Agricultural mechanization and engineering
Between existing and prospected: 535-554

SOME PARAMTERS AFFECTING CLEANING AND GRADING OF FENUGREEK SEEDS

A. A. El-Nakib*   H. S. Abdel-Galil**

ABSTRACT

The purpose of this study was to develop and evaluate rotating screen separator for grading and cleaning fenugreek seeds. A horizontal cylindrical screen unit was designed, constructed in special workshop, and used to grade fenugreek seeds and to separate trashy materials from it. The horizontal cylindrical screen unit had dimensions of 60-cm long and 10-cm diameter, and had gradual holes with ability to change its slope. It was divided into three gradual scales of sieves, and it was operated by electric motor (0.25 kW) with different tires and belts for changing its angular velocity. Under the horizontal cylindrical screen unit, there was a wooden collection box, which is divided into three parts, same as the screens. Physical and Mechanical properties of fenugreek seeds were determined. A theoretical analysis was made to determine the critical velocity for seeds separation, and test it experimentally. The obtained results indicated that the average moisture content and bulk density of fenugreek seeds used in this study were 13.6% (w.b.) and 0.52 g/cm^3, respectively. The average length, width and thickness of fenugreek seeds were 4.2 mm, 2.8 mm and 1.8 mm, respectively. The average values of seed volume (V), spherical percentage (S_p), geometric diameter (D_g), arithmetic diameter (D_a), flat surface area (A_f) and transverse surface area (A_{th}) were 11.8 mm^3, 65.86%, 2.77 mm, 4.26 mm, 11.76 mm^2, 3.96 mm^2, respectively. The friction angle between seeds and stainless steel, metal and wood surfaces was 22°, 30° and 35°, respectively. The average seeds terminal velocity and angle of repose was 35 m/s and 33°, respectively. The machine efficiency for separating fenugreek seeds increased by increasing the screen speed and decreasing the feeding rate. Zero slope of the horizontal sieve gave higher machine separating efficiency of fenugreek seeds at conditions mentioned previously.

* Prof. of Ag. Eng., Ag. Eng. Dept. Al-Azhar Univ., Egypt.
** Lec of Ag. Eng.; Fac. of Ag.; Fayoum Univ., Egypt.

The machine separating efficiency for fenugreek seeds increased by increasing the angular velocity of the horizontal cylindrical sieve (about 7% less than the critical velocity), with optimum velocity of 140 r.p.m. The optimum parameters for separating fenugreek seeds under the specific conditions of this study are screen speed (140°), feeding rate (5 kg/h) and screen slope (0°).

INTRODUCTION

Cleaning and grading of agricultural products may be considered as the most important processes affecting quality of crop after harvest. Cleaning of grains is used to separate the undesirable materials.

Grading is the most important process to produce high quality production and obtain grains of similar shape and size. Therefore, cleaning and grading of grains are essential for modern marketing as pricing is tied to product quality and they play an active role in the marketing attractiveness. Medicinal plants are important crops in the exporting list. Manual cleaning or/and grading is less efficient and more costly because they always result in high amounts of broken seeds and impurities, which in turn reduce the price of the product. Fenugreek (Hellba الحلبة) is a medicinal plant of economical exporting significance. **Metwalli et al. (1999)** mentioned that after harvesting, grains still contain leaves, stalks, other seeds and immature kernels, and they often must be cleaned. Grading of grains depends on their purity and cleanliness, while their price depends on the percentage of the foreign and other undesirable materials. **Mohsenin (1986)** mentioned that the physical properties of material such as: shape, size, volume and surface area are important in many problems associated with design or development of specific machine, analysis of the behavior of the product in handling of the material, stress distribution in the material under load, electrostatic separation, light reflectance and color evaluation. Accurate estimates of the frontal area and the related diameters are essential for determination of terminal velocity, drag coefficient and Reynolds number. **Awady et al. (1994)** indicated that the terminal velocity of different product components of shelled peanut can be predicted according to their surface dimensions, mass and coefficient of drag.

Ebaid (2005) determined the properties of some medical grains affecting sieve unit selection. He found that the diameter of round sieve hole was 6, 3.5, 12 and 4.5 mm for karkadi, fennel flower, lupine and fenugreek, respectively. The maximum live area was 0.3 and the holes on the sieve 0.99%/1m^2 for the total area of the sieve. For fenugreek, the length, width, thickness were 4.1, 2.7 and 1.7 mm, respectively, while the volume and percentage of sphericity were 9.85 mm^3 and 65%, respectively. The friction angles between fenugreek seeds and stainless steel, metal and wood surfaces were 23, 30 and 35 degree, respectively. The terminal velocity for fenugreek was 35 m/s. **Metwalli (1975)** used a horizontal cylindrical screen for grain-straw separation by centrifugal and gravity forces. He mentioned that the forces affecting the separation of particles' in a rotary horizontal screen were gravity force, centrifugal force and the normal force between the screen and the particles. He concluded that the centrifugal force must be equal to approximately eleven times as the gravity force, in order to obtain high capacity per unit area of the horizontal cylindrical screen. **Amin et al. (2002)** developed and evaluated a simple grading machine (reciprocating type) for grading the spherical crops as a dual-purpose machine to suit for grading the cylindroid crops such as cucumber and squash crops. Their results showed that the machine is quite successful for grading the previous crops. Their best results obtained at speed roller seizer of 0.15 m/s and slope angle of zero. **Amin (2003)** stated that four different crops with different percentage of sphericity (radish about 100%, lentils 78%, haricot beans 76% and kidney beans 53%) were used to assess the grading efficiency of vibrating and rotary sieve machines. He found that the cell shape, speed, position of cells sieves inclination, sieves speeds and sieving time were the main factors that affect on separation and grading efficiencies of the grading machine.

