DEVELOPMENT OF A LOCAL THRESHING MACHINE SUITS FOR THRESHING BLACK SEED (*Nigella sativa*)

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ABSTRACT

Medical and aromatic seeds are mainly considered among the most important plants in Egypt and the world. They are potentially usable for many medical industries. So, the aim of this research concerns in development of a small thresher to suit threshing of Black seed (nigella sativa). The thresher was evaluated and tested at drum speeds of (200) 4.19, (250) 5.23, (300) 6.28, and (350) 7.32 (rpm) m/s, feed rates of 600, 700, 800, and 900 kg/h and capsules moisture contents of 11.82, 13.63, 15.72, and 17.61 % (w.b.). The results showed that the minimum total seed losses of 2.63 %, stripping efficiency of 99.31 %, threshing efficiency of 98.74 %, cleaning efficiency of 95.88 %, required energy of 2.85 kW.h/ton and criterion cost of 199.18 L.E/ton were recorded under drum speed of 6.28 m/s, feed rate of 600 kg/h and capsules moisture content of 13.63 %.

INTRODUCTION

Black Seed (*Nigella sativa*) is an herbaceous plant which grows in the Mediterranean countries, and is cultivated in Egypt and Syria for its seed and belongs to the Ranunculaceae family. The plant is also known by other names differ between different regions and countries such as black caraway (Europe), Black Cumin, black seed , and Corekotu (America), Fitch (Bible), Habba soda (Oman), Faux cumin, Fennel flower (France), and Habet el Baraka (Egypt). Nigella is a genus of about 14 species of annual plants in the family Ranunculaceae, native to southern Europe, north Africa and southwest Asia.The species grow to 20-90 cm tall, with finely divided leaves, the leaf segments narrowly linear to threadlike. The flowers are white, yellow, pink, pale blue or pale purple, with 5-10

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petals. The fruit is a capsule composed of several united follicles, each containing numerous seeds.

Paulsen *et al.* (1980) indicated that the moisture content of grain is one of the major physical factors for the design and operation of the threshing machine that affect the mechanical damage to grains and the threshing efficiency of machines. The effect of moisture content on hardness and strength of several grains indicates that greater energy is required to break grains having higher moisture content by impact compared to those having lower moisture content. **Huynh *et al.* (1982)** stated that the seed separation from stalks and passage of seed through the concave gate is a function of some variables such as feed rate, threshing speed, concave length, cylinder diameter and concave clearance. These variables are also related to the threshing losses and seed separation efficiency. **Kaul and Egbo (1985)** stated that an optimum speed is desirable to get an optimum performance of a thresher as excessive speed can cause the grain to crack, and too low a speed can give unthreshed heads. **Gol and Nada (1991)** concluded that the important factors affecting the efficiency of mechanical pod stripping element are operation speed and crop conditions. Percentage of stripping pods increased by increasing of peripheral drum speed which ranged from (473 rpm) 0.1m/s to (675 rpm) 3 m/s. **Ajayi (1991)** found that the moisture content of the crop influenced the material capacity of a locust bean thresher. Threshing effectiveness was also found to be affected by the cylinder speed. **El-Behairy *et al.