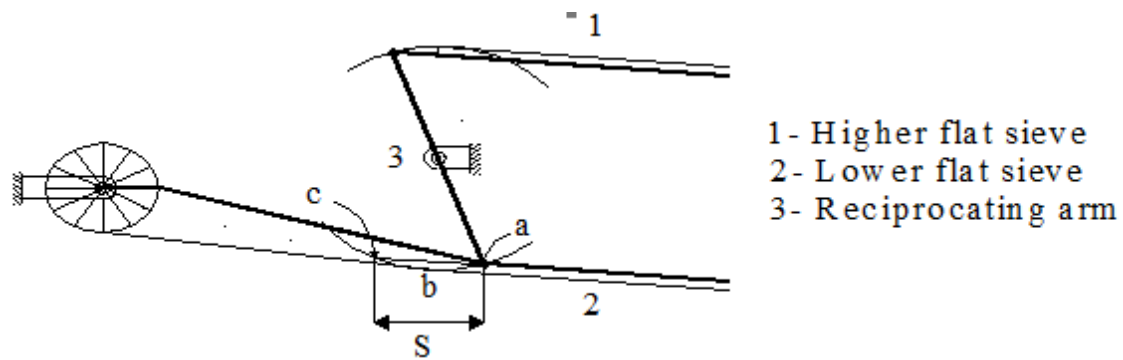


Figure 3. Flat sieve harmonic motion.

From Equations 1 and 2 and Figure 3, the values of F_{ss} were 0.62, 0.88 and 1.08 m s^{-1} that equivalent for eccentric crank radius 50, 100 and 150 mm.

Aerodynamic cleaning unit

Aerodynamic cleaning unit, Figure 4, receiving canola-seeds and fine sand from the mechanical cleaning unit through a conical hopper made from iron-sheet 3 mm thickness having 300 mm diameter at bottom and 500 mm diameter at the top. The design of aerodynamic cleaning unit based upon the determination of terminal velocity of canola-seeds. Where, the average value of terminal velocity was 7.23 m s^{-1} for canola-seeds. In this unit a fan with 500 mm diameter, 0.55 $\text{m}^3 \text{s}^{-1}$ discharge and 950 rpm was used. This fan was connected with 125 mm diameter iron pipe.

- 1- Cleaning fan
- 2- Conical hopper
- 3- Manually adjustable door
- 4- Air transmission pipe
- 5- Sand-exit hole
- 6- Seeds-exit hole

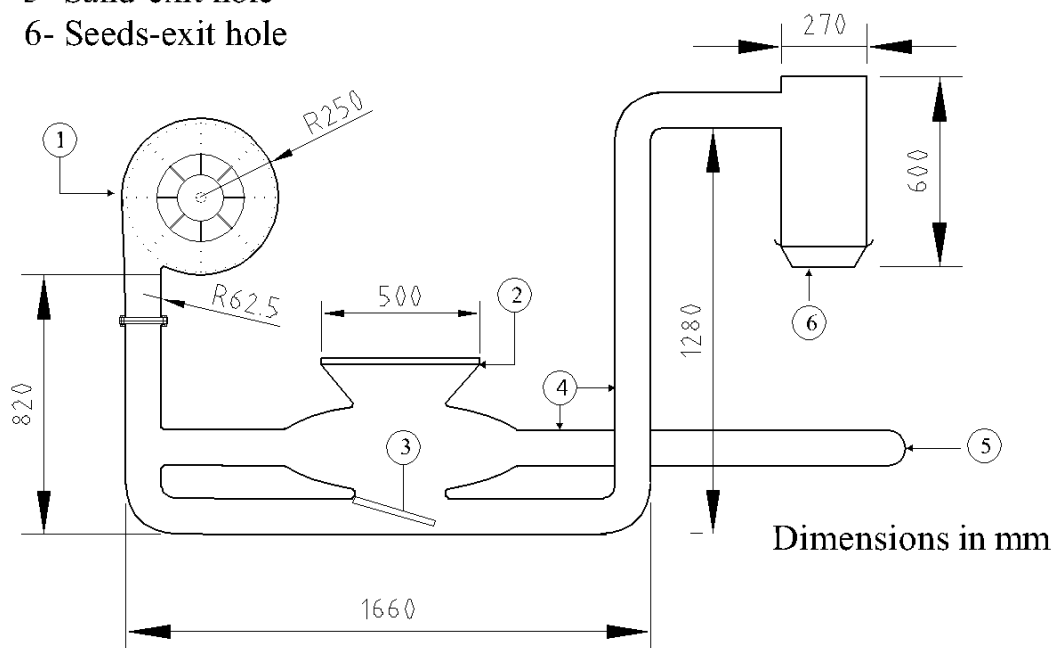


Figure 4. Aerodynamic cleaning unit.