Awady et al. (2003) mentioned that the cleaning efficiency and total losses of seeds were positively affected by air speed and sieve tilt angle, while purity was negatively affected by moisture content and feed rate. The seeds purity increased by using round-hole sieve compared with slotted sieve. The optimum performance was obtained at air speed of 4m/s, moisture content 18%, sieve tilt-angle of 0.03 rad. (2 degree), round-shaped sieve and feed rate of 1200 kg/h. The purity and total losses at these conditions were 98.98% and 0.21%, respectively. **Abd El-Rahman (2004)** used and tested a portable shaker type-grading machine with garlic and onion bulbs, and the results showed that grading efficiency decreased as feeding rates and frequency levels increased. The best result was obtained at bulbs feeding of 800 kg/h. and frequency levels of 30 cps for the grading unit. **El-Gayar (2005)** used a laboratory vibratory apparatus to clean and grade flax seeds. The obtained results showed that the seeds moisture content related positively with the energy requirements and inversely with the apparatus productively and the seeds quality. Also, the mesh hole size (4 mm) affected positively the seeds quality. **Arfia (2006)** studied the engineering parameters affecting cleaning of soybean grains. He concluded that the separation process increased by increasing sieve oscillation, air speed and sieve tilt angle, but the total losses decreased by decreasing sieve oscillation, air speed and sieve tilt angle. The optimum performance was achieved at air speed of 19 m/s with sieve tilt angle of 4 degree (0.07 rad.) and oscillation of 2.6 Hz (220 r.p.m.), feed rate of 1000 kg/h and moisture content of 13%. The separation efficiency and total losses at these conditions were 99.65%, 0.35%, respectively.

The main objective of this study is to obtain a high quality of the fenugreek seeds throughout evaluating some factors affecting cleaning and grading processes as follows:

1. Characteristics of seed as volume, percentage of sphericity, geometric and arithmetic diameters, flat and transverse surfaces, moisture content, bulk density, friction coefficient between seed and the used screen.
2. Characteristics of machine design and its operation, screen diameter, slope, angular velocity and seed feeding rate.
3. Efficiency of the grading machine on separating and grading fenugreek seeds.

MATERIALS AND METHODS

A- Description of the Cleaning and Grading Unit:

A laboratory model was developed, designed, constructed in special workshop and installed at Faculty of Agriculture, El-Azhar University, Egypt in (2007), for cleaning and grading fenugreek seeds. A schematic representation of the experimental setup is shown in Fig. (1). Sectional side view of the horizontal cylindrical screen and the wooden collection box are shown in Fig. (2) and the following are details of the components.

1. **Main Frame:** The main frame of the machine was made as a rectangular box frame (1.4 m long, 0.75 m wide and 0.50 m deep) from steel angle sections. The main frame has three levels:
   - In the top of the cylindrical shape separator, there is a screen.
   - In middle of the main rectangular steel box; there is a wooden box which is divided into three sections for collecting the cleaned and other products.
   - In the lower section, there is an electric motor and power transmission system.

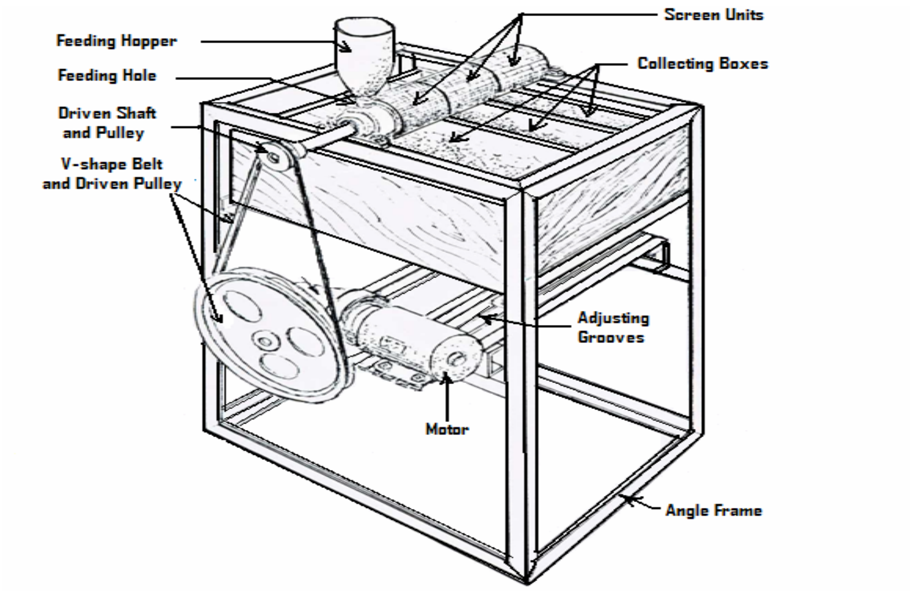


Fig: (1): Schematic diagram of the horizontal cylindrical screen (Rotating screen separator).