* (1997)** found that the feeding rate increasing linearly by increasing drum speed. Also feeding rate depends on the experience of the thresher labour. The straw sizes decreased by increasing drum speed while the grain losses decreased. **Afify (1998)** fabricated and constructed a simple flax thresher to remove the capsules with minimum stalk damage. He used three drum shapes (peg-teeth, beaters, and peg-teeth with beaters). The results showed that the drum with beaters recorded threshing efficiency of 96.52 %, separation efficiency of 98.21 %, cleaning efficiency of 95.79 %, stripping efficiency of 99.35 %, threshing capacity of 1.01 t/h, energy, 2.79 kW.h/ton and less criterion cost of 10.29 L.E / ton under the conditions of drum speed of 5.23 m/s and capsules moisture content of 14.20 %. **El-Hadad (2000)** stated that the threshing efficiency increased with increasing drum speed and decreasing feed rate. The maximum threshing efficiency was 99.76 % at drum speed of 21.25 m/s (1400 rpm), and feed rate of 15 kg/min. The maximum amount of visible grain damage was 0.90 % under these conditions. **El-Nono and Mohammed (2000)** found that, the machine power requirement was directly proportional to the drum speed, moisture content and grain damage. Studies on the effect of swinging hammer, spike tooth and rasp bas cylinders on threshing effectiveness and damage of wheat revealed that the cylinder speed and concave clearance were found to be important variable in unthreshed grain and damage model. Increase in cylinder speed and decrease in concave clearance decreased the rate or unthreshed grain and increased grain damage and power requirement. They found out that the swinging hammer type cylinder consumed more power than the rasp bar and spike cylinders. **Mandouh *et al.* (2000)** stated that Threshing effectiveness was also found to be affected by the cylinder speed, the concave clearance for wheat, feed rate of crops, the number of rows of concave teeth used with spike tooth cylinder, and the type of crop. **Simonyan and Oni (2001)** reported that there is an increase in threshing efficiency and extractor efficiency with decrease in moisture content. Threshing effectiveness was also found to be affected by the cylinder speed. **Badawy (2002)** reported that the highest threshing efficiency was 97.17 % at the optimum performance of flax deseeding machine. By increasing the drum speed from 9.28 to 15.33 m/s the capacity increased from 1800 to 2400 kg/h. **El-Ashry *et al.* (2003)** indicated that the energy requirement were 3.19, 3.4, and 1.6 kW.h/Mg for complete, partial mechanized and conventional systems, respectively. At one Mg of flax, the cost of threshing were 44.44 L.E at complete mechanized system because of increasing the stalk losses and damage, while the cost of conventional system was 37.76 L.E. **Ebaid *et al.* (2004)** developed the threshing chamber in a wheat thresher by removing the feeding auger to increase the feed rate and production rate. The machine was tested and evaluated under different operating conditions. The results showed that the purity efficiency of 99.30 % and total grain losses of 0.16 % were achieved at drum speed of 870 rpm, feed rate of 1200 kg/h, air speed suction of 32 m/s, blower air speed of 6 m/s, and sieve tilt angle of 5˚. **Zakaria (2006)** developed the threshing drum in a local stationary thresher to suit separation of flax capsules. The machine was tested under feed rates of 8.57, 12.86, 17.14 and 21.43 kg/min, and four drum speeds of 24.25, 25.81, 27.33, and 28.85 m/s. The results showed that the optimum performance was at drum speed of 28.85m/s, feed rate of 8.57 kg/min, drum fingers of 12 and separation time of 15 seconds where the threshing efficiency was 96.92 %. **Zaky (2006)** recommended that the optimum conditions to reduce the seed damage and total losses of black seed with acceptable level of cleaning efficiency were the drum speed ranged from 3.3 to 4.4 m/s, clearance ranged from 2.5 – 3 mm and air velocity of 2 m/s to consumed energy of 25.12 kW.h/ton and criterion cost of 752 L.E/ton. Heretofore, there are no papers published on the design or development of a machine for threshing black seed capsules. With the availability of reports on the properties of other similar crops and threshing, the objective of this study concerned in development of appropriate threshing machine suits black seed which will reduce the drudgery associated with the traditional methods of threshing black seed capsules with high stripping, threshing and cleaning efficiencies in addition to low required energy and cost.