Figure 5 shows the cleaning zone between canola-seeds and fine sand. The air path diameter at the section (A) was determined using Equation (3) where, the forward air velocity is equal to 4.3 m s^{-1} and it should be less than canola-seeds terminal velocity. The air velocity at section (B) is equal to 22 m s^{-1} and it should be more than seeds terminal velocity to cause a dragging force for canola-seeds toward exit hole. The manually adjustable door is used for controlling air velocity at the section (B).

Section (A):	Section (B):	Section (C):
$Q = 0.28 \text{ m}^3 \text{ s}^{-1}$	$Q = 0.28 \text{ m}^3 \text{ s}^{-1}$	$Q = 0.55 \text{ m}^3 \text{ s}^{-1}$
$V = 4.3 \text{ m s}^{-1}$	$V = 22.83 \text{ m s}^{-1}$	$d = 125 \text{ mm}$
$d = 280 \text{ mm}$	$d = 125 \text{ mm}$	

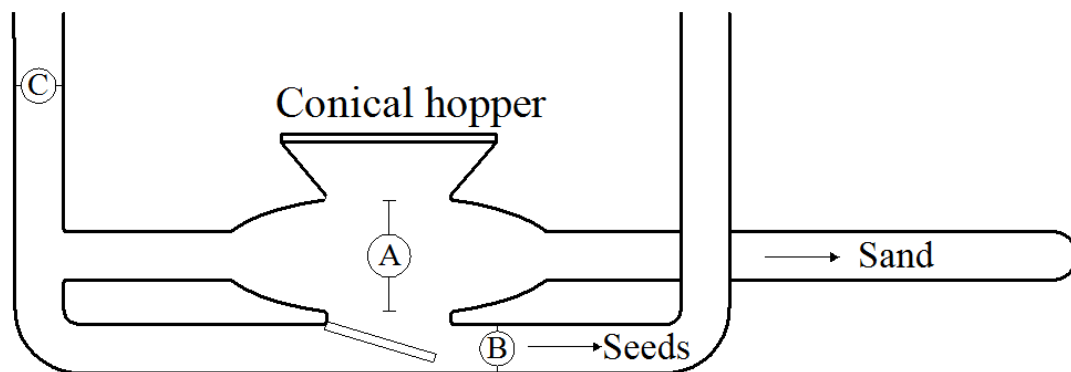


Figure 5. Separation zone between canola-seeds and fine sand.

$$d = \left(\frac{4q}{\pi V_t} \right)^{0.5} \quad (3)$$

Where:

d	=	Air path diameter, m;
q	=	Air flow rate, $\text{m}^3 \text{ s}^{-1}$;
V_t	=	Terminal velocity, m s^{-1} .

Feeding hopper

Feeding hopper was fabricated with a total capacity of 50 kg of canola-seeds. The feeding hopper was designed with a slope to allow easy movement of canola-seeds to cylindrical sieve.

Transmission system

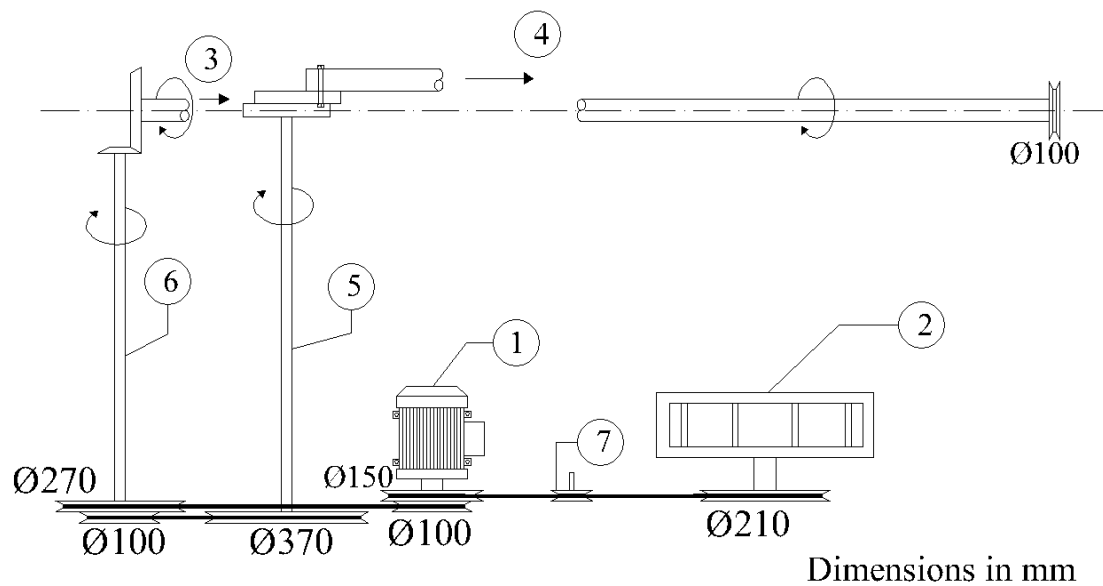
Transmission system of canola cleaning machine was graphically presented in Figure 6. It consists of electrical motor (4 kW at 1330 rpm) as a source of power. This motor was connected with two pulleys 150 and 100 mm diameters.