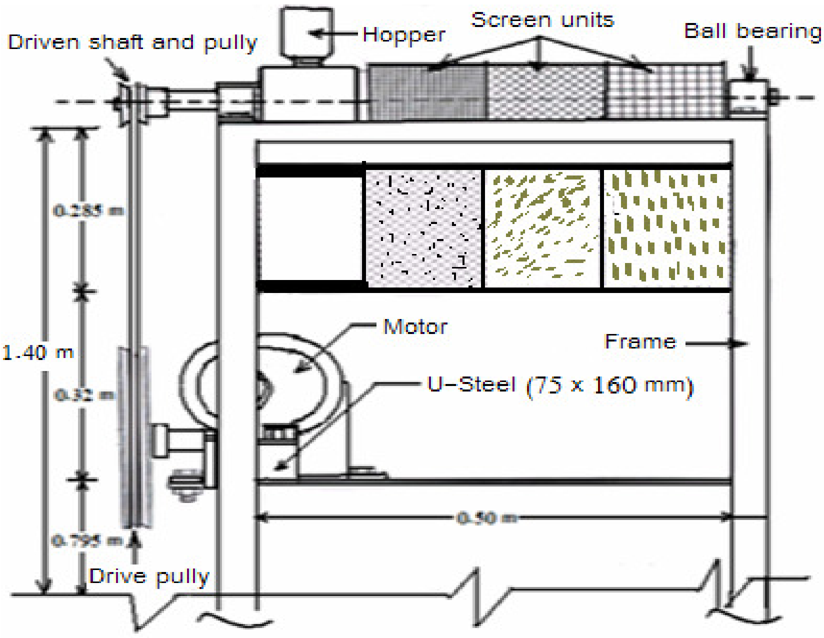


Fig. (2): Rotating screen separator**.**

2. **Screens:** Three screens of 16, 14 and 10 mesh are used in this study. The screens were driven by electric motor and rotated by driven pulleys and belt.
3. **Feed unit**: A small feed hopper with a hole of 25mm diameter is made from galvanized steel, fixed on the feeding unit frame and used for feeding fenugreek Seeds.
4. **Grading unit:** The grading unit is set on two rotating rollers; each one was supported on two adjustable ball bearings, which are attached on the main steel frame.
5. **Transmission system:** The driving system consisted of electric motor and belt, which were used for driving the sieves and the feeding unit. The electric motor has 220V, 0.25kW, 2A, 1420 r.p.m and variable speeds. The motion is transmitted from the drive shaft of the motor to the sieves by means of chains, gears and gear box with reduction ratio of 40:1.

B. Physical and Mechanical Properties of Fenugreek Seeds:

Four hundreds fenugreek seeds were taken for determining physical and mechanical properties required in this study. Some physical properties are: seed dimensions (length, width and thickness), moisture content, mass of 1000 seeds, volume, spherical percentage, geometric diameter, arithmetic diameter, flat surface area and transverse surface area were calculated according to **El-Raie et al. (1996)** as follows:

$$V = (\pi/6)\,(L \times W \times T) \quad (1)$$

$$S_p = 100\,(L \times W \times T)^{1/3} / L \quad (2)$$

$$D_g = (L \times W \times T)^{1/3}) \quad (3)$$

$$D_a = (L + W + T)^{2/3}) \quad (4)$$

$$A_f = (\pi/4)\,(L \times W) \quad (5)$$

$$A_{th} = (\pi/4)\,(T \times W) \quad (6)$$

Where:

L, W and T are seed length, width and thickness, (mm), respectively.

V is the seed volume, (mm^3). ; S_p is the percentage of sphericity,(%).

D_g is geometric diameter, (mm). ; D_a is arithmetic diameter, (mm).

A_f is the flat surface, (mm^2). ; A_{th} is the transverse surfaces, (mm^2).

Some mechanical properties were determined such as: friction angle between seeds and stainless steel, metal and wood surfaces (degrees), coefficient of friction (-), terminal velocity (m/sec).

C. Measurements:

1. Seeds Dimensions: Dimensions of fenugreek seeds (length, width and thickness) were measured considering the three axes (x, y and z) using a digital dial caliper, which reads up to 15-cm with accuracy of 0.05 mm. The seeds dimensions were measured to calculate the others physical properties of fenugreek seeds as mentioned before.

2. Seeds mass and moisture content: An electric balance and moisture content meter were used for weighing the required seeds (before and after cleaning) and for determining the moisture content of seeds, respectively.

3. Seeds bulk density: A graduated volume cylinder was used to measure the volume of the mass of a seeds quantity, and then the bulk density was calculated.

4. Friction coefficient: The friction angles between fenugreek seeds and stainless steel, metal and wood surfaces were measured using a digital measuring device (15 × 12 cm), which was constructed for this purpose.

5. Angle of repose (θ): It is the angle between the inclined side of the feeding cone and its horizontal base due to the free fall of fenugreek seeds through it. Assuming that the horizontal base length of the cone (X) and the cone height (L), then the repose angle can be calculated using the following equation:

$$\tan(\theta) = L / 0.5\,X \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (7)$$

D. Experimental Procedure:

The following are the experimental details:

1. To fulfill the objective of this study, an experiment was designed and carried out to study the effect of the following factors on separating efficiency.
   - Six different feeding rates (3, 5, 7, 9, 11, and 13 kg/h).
   - Five different separating speeds (25, 50, 75, 100 and 140 r.p.m.
   - Five different slopes for the separating unit 0, 10, 20, 30 and 40º.
2. Each sample is weighed before fed into the apparatus and the products are received in the three sections: the first section for dust and smashed straw, the second section for small particles and, and the third section for the clean grains.
3. Calculating the efficiency of separation and cleanness are performed. Each sample taken from the three sections was weighed. Manual separation of smashed grains. Impurities and the clean grains were estimated. Then the separating efficiency was determined.
4. Slope of screen separator and rotating speed were changed as mentioned previously.

E. Dimensional and Force Analyses:

The dimensional analysis given well serves as a guide in arranging the various factors in dimensionless groups, helping to plan the tests. The group to desired level of centrifugal force (F) for enough time to cause seed separation as seed characteristics are: effect of static friction angle between the seeds and the screen, seed bulk density (ρ), diameter of seed (di), acceleration due to gravity (g), the angular velocity of screen (ω), diameter of screen and material feeding rate (kg/h).

Depending upon the relationship between the above factors, the fenugreek seed in the cylinder may slide along it, separate from the surface and perform a free flight or may move with the surface being at rest relative to it. In the last case seed is not sieved **(Bosoi et al., 1991).**

The release of seeds in a cylindrical sieve depends upon their relative velocity and the forces acting on them. These forces are:

- The mass of the particle directed downward, (m . g).
- The centrifugal force, $(m \cdot r \cdot \omega^2)$.

$$\pi_1 = d \cdot \omega^2 / g, \quad \text{and} \quad \pi_2 = Q / (\rho \cdot \omega \cdot di^3) \ldots\ldots \quad (8)$$

$$\acute{\eta} = f(Q, \omega, d, g, \rho, di) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Where:

d is the screen diameter, (cm)., ω is the angular velocity cylindrical sieve, (rad./sec.)., g is the acceleration gravity, (cm/sec^2)., Q is the seed feeding rate, (kg/h)., ρ is the seed bulk density, (g/cm^3)**.,** di is the seed diameter, (cm) and ή is the separating efficiency.