MATERIALS AND METHODS

Field experiments were carried out during the growing season of 2007 in the Agricultural engineering department workshop, faculty of agriculture, Zagazig University. Black seed crop (***nigella sativa***) was planted with pneumatic planter in Kafr El-Hamam farm – Sharkia governorate.

1 - MATERIALS:

- **Threshing machine:** The threshing machine was designed and manufactured for threshing flax crop in Agricultural Engineering Department, Faculty of Agriculture, Zagazig University. **Afify (1998)**. The elevation and side view of the machine before development shown in Fig. (1).
- **Engine:** Type of Lombardini (Carburetor), one cylinder, air cooling, gas oil fuel and power of 3.5 kW at 3600 rpm to operate the black seed thresher. Fig. (1).
- **Stop watch:** of 0.02 sec. to record the threshing time.
- **Tachometer:** (Cole-parmer 8204), ranged from 60 to 19999 rpm, resolution 1 rpm to calculate the rotating speed of drum.
- **Electric balance:** of 0.01 g as accuracy to estimate the seed losses.
- **Electric oven:** to estimate the moisture content.

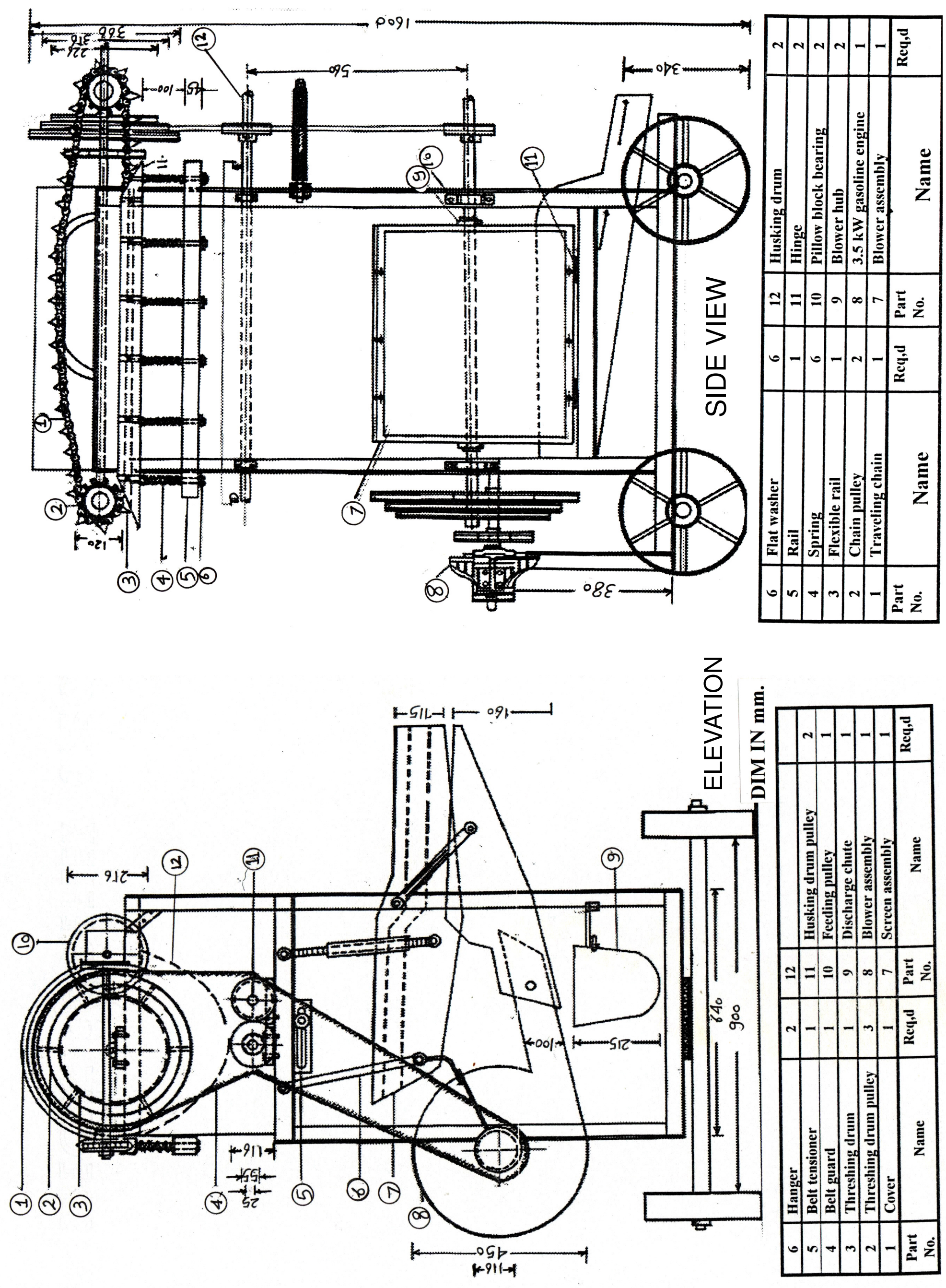


Fig.(1): The elevation and side view of the black seed threshing machine before development.

2 – METHODS:

Nigella sativa plants were cut when pods reach maximum size and color. *Nigella sativa* capsules ranged from deep green to deep burgundy, with stripes in between. The first few pods are picked with as long a stem as possible, one at a time.

The plants flowers profusely and so when most of the flowers become seed pods, pull the entire plant and cut the stems. Then wrap a rubber band around a small bundle of stems and then hang them upside down for drying in a dark, airy place until dry. The physical proprties of Black seed plants (*Nigella sativa*) were measured from 30 plants taken randomly as shown in Table (1). Also, seed mechanical properties were measured using the following equations **(El-Raie *et al.* 1996)**, as shown in table (2).

$$V = \frac{\pi}{6}(L.W.T), \text{ mm}^3 \quad \ldots\ldots(1)$$

$$S = \frac{3\sqrt{L.W.T}}{L} \times 100, \% \quad \ldots\ldots(2)$$

$$D_g = 3\sqrt{L.W.T}, \text{ m} \quad \ldots\ldots(3)$$

$$D_a = \frac{(L+W+T)}{3}, \text{ mm} \quad \ldots\ldots(4)$$

$$A_f = \frac{\pi}{4} L.W, \text{ mm}^2 \quad \ldots\ldots(5)$$

$$A_t = \frac{\pi}{4} \frac{(L+W+T)^2}{3}, \text{ mm}^2 \quad \ldots\ldots(6)$$

Where:

L: Length (mm), W: Width (mm), T: Thickness (mm), V: Volume $(mm)^3$, D_g: Geometric diameter (mm), D_a: Arithmetic diameter (mm), S: Sphericity (%), A_f: Flat surface area (mm^2), A_t : Transverse surface area of the individual seed (mm^2).

Table (1): The physical properties of Black seed plants.