The transmission system consists of four units. The first unit transmits the motion from electrical motor (using the 150 mm diameter pulley) to separation fan (950 rpm and 210 mm diameter pulley). The second unit transmits the motion from the electrical motor (using the 100 mm diameter pulley) to the cylindrical sieve using 270 mm diameter pulley fixed with shaft ending with two bevel gears 26 and 15 teeth respectively. The recommended rotating speed of the cylindrical sieve was 878 rpm

according to [Kepner et al. \(2005\)](#). Hence, the final used bevel gear was 15 teeth; the rotating speed of the cylindrical sieve became 853 rpm. The third unit transmits the motion from the shaft No. 6 (transmission shaft to cylindrical sieve), Figure 6, to the flat sieves using 100 mm diameter pulley to 260 or 370 or 450 mm diameters pulleys that fixed with shaft No. 5 (transmission shaft to flat sieve) which rotates at 189 or 133 or 109 rpm respectively. The fourth unit transmits the motion from the end of cylindrical sieve shaft using 100 mm diameter pulley to straw and empty pods receiver using 100 mm diameter pulley.

The driving and driven pulleys diameters for each transmitting stage were determined according to the rotating speed of the driving and driven pulleys.

Open V-belts are used to transmit the motion between driving and driven pulleys. The length of V-belts is standardized by ANSI in U.S. customary units and SI units and was calculated according to [Gope \(2012\)](#).



- | | |
|-------------------------|--|
| 1- Electric motor | 5- Transmission shaft to flat sieve |
| 2- Cleaning fan | 6- Transmission shaft to cylindrical sieve |
| 3- To cylindrical sieve | 7- Belt tension adjustment pulley |
| 4- To flat sieve | |

Figure 6. Transmission system.

Machine frame

The frame of canola cleaning machine, Figure 7, was manufactured from U-beam (100 x 45 x 6 mm). Machine sides were fabricated from iron-sheet 3 mm thickness. The total width for the canola cleaning machine was 900 mm, the total length was 4820 mm including the trailed arm and total height was 2270 mm including the higher part of cylindrical sieve.

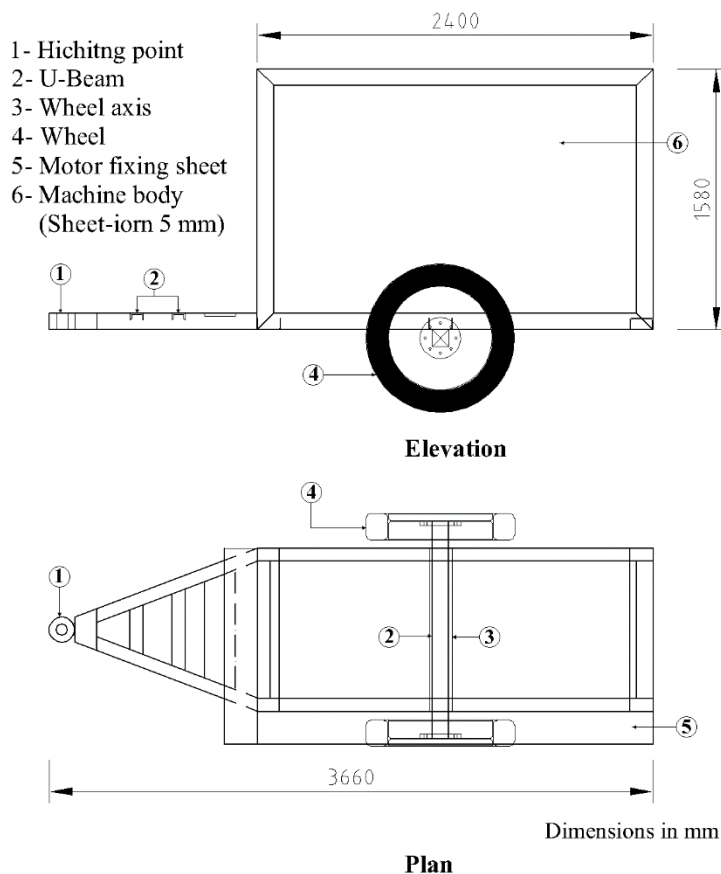


Figure 7. Machine frame.