Joseph (1974) determined an equation to describe the forces acting on the rotating screen as follows:

$$F_n = \omega^2 \cdot r / g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

Where:

F_n is the normal force.

r is the cylinder radius.

The motion of the fenugreek seed on the cylinder surface is not determined by the tangential force alone, because the particle will lose contact with the cylinder, if the resultant of the normal force (F_n) is not directed towards the cylinder surface. The equations that describe the particle motion at a critical speed of the cylindrical sieve surface (as illustrated in Figure (3)) are:

$$F_n = m \cdot \omega^2 \cdot r - m \cdot g \sin \alpha \ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$\mu F_n = m.g \cdot \cos \alpha \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (12)$$

Where:

F_n is the force in the normal direction of fenugreek Seed particle.

μF_n is the force in the tangential direction of fenugreek Seed particle.

m is the mass of fenugreek seed.

α is the angular position of particle on cylindrical sieve surface measured from the horizontal axis in the direction of rotation.

μ is the coefficient of friction between the fenugreek seeds and the cylindrical surface.

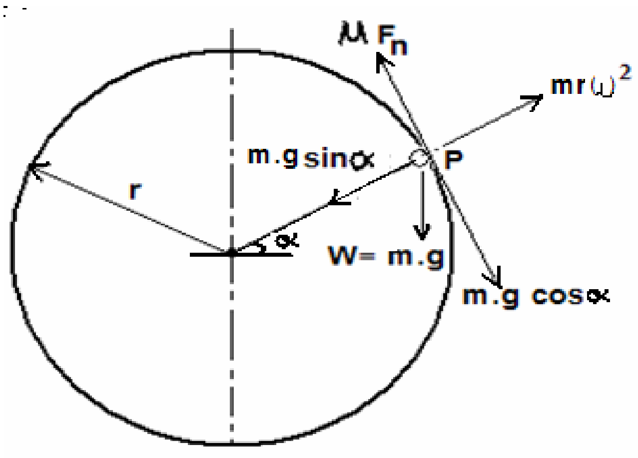


Fig. (3): The forces acting on a fenugreek seed in the rotating cylinder.

At the critical speed (which makes the seeds stick with the screen and do not fall down), the angular velocity of fenugreek seed ($\omega_p = \omega$).
Substituting the force in the normal direction of fenugreek Seed particle (F_n) from equations (11) into equation (12) yields the following equation (13):

$$m.g \cos \alpha = \mu \, (m \, \omega^2 \, r - m.g \cos \alpha) \; \ldots\ldots\ldots\ldots. \; (13)$$

Equation (13) can be re-arranged by cancelling (m) from both sides yields the following equations:

$$g \cos \alpha = \mu \, (\omega^2 . \; r - g . \sin \alpha) \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots. \; (14)$$

$$\omega^2 = (g . \cos \alpha + \mu . g . \sin \alpha) / (\mu . r) \; \ldots\ldots\ldots\ldots\ldots. \; (15)$$

$$\omega = \sqrt{\frac{g}{\mu r} (\cos \alpha + \mu \sin \alpha)} \ldots\ldots..(16)$$

But

$$\omega = (2\ \pi\ N) / 60 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

The following equation is used to calculate the number of sieve rotations per minute (N):

$$N = \frac{60}{2\pi}\sqrt{\frac{g}{\mu r}(\cos\alpha + \mu \sin\alpha)} \ldots\ldots\ldots\ldots\ldots\ldots (18)$$

Under the conditions of this study, substituting the parameter (α) by its value used as: $\alpha = 90^o$.

$$N = \frac{60}{2\pi}\sqrt{\frac{g}{r}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

The critical speed of the sieve (N) was calculated by substituting the parameter (r) by its value used in this study as follows:

$$N = \frac{60}{2\pi}\sqrt{\frac{981}{4}} \quad \ldots\ldots\ldots\ldots\ldots (20)$$

The critical speed of the sieve (number of sieve rotations per minute) was calculated using equation (20), and found to be N = 149.62 ~ 150 r.p.m.

RESULTS AND DISCSSION

1. Physical and Chemical Properties of Fenugreek Seeds:

At the beginning of the experiments, twelve samples of fenugreek seeds used in this study were taken to determine their moisture content on wet basis. The measured moisture content ranged from 12.8% to 14.3%, with average percentage of 13.6% (w.b). At this percentage of moisture content (13.6%, w.b), samples were taken for determining the physical and chemical properties of seeds and the results are listed in Table (1).

Volume (V), spherical percent (S_p) , geometric diameter (D_g) , arithmetic diameter (D_a), flat surface area (A_f) and transverse surface area (A_{th}) are values are difficult to determine rapidly by a direct measurements, but they can be calculated as a function of length (L), width (W) and thickness (T). One of the most accurate methods is to predict these values from the measurements of length, width and thickness of the seeds. In this study, the pervious equations from (1) to (6) were used to determine these values.

Table (1): Physical and chemical properties of fenugreek seeds.

Physical properties		Chemical properties	
Item	Estimated values	Item	Estimated values
Length , mm	4.2	Friction angle,(°)	
Width , mm	2.8	* stainless	22
Thickness , mm	1.8	* metal	30
Volume , mm^3	11.8	*wood	35
Spherical percentage, (%)	65.86	Coeff. of friction:	
Geometric diameter , mm	2.77	* stainless	0.42
Arithmetic diameter , mm	4.26	* metal	0.58
Flat surface area , mm^2	11.76	*wood	0.72
Transverse surface , mm^2	3.96	Angle of repose,(°)	33
Moisture content ,(% w.b)	13.6	Terminal velocity,(m/s)	35
Bulk density , (g/cm^3)	0.52		

The results in Table (1) were analyzed statistically given the following general equations, which express the relationships between the items L, W, T, V, S_p, D_g, D_a, A_f and A_{th} for fenugreek seeds.

$$V = 0.1495\ L^3 = 0.5047\ W^3 = 1.8998\ T^3 \quad \ldots\ldots (21)$$

$$D_g = 0.1570\ L^2 = 0.3533\ W^2 = 0.8549\ T^2 \quad \ldots\ldots (22)$$

$$D_a = 0.2415\ L^2 = 0.5434\ W^2 = 1.3148\ T^2 \quad \ldots\ldots (23)$$

$$A_f = 0.6666\ L^2 = 1.5000\ W^2 = 3.6296\ T^2 \quad \ldots\ldots (24)$$

$$A_{th} = 0.2245\ L^2 = 0.5051 W^2 = 1.2222\ T^2 \quad \ldots\ldots (25)$$

Equations (21) to (25) can be used for prediction V, D_g, D_a, A_f and A_{th} for fenugreek seeds with reasonable accuracy from a measurement of any one of the three principal dimensions of L, W and T.

2. Determination of Maximum Screen Speed:

The experiment was done to study the effect of different screen speeds of rotating screen separator at different feeding rates of fenugreek seeds and different screen slopes on the separation efficiency of seeds, straw, and dust. Preliminary testes were carried out before starting the actual experiments to test the performance of the machine and to select the maximum screen speed that can be used with the separating system using different screen speeds at feeding rate of 5 kg/h and screen slope of 0°. During feeding the samples, the straw moved centrally and falls down very fast, but the seeds moved tangential to the screen and fall vertically by the effect of their weight and rear fall down from sides. At speed of 165 rpm, it was clearly noted that the seeds stick with the screen and do not fall down. From the previous notice, it was decided that the maximum screen speed should be lower than 150 rpm. Thus, five screen speeds were used in this study: 25, 50, 75, 100 and 140 rpm.

3. Parameters Affecting Machine Separating Efficiency:

The parameters which affect the separating efficiency of the rotating screen separator are: screen speed, feeding rate of seeds and screen slope. The effects of these parameters and their interactions on the machine separating efficiency were investigated in this study and the obtained results are discussed as follows:

3.1. Effect of screen speed on the machine separating efficiency:

Fig. (4) shows the machine separating efficiency at five screen speeds (25, 50, 75, 100 and 140 rpm) for six feeding rates of seeds (3, 5, 7, 9 ,11 and 13 kg/h) and screen slope of 0°. The results showed that higher machine separating efficiencies were observed at screen speed of 140 rpm for all feeding rates as compared with the others screen speeds.

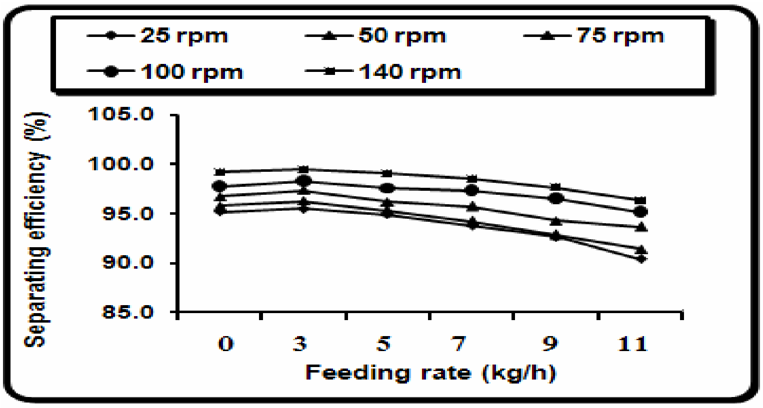


Fig. (4): Effect of Screen speed on the separating efficiency of rotating screen separator at various feeding rates and screen slope 0°.

The maximum machine separating efficiency (99.45%) was obtained at screen speed 140 rpm for feeding rate 5kg/h, while the minimum machine separating efficiency (90.43%) was obtained at the lowest screen speed (25 rpm) for the highest feeding rate (13 kg/h). Thus, increasing the screen speed and decreasing the feeding rate increase the machine separating efficiency.

3.2. Effect of seeds feeding rate on the machine separating efficiency:

Fig. (5) shows the machine separating efficiency at six feeding rates (3, 5, 7, 9, 11 and 13 kg/h) and five screen slopes (0, 10, 20, 30 and 40°) for screen speed of 140 rpm. The results indicated that higher machine separating efficiency was obtained at feeding rate of 5 kg/h for all screen slopes at screen speed 140 rpm as compared with the corresponding values of the others feeding rates, while the lower machine separating efficiencies were obtained at the higher feeding rate (13 kg/h) for all screen slopes at screen speed of 140 rpm. The highest machine separating efficiency (99.45%) was obtained at feeding rate of 5 kg/h and screen slope of 0° for screen speed of 140 rpm, while the lowest machine separating efficiency (93.05) was obtained at feeding rate of 13 kg/h for screen slope of 40° and screen speed of 140 rpm. Thus, increasing both of the feeding rates and screen slopes decrease the machine separating efficiency.