The design of the rotating shafts

All rotating shafts for the canola cleaning machine were designed according to the stability of the shaft during rotation and not according to transmitted torque. The design of cylindrical sieve shaft were 2400 mm length and 45 mm diameter. The dimensions of the transmission shaft to cylindrical sieve were 750 mm length and 25 mm diameter while that for the transmission shaft to flat sieve were 780 mm length and 25 mm in diameter. The diameter of each rotating shaft was calculated according to ASME code (Gope, 2012). Each rotating shaft was fixed to the machine frame through two ball-bearings. Field experiment was carried out at the experimental station farm, Faculty of Agriculture, Cairo University, Giza, Egypt to evaluate the designed canola seed cleaning machine.

Treatments

Cylindrical sieve slope angle (C_{ssa})

The tested values of cylindrical sieve slope angle were 4, 7 and 10 degree according to Kepner *et al.* (2005).

Flat sieve speed (F_{ss})

The tested values of flat sieve speed were 0.62, 0.88 and 1.08 m s⁻¹ according to Kepner *et al.* (2005).

Measurements and Calculations

Canola seed diameter projected diameter and area

To find the drag coefficient (D_c) and drag force (D_f) it was necessary to find the projected diameter and area of canola seeds. Using AutoCAD program and a digital camera, the projected diameter and area were determined by pasting a set of scattered seeds on graph paper. Using the AutoCAD program, the paper pasted with scale (1:1) on drawing worksheet. By drawing the outlines of the images, it was easy to get the projected diameter and area directly

Terminal velocity of canola-seeds

The terminal velocity of canola-seeds was measured according to the method described by [Behroozi \(2018\)](#). The air velocity was measured using air velocity meter (range, from 0.1 to 25.41 m s⁻¹ and accuracy of 0.1 m s⁻¹).

Drag coefficient (D_c)

The drag coefficient of canola-seeds was calculated from Equation (4) according to [Mohsenin \(1970\)](#).

$$D_c = \frac{4gd_p(\rho_p - \rho_a)}{3\rho_a V_t^2} \quad (4)$$

Where:

D_c	=	Drag coefficient, - ;
d_p	=	Projected diameter, m;
ρ_p	=	Particle density, kg m ⁻³ ;
ρ_a	=	Air density, kg m ⁻³ ;
V_t	=	Terminal velocity, m s ⁻¹ .

Drag force (D_f)

The drag force of canola-seeds was calculated from Equation (5) according to [Mohsenin \(1970\)](#).

$$D_f = \frac{DC \times a \times \rho_a \times V_t}{2} \quad (5)$$

Where:

D_f	=	Drag force, kgf;
a	=	Seed projected area, m ² ;
ρ_a	=	Air density, kg m ⁻³ ;
V_t	=	Canola-seeds terminal velocity, m s ⁻¹

Machine productivity (*MP*)

The machine productivity was calculated from Equation (6).

$$MP = \frac{S}{T} \quad (6)$$

Where:

- MP* = Machine productivity, kg h⁻¹;
S = The total weight at seeds outlet, kg;
T = Consumed time, h.

Cleaning efficiency (*CE*)

The cleaning efficiency (*CE*) was calculated from Equation (7) ([RNAS, 1995](#)).

$$CE = \frac{S_1}{MP} \times 100 \quad (7)$$

Where:

- CE* = Cleaning efficiency, %;
S₁ = Seeds weight at seeds outlet per unit time, kg h⁻¹;
MP = Machine productivity, kg h⁻¹.

Percentage of seed losses (*P_{sl}*)

The percentage of seed losses (*P_{sl}*) was calculated from Equation (8) according to [RNAS \(1995\)](#).

$$P_{sl} = \frac{S_2}{FR} \times 100 \quad (8)$$

Where:

- P_{sl}* = Percentage of seed losses, %;
S₂ = Weight of seed per unit time collected at all outlets except for seed outlet, kg h⁻¹;
FR = Feed rate, kg h⁻¹.

Specific consumed energy (*E_c*)

The specific consumed energy (*E_c*) was calculated from Equation (9).

$$E_c = \frac{P}{MP} \quad (9)$$

Where:

- E_c* = specific consumed energy, kWh ton⁻¹;
P = Motor power, kW.

Germination percentage (*Gp*)

The germination percentage (*Gp*) was experimented to test the effect of mechanical cleaning on the germination ratio, as this ratio is affected by invisible damage caused by mechanical cleaning. The *Gp* was calculated from equation (10) according to [Sreekissoon et al. \(2021\)](#).

$$Gp = \frac{N_g}{N_t} \times 100 \quad (10)$$

Where:

- Gp = germination percentage , %;
 N_g = Number of seeds germinated;
 N_t = Total number of seeds sown.