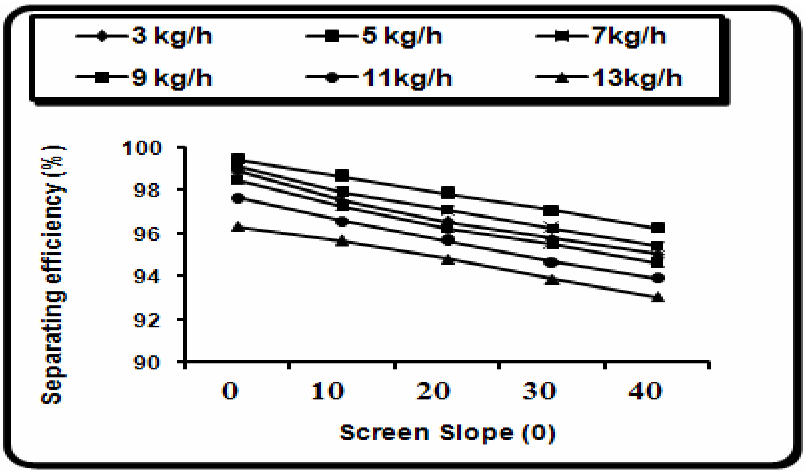
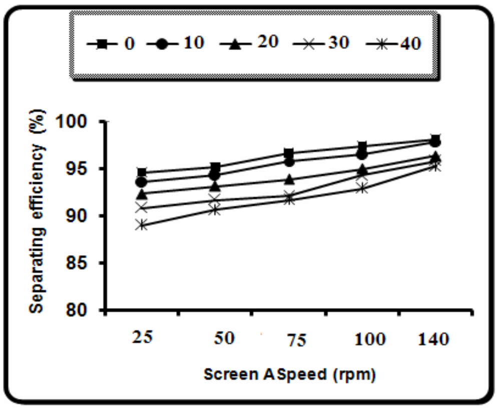


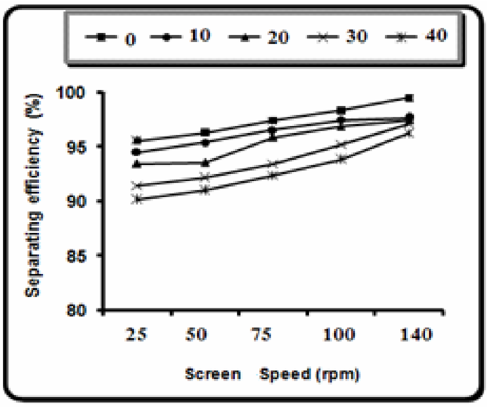
Fig. (5): Effect of feeding rate on the separating efficiency of rotating screen separator at various screen slopes and screen speed 140 rpm.

3.3. Effect of screen slope on the machine separating efficiency:

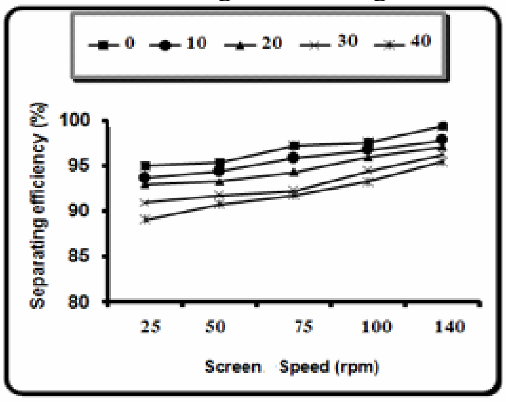
Fig. (6, a-f) shows the machine separating efficiency at five screen slopes (0, 10, 20, 30, and 40°) for five screen speeds (25, 50, 75, 100 and 140 rpm) and six feeding rate (3, 5, 7, 9, 11 and 13 kg/h).



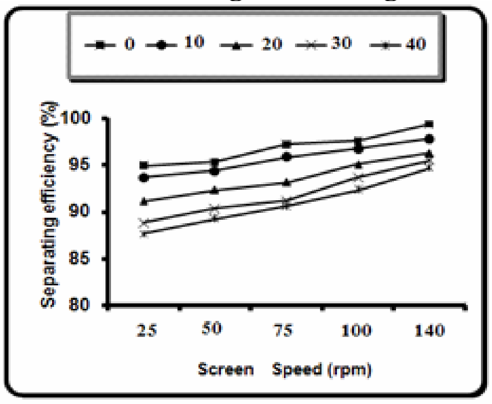
a) Feeding rate = 3 kg/h



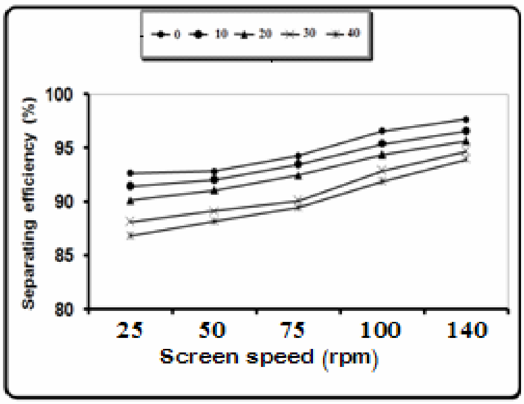
b) Feeding rate = 5 kg/h



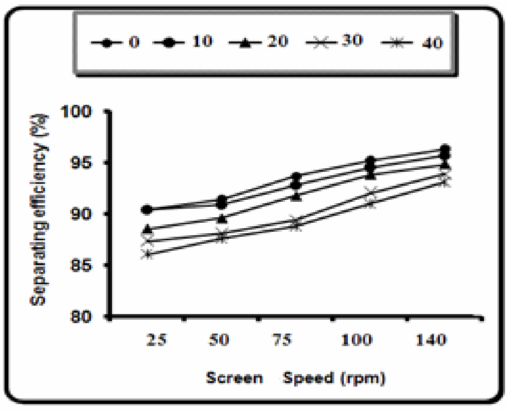
c) Feeding rate = 7 kg/h



d) Feeding rate = 9 kg/h



e) Feeding rate = 11 kg/h



f) Feeding rate = 13 kg/h

Fig. (6): Effect of screen slope on the separating efficiency of the rotating screen separator at various feeding rates and screen speeds.

The results indicated that the higher machine separating efficiency was obtained at screen slope of 0° for all screen speeds and feeding rates. The highest machine separating efficiency (99.45%) was obtained at screen slope of 0° for feeding rate of 5 kg/h and screen speed of 140 rpm (Fig. 6, b), while the lowest machine separating efficiency (86.02%) was obtained at screen slope of 40° for feeding rate of 13 kg/h and screen speed of 25 rpm. Thus, increasing both of the feeding rates and screen slopes decrease the machine separating efficiency, but increasing the screen speed increases the machine separating efficiency.

4. The Mechanical Damage Percentage:

The mechanical damage percentage of fenugreek seeds was measured at the optimum screen speed (140 rpm) for five screen slopes and six feeding rates. The results are listed in Table (2). The results showed that increasing both screen slope and feeding rate of fenugreek seeds increase the smashed seeds ratio. The highest smashed seeds ratio caused by the machine (3%) was observed at the highest feeding rate (13 kg/h) and highest screen slope (40 0°), whereas the lowest smashed seeds ratio (1.45 %) was obtained at the lowest values of feeding rate (3kg/h) and screen slope (0°).

Table (2): Mechanical damage of fenugreek seeds at various feeding rates and screen slopes for screen speed of 140 rpm.

Screen slope (°)	Mechanical damage (%)					
	Feeding rate (kg/h)					
	3	5	7	9	11	13
0	1.45	1.60	1.75	1.92	2.04	2.14
10	1.54	1.68	1.84	2.12	2.19	2.19
20	1.62	1.87	2.04	2.38	2.33	2.27
30	1.74	1.96	2.22	2.56	2.49	2.76
40	2.10	2.18	2.32	2.63	2.78	3.00

CONCULSION

The obtained results from this investigation can be concluded as follows:

1. The average moisture content and bulk density of fenugreek seeds used in this study were 13.6% (w.b.) and 0.52 g/cm^3, respectively.

2. The average measured length, width and thickness of fenugreek seeds were 4.2 mm, 2.8 mm and 1.8 mm, respectively. They gave a reasonable prediction of seed volume, spherical percent, geometric and arithmetic diameters, flat and transverse surfaces areas.

3. The average values of seed volume (V), spherical percent (S_p), geometric diameter (D_g), arithmetic diameter (D_a), flat surface area (A_f) and transverse surface area (A_{th}) were calculated as functions of length (L), width (W) and thickness (T) and they were found to be 11.8 mm^3, 65.86%, 2.77 mm, 4.26 mm, 11.76 mm^2, 3.96 mm^2, respectively.

4. The friction angles between fenugreek seeds and stainless steel, metal and wood surfaces were 22°, 30° and 35°, respectively.

5. The coefficients of friction for fenugreek seeds with stainless steel, metal and wood were 0.42, 58 and 0.72, respectively.

6. The average seeds terminal velocity and angle of repose were 35 m/s and 33°, respectively.

7. Screen speed of 140 rpm gave higher machine separating efficiencies for all feeding rates at screen slope 0° as compared with others screen speeds. The maximum machine separating efficiency (99.45%) was obtained at screen speed 140 rpm for feeding rate 5kg/h, while the minimum machine separating efficiency (90.43%) was obtained at the screen speed 25 rpm for the highest feeding rate 13 kg/h.

8. Feeding rate of 5 kg/h gave the highest machine separating efficiencies for all screen slopes at screen speed of 140 rpm as compared with other feeding rates, while lower machine separating efficiencies were obtained at high feeding rate (13 kg/h) for all screen slopes at screen speed of 140 rpm.

9. Screen slope of 0° gave the highest machine separating efficiency for all screen speeds and feeding rates. The maximum machine separating efficiency (99.45%) was obtained at screen slope of 0° for feeding rate of 5 kg/h and screen speed of 140 rpm.

10. The highest smashed seeds ratio caused by the machine (3%) was observed at the highest feeding rate (13 kg/h) and highest screen slope (40°) for screen speed of 140 rpm.

REFERENCES

Abed El-Rahman, M. M. (2004). Improving the field performance of a portable bulbs grader. Misr J. Ag. Eng., 21(2): 199-211.

Amin, E. E. A.; Magda, M. A. M. and Magda, M. M. (2002). Development and evaluation a roller sizer suitable for cylindroids crops. The 10th An. Conf. Misr Soc. Ag. Eng., Oct., 20 (4):237-250.

Amin, E. E. A. (2003). Effect of some physical and mechanical properties on grading efficiency. The 11th An. Conf. Misr Soc. Ag. Eng., Oct., 2003: 415-470.

Arfia, G. K. (2006). Engineering parameters affecting cleaning of soybean grains. The 14th An. Conf. Misr Soc. Ag. Eng., 22 Nov., 2006. 23(4):813-828.

Awady, M. N. and Sayed, A. S. (1994). Separation of peanuts seeds by air stream, Misr Soc. Ag. Eng., 11(1):137-147.

Awady, M. N.; Yehia, I.; Ebaid, M. T.; and Arif, E. M. (2003). Development and theory of rice cleaner for reduced impurities and losses. Misr J. Ag. Eng., 21(2):199-211.

Bosoi, E. S.; Verniaev, O. V.; Smimov, I. I. and Sultan-Shakh, E. G. (1991). Theory construction and calculations of agricultural machines. Vol.(2), Mec. Pub., Moscow.

Ebaid, M. T. (2005). Properties of some medical grains affecting sieve unit selection. Misr J. Ag. Eng., 22(3):861-873.

El-Gayar, S. M. (2005). Flux seeds cleaning and grading using vibratory apparatus. Misr J. Ag. Eng., 22(3):923-942.

El-Raie, A. E. S.; Hendawy, N. A.; and Taib, A. Z. (1996). Study of physical and engineering properties for some agricultural products. Misr J. Ag. Eng., 13(1):211-226.

Joseph, K. P. (1874). Vertical rotating screens for separating seeds. Trans. of ASAE., 18(3):606-610.

Metwalli, M. M. (1975). Design of a horizontal cylindrical screen for separating grains during harvesting by centrifugal and gravity forces. Fac. of Agric., Kafr El-Sheikh, Tanta Univ., Bulletin (16):1-12.

Metwalli, M. M.; Khalifa, E. A. and Desouky, E. D. (1999). Study on performance of gravity separator to produce seeds. Misr J. Ag. Eng., 16(2):261-279.