Statistical analysis

The measured data for all variables were statistically analyzed by microcomputer program (CoStat ver. 6.400, 2008) via analysis of variance using complete randomized design (CRD), two factors model. The means of treatments were obtained, and differences were assessed with Student-Newman-Keuls at 5% level of probability.

RESULTS AND DISCUSSION

Canola-seeds characteristics

The values of canola-seeds diameter, density, terminal velocity and drag coefficient are shown in Table (1). From Table (1) it's clear that the average values of canola-seeds projected diameter, projected area, moisture content, and density were 2.8 mm, 6.2 mm², 12%, and 0.65 g cm⁻³ respectively. The average value of terminal velocity was 7.23 m s⁻¹. Also, the drag coefficient value of canola-seeds was 0.39. While the drag force of canola-seeds was 1.01x10⁻⁵ N.

Table 1. Some characteristics of canola-seeds.

Characteristics	Value
Projected diameter, mm	2.8
Projected area mm ²	6.2
Moisture content, %	12
Density, g cm ⁻³	0.65
Terminal velocity, m s ⁻¹	7.23
Drag coefficient,	0.39
Drag force, N	1.01*10 ⁻⁵

Designed machine productivity (MP) and specific consumed energy (E_c)

The performance of the designed machine depends upon the cylindrical sieve slope angle (C_{ssa}) and flat sieve speed (F_{ss}). Figure 8 shows the effect of C_{ssa} and F_{ss} on the MP and E_c . From Figure 8 it's clear that the maximum value of machine productivity (680.14 kg h⁻¹) and the minimum value of specific consumed energy (5.88 kWh ton⁻¹) were achieved at cylindrical sieve slope angle of 7 degree and flat sieve speed of 0.88 m s⁻¹. While the minimum value of machine productivity (590.64 kg h⁻¹) and the maximum value of specific consumed energy (6.77 kWh ton⁻¹) were found at cylindrical sieve slope angle of 4 degree and flat sieve speed of 0.62 m s⁻¹. From Figure 8 it's also clear that the productivity values of the designed machine increased by increasing of the cylindrical sieve slope value up to 7 degree and by increasing the flat sieve speed up to 0.88 m s⁻¹.

Through the above mentioned conditioned the MP and Ec values were in decreasing trend with the increasing of slope angle up to 7 degree. After that, the machine productivity decreased, and the consumed energy increased exponentially. These results were in agreement with the findings obtained by [Priporov et al. \(2021\)](#). They reported that to optimize in pneumatic systems of seed-cleaning machines, while increasing performance and improving the functional efficiency, it is necessary to improve their constructive and technological parameters. Improving pneumatic system parameters requires the development of a methodology for modeling the processes of airflow motion for their qualitative characteristics.

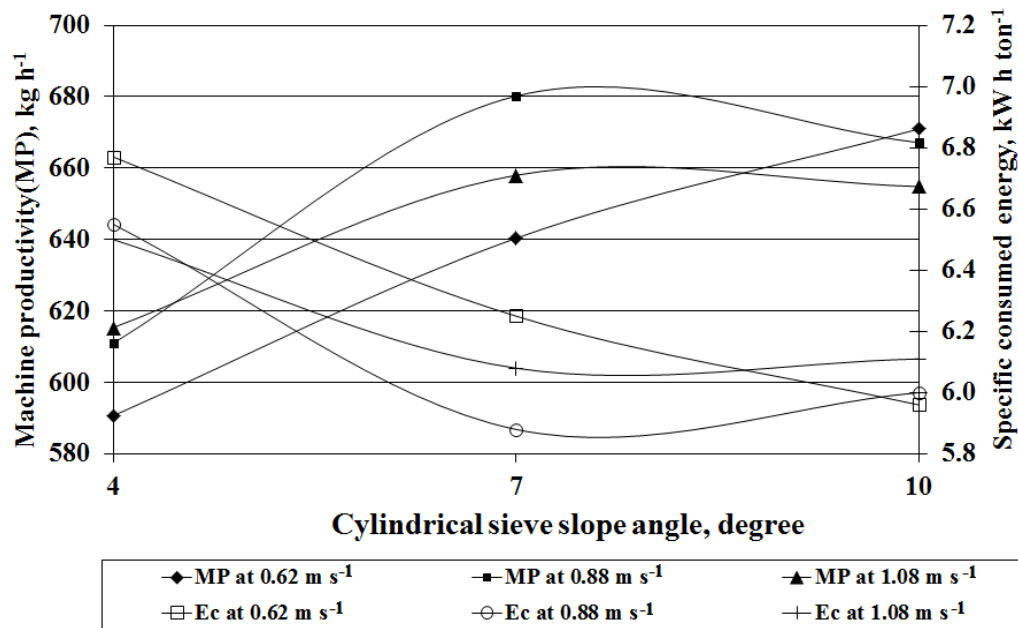


Figure 8. The effect of cylindrical sieve slope angle and flat sieve speed (F_{ss}) on the machine productivity and specific consumed energy.

Cleaning efficiency (CE)

The average value of cleaning efficiency (CE) of the designed machine is shown in Figure 9. From figure 9 its clear that the CE decreased by increasing of cylindrical sieve slope angle (C_{ssa}) and flat sieve speed (F_{ss}). At 4 degree of C_{ssa} , the CE decreased by 0.02 and 2.7% when the F_{ss} was increased from 0.62 m s⁻¹ to 0.88 and 1.08 m s⁻¹ respectively. The same trend was found at 7 degree and 10 degree of F_{ss} . At 0.62 m s⁻¹ of F_{ss} , the CE decreased by 0.13 and 1.22% when the C_{ssa} was increased from 4 degree to 7 and 10 degree respectively. The same trend was noticed at 0.88 m s⁻¹ and 1.08 m s⁻¹ of F_{ss} . These results agree with the findings of [Ali et al. \(2022\)](#) they found that the maximum cleaning efficiency, 96.25%, was achieved at 5 m s⁻¹ air velocity, 5° sieve slope, 1 kg min⁻¹ feed rate, and 0.95 m s⁻¹ sieve linear speed.

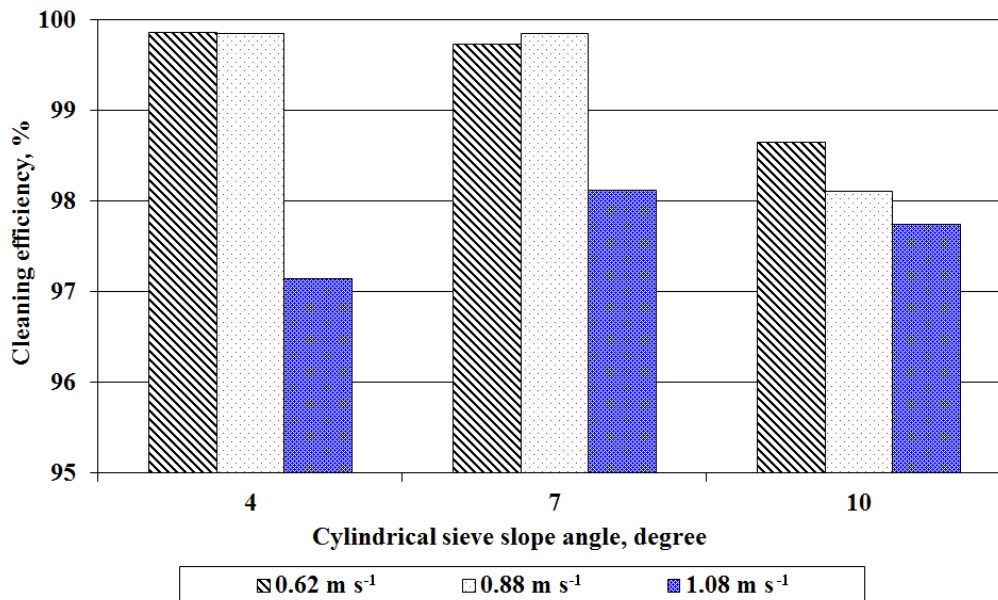


Figure 9. The effect of cylindrical sieve slope angle and flat sieve speed (F_{ss}) on the cleaning efficiency.

Percentage of seed losses (P_{sl})

The average values of P_{sl} are shown in Figure 10. From Figure 10 its clear that the P_{sl} increased by increasing of cylindrical sieve slope angle (C_{ssa}) and flat sieve speed (F_{ss}). The minimum value of P_{sl} , 3.71%, was found at 4 degree of C_{ssa} and 0.62 m s⁻¹ of F_{ss} . While the maximum value of P_{sl} , 6.33%, was found at 10 degree of C_{ssa} and 1.08 m s⁻¹ of F_{ss} .

At 4 degree of cylindrical sieve slope angle (C_{ssa}), the percentage of seed losses (P_{sl}) increased by 0.17 and 2.15% when the flat sieve speed increased from 0.62 m s⁻¹ to 0.88 and 1.08 m s⁻¹ respectively. The same trend was found at 7 and 10 degree of C_{ssa} . This increase might be due to the increase of canola-seeds acquainting kinetic energy resulted from the increasing of sieve speed. This acquainting kinetic energy caused the increasing of lost seeds percentage.