Mohsenin, N. N. (1986). Physical properties of plant and animal materials. Gordon and Breach Sc. Pub., N. Y., :734.

الملخص العربى

بعض العوامل المؤثرة على تنظيف وتدريج حبوب الحلبة

أ.د/ عبد القادر على النقيب* د/ حمدى سالم السيد عبد الجليل**

أجرى هذا البحث بهدف تصميم وإختبار وحدة غربلة وتدريج إسطوانية الشكل دورانية لتنظيف حبوب الحلبة وفصل الشوائب منها وتدريجها لما لهذا المحصول من أهمية إقتصادية، نظرا لإنتشار إستخدامه فى وجبات الطعام بجانب إستخدامه فى تصنيع كثير من الصناعات الغذائية والطبية. تم أولاً دراسة الخواص الطبيعية والميكانيكية لهذا المحصول لما لهما من أهمية كبرى فى عمليات الفرز والتدريج. تم تصميم نموذج لجهاز التنظيف والتدريج بإحدى ورش القطاع الخاص، وهوعبارة عن وحدة غربلة إسطوانية الشكل أفقية بطول 60 سم وقطر10 سم متدرجة الفتحات مع إمكانية تغير ميل وحدة الغربلة. وقد تم تقسيم وحدة الغربلة الإسطوانية إلى ثلاثة غرابيل متدرجة المقاس، الأول لنزول الأتربة والشوائب، والثانى لنزول الحبوب المكسورة والصغيرة والثالث لنزول الحبوب السليمة والنظيفة. ويتم إدارة وحدة الغربلة بمحرك كهربائى (¼ ك.وات) ومجموعة من الطارات والسيور يمكن عن طريقها تغير سرعة دوران الغرابيل. ويوجد أسفل وحدة الغربلة صندوق تجميع خشبى مقسم إلى ثلاثة أقسام، القسم الأول لتجميع الأتربة والشوائب والثانى لتجميع الحبوب المكسورة والثالث لتجميع الحبوب السليمة والنظيفة. وقد أجريت هذه التجارب بهدف تقييم أداء وحدة الغربلة من حيث مقدرتها على فصل الأتربة والشوائب من حبوب الحلبة وكفاءتها من حيث نسبة فصل البوب السليمة والنظيفة.

وقد تم دراسة العوامل التالية:

- الخواص الطبيعية والميكا نيكية لحبوب الحلبة.
- سرعة دوران جهاز الفصل.
- معدل تغذية الحبوب.
- ميل إسطوانة الفصل.

كما أجرى تحليل نظرى لتحديد السرعة الحرجة لفصل حبوب الحلبة وإختبارها عمليا، وإستنبطت مجاميع لا بعدية كما يلى:

$$\pi_1 = C1d \cdot \omega^2 / g \;,\; \pi_2 = C2\, Q / \rho \cdot \omega \cdot (di)^3 \;,\; \pi_3 = C \cdot \pi_1 \cdot \pi_2 \;,\; \pi_3 = \acute{\eta}$$

---

* أستاذ الهندسة الزراعية – قسم الهندسة الزراعية - جامعة الأزهر.

** مدرس الهندسة الزراعية – كلية الزراعة – جامعة الفيوم.

حيث أن:

ή هى كفاءة الفصل، (%).

d هى قطر إسطوانة الغربال، (سم).

ω هى السرعة الزاوية، (لفة/ث).

g هى عجلة الجاذبية الأرضية، (سم/ث^2).

Q هى معدل تغذية الحبوب، (كج/س).

ρ هى كثافة الحبوب، (جم/سم^3).

di هى قطر الحبة، (مم).

وقد أوضحت نتائج الدراسة مايلى :

1. متوسط المحتوى الرطوبى والكثافة الحجمية لحبوب الحلبة المستخدمة فى هذه التجارب 13.6% ، 0.52 ج/سم^3 على الترتيب.
2. متوسط أبعاد الحبوب المقاسة 4.2 ، 2.8 ، 1.8 مم طولاً وعرضاً وسمكاً على الترتيب. بينما كان مساحة المسطح للحبة والمساحة المسقطة وحجم الحبة 11.76 مم^2 ، 3.96 مم^2 ، 11.8 مم^3 على الترتيب.
3. متوسط السرعة الحدية (الحرجة) ونسبة التكور لحبوب الحلبة 35 م/ث، 65.86 % على الترتيب.
4. وجد أن معامل الإحتكاك لحبوب الحلبة مع أسطح الأستانلس (الصلب المقاوم للصدأ) والمعدن والخشب 0.42 ، 0.58 ، 0.72 على الترتيب.
5. تم التوصل إلى علاقات نربط بين الأبعاد الأساسية (الطول والعرض والسمك) لحبة الحلبة كما يلى:

$$L = 1.5\ W = 2.33\ T.$$

6. تم التوصل إلى علاقات يمكن بها التنبؤ بحجم الحبة، مساحة مسطح الحبة، المساحة المسقطة للحبوب.
7. تأثرت كفاءة الفصل بالسرعة الدورانية لجهاز الفصل ومعدل تغذية الحبوب ، حيث زادت كفاءة الفصل بزيادة السرعة الدورانية لجهاز الفصل (بأقل من الحد الحرج بحوالى 7%)، وكانت أفضل سرعة لفصل الحبوب هى 140 لفة/د (قطر الحبة 2.8 مم).
8. زادت كفاءة فصل حبوب الحلبة بخفض معدل تغذية الجهاز بالحبوب إلى حد معين، حيث كانت أعلى كفاءة ممكنة (99.45%) عند سرعة غربال 140 لفة/د ومعدل تغذية للحبوب 5 كج/ساعة وميل صفر لجهاز الفصل.
9. أظهرت النتائج أن العوامل المثلى لتشغيل جهاز الفصل للحصول على أعلى كفاءة ممكنة هى سرعة الغربال 140 لفة /دقيقة ، معدل تغذية الحبوب 5 كج / س ، ميل الغربال 0°.