At 0.62 m s⁻¹ of flat sieve speed, the percentage of seed losses (P_{sl}) increased by 0.31 and 2.22% when the cylindrical sieve slope angle increased from 4 degree to 7 and 10 degree respectively. The same trend was found at 0.88 and 1.08 m s⁻¹ of F_{ss} . This increase might be referred to the increase of cylindrical sieve slope angle that increases the acquainting kinetic energy of the seeds with centrifugal force that caused increasing of seeds pushing towards blemishes receiver. Therefore, the percentage of seeds losses was increased. These results are similar to those found by [Komil and Makhmud \(2016\)](#), who reported that the seed losses ranged between 1.3 and 2.8% at 3 to 15 degree of sieve angle.

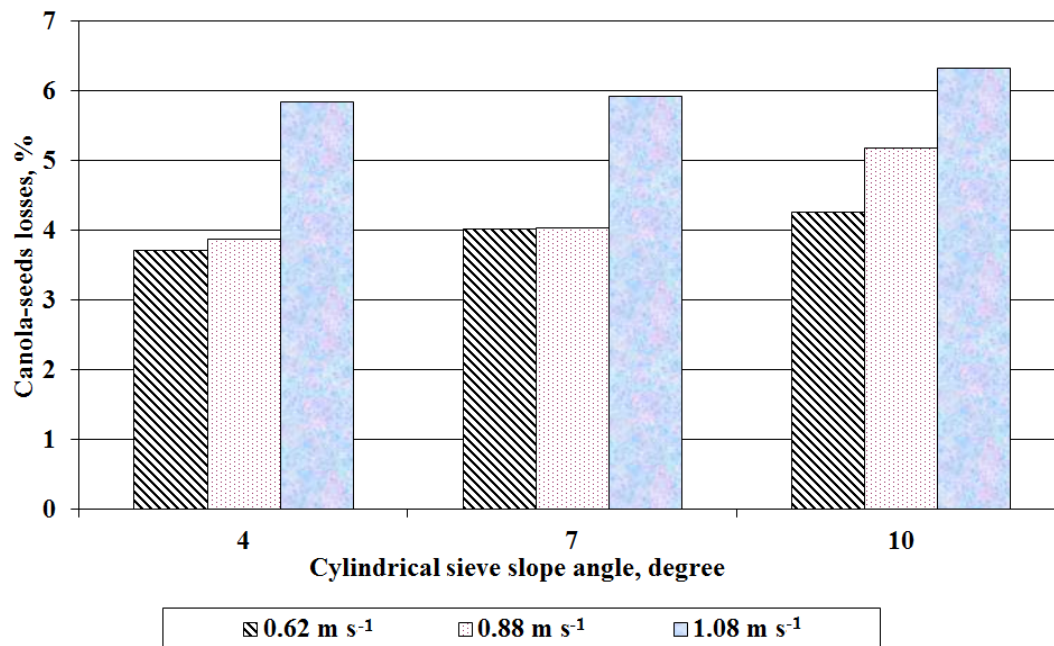


Figure 10. The effect of cylindrical sieve slope angle and flat sieve speed (F_{ss}) on percentage of canola-seeds losses.

Canola-seeds germination percentage (G_p)

Germination percentages of canola-seeds from seeds exit were determined and are illustrated in Table 2.

Table 2. Germination percentage of canola-seed at different cylindrical sieve slope angle and flat sieve speed.

Cylindrical sieve slope angle, degree	Flat sieve speed, $m s^{-1}$	Germination percentage, %
4	0.62	97.0
4	0.88	99.5
4	1.08	98.3
7	0.62	99.2
7	0.88	98.3
7	1.08	98.6
10	0.62	98.0
10	0.88	99.1
10	1.08	98.2

From Table 2 its clear that the germination percentage of canola-seeds at seeds exit ranged from 97 to 99.5%. From Figures, 9 and 10 its clear that the optimum value of machine productivity (MP), specific consumed energy (E_c) and cleaning efficiency (CE) could be realized when cylindrical sieve slope angle was 7 degree and flat sieve speed was 0.88 $m s^{-1}$. Under these working conditions, the values of MP , E_c and CE were 680.14 $kg h^{-1}$, 5.88 $kWh ton^{-1}$ and 99.85% respectively.

CONCLUSION

From this investigation the following conclusions can be done:

1. The terminal velocity of canola-seeds was 7.23 m s^{-1} .
2. The productivity of the designed machine increased by increasing of cylindrical sieve slope angle up to 7 degree and increasing of flat sieve speed up to 0.88 m s^{-1} .
3. The minimum value of specific consumed energy, $5.88 \text{ kWh ton}^{-1}$, deduced at cylindrical sieve slope angle of 7 degree and flat sieve speed of 0.88 m s^{-1} .
4. The maximum value of cleaning efficiency, 99.85%, was found at cylindrical sieve slope angle of 7 degree and flat sieve speed of 0.88 m s^{-1} .
5. The percentage of canola seed losses increased by increasing of cylindrical sieve slope angle and flat sieve speed.
6. The germination percentage of canola-seeds ranged from 97 to 99.5%.

DECLARATION OF COMPETING INTEREST

There is no conflict of interest between authors.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

This research work was carried out in collaboration with the authors (Ghonimy and Rostom).

Mohamed Ibrahim Ghonimy contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the artical and also coordinated the activities with the co-author.

Mohamed Naguib Rostom contributed equally in various roles including setting research goals, development of methodology, performing the experiments, analyzing data, and writing the artical.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

REFERENCES

- Ali MA, Abd El-Rahman E and Nasr GED (2022). Design and assessment of a small-scale machine for cleaning wheat grains. *Acta Technologica Agriculturae*, 25(1): 13-19.
- Alsharifi SKA (2018). Affecting on threshing machine types, grain moisture content and cylinder speeds for maize, Cadiz variety. *Agricultural Engineering International: CIGR Journal*, 20(3): 233-244.
- Behroozi F (2018). Weighing a magnet as it falls with terminal velocity through an aluminum pipe. *The Physics Teacher*, 56(7): 474-477.
- Binelo MO, de Lima RF, Khatchatourian OA and Stránský J (2019). Modelling of the drag force of agricultural seeds applied to the discrete element method. *Biosystems Engineering*, 178: 168-175.
- El-Sayed GH, El-Attar MA, Badr SE and Yehia I (2001). Effect of some mechanical-planting systems on canola crop yield. *Misir Journal of Agricultural Engineering*, 18(4): 163-172.

- Gemeda T (2020). *Performance evaluation of seed cleaning machines: a case of oromia seed enterprise*. M.Sc. Degree, Department of Mechanical System and Vehicle Engineering, School of Mechanical, Chemical and Material Engineering, Adama Science and Technology University, Oromia Regional State, Ethiopia.
- Giyevskiy AM, Orobinsky VI, Tarasenko AP, Chernyshov AV and Kurilov DO (2018). Substantiation of basic scheme of grain cleaning machine for preparation of agricultural crops seeds. *In IOP Conference Series: Materials Science and Engineering*, 327(4): e042035). IOP Publishing.
- Gope PC (2012). *Machine design: Fundamentals and applications*. PHI Learning Pvt. Ltd.
- Jenks B (2000). Canola weeding control costs. *North Dakota State University*, Bjenks@ndsuext.nodak.edu
- Kepner RA, Bainer R and Barger EL (2005). *Principals of farm machinery* 3rd Ed., AVI-Pub.
- Komil A and Makhmud K (2016). Working out and implementation of the safflower cleaning machine. *European Science Review*, (3-4): 278-280.
- Longwic R, Sander P, Jańczuk B, Zdziennicka A and Szymczyk K (2021). Modification of canola oil physicochemical properties by hexane and ethanol with regards of its application in diesel engine. *Energies*, 14(15): 1-14.
- Mohsenin NN (1970). *Physical properties of plant and animal materials*. Gordon and Breach Science Publishers, New York.
- Oladimeji AO, Imoukhuede OB and Ayodele BB (2020). Design and construction of a multipurpose air screen grain cleaner. *International Journal of Advanced Research*, 6(5): 204-207.
- Priporov IE, Kurasov VS, Samurganov EE and Shepelev AB (2021). Modeling the sunflower seeds separation process in air-sieve grain-cleaning machines. International Conference: Actual Issues of Mechanical Engineering (AIME 2020) In IOP Conference Series: *Materials Science and Engineering*, 1111(1): 012048. IOP Publishing.
- RNAM (1995). *Test code and procedures for agricultural machinery*. Technical Series 12, Regional Network for Agricultural Machinery (RNAM) of the United Nations. Philippines, p: 227 -246.
- Serio MA, Carollo FG and Ferro V (2019). Raindrop size distribution and terminal velocity for rainfall erosivity studies. A review. *Journal of Hydrology*, 576: 210-228.
- Simonyan JK and Yiljep DY (2008). Investigating grain separation and cleaning efficiency distribution of a conventional stationary rasp-bar sorghum thresher. *Agricultural Engineering International: CIGR Journal*, PM 07 028. Vol. X. August, 2008.
- Sreekissoon A, Finnie JF and Van Staden J (2021). Effects of smoke water on germination, seedling vigour and growth of *Sceletium tortuosum*. *South African Journal of Botany*, 139: 427-431.
- Statistical Year-Book (2018). Agricultural Research Center, Ministry of Agriculture, Egypt.