Physical properties	Value	Unit
Av. Plant height	67.7	cm
Av. Stem diameter	0.7	cm
Av. No. of branches/plant	12.57	
Av. No Capsules/plant	43.2	
Av. No. Seed/capsules	110	Seed
Av. Weight seed/plant	11.07	g
Av. Weight of 1000 seed	2.87	g
Av. Seed yield	775.84	kg/fed
Av. Seed/straw ratio	1 : 3.2	

Table (2): The geometric and mechanical properties of black seed plants.

Geometric and mechanical properties	Value	Unit
Av. Length	3.02	mm
Av. Width	1.28	mm
Av. Thickness	0.8	mm
Av. Volume	1.63	mm^3
Av. Geometric diameter	1.47	mm
Av. Arithmetic diameter	1.62	mm
Av. Flat surface area	3.03	mm^2
Av. Sphericity	48.22	%
Av. Transverse surface area of the individual seed	0.80	mm^2
Av. Coefficient of friction (Seed/metal)	0.85	

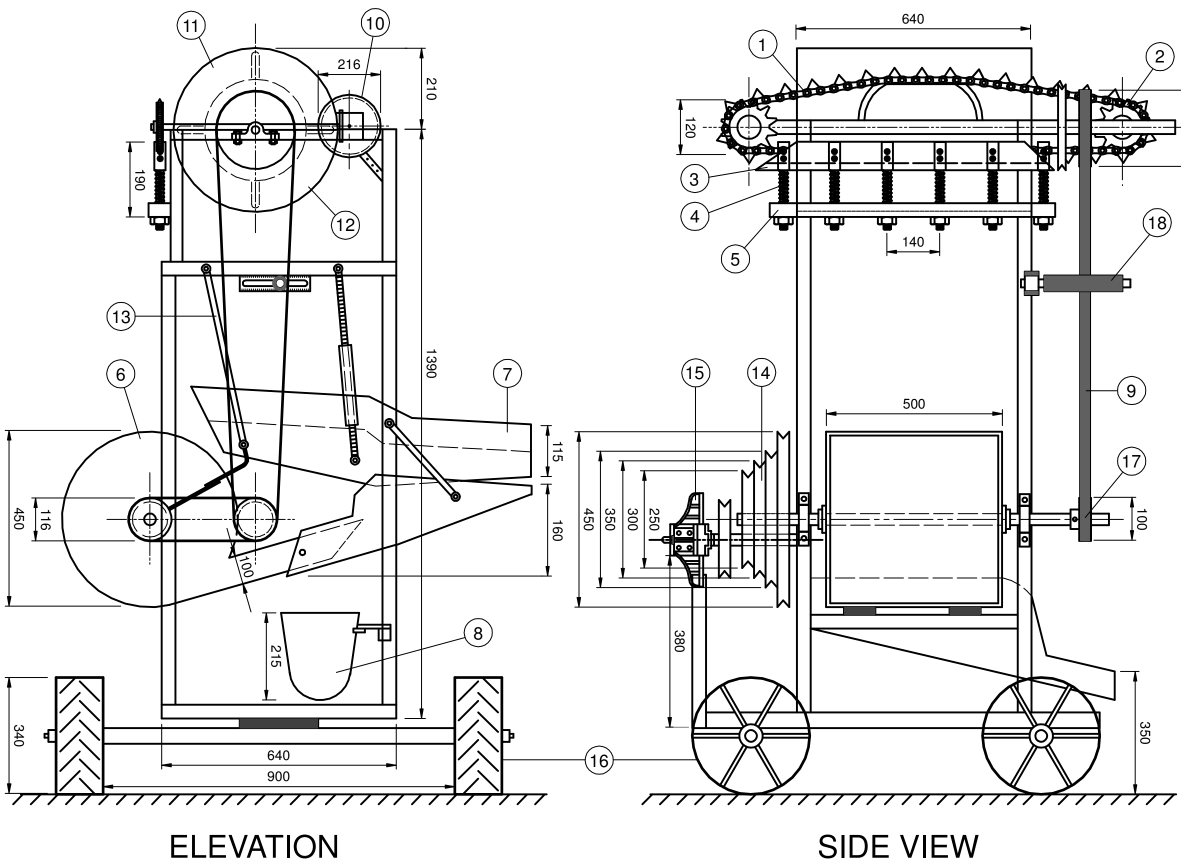
•DESIGN CONSIDERATIONS:

The following were considered in the design of the Machine; ability to thresh black seed capsules without damage at a rate higher than the manual method, ease of operation, reduction of the energy requirements and the drudgery involved in the traditional methods of threshing, economy to make the machine affordable and within the capacity of the local farmers and the choice of materials for the development of the machine to reduce the total energy requirements. The elevation and side view of the flax threshing machine after development to suit threshing black seed crop are shown in Fig. (2).

A- The development of threshing system:

1- The threshing drum as shown in Fig. (3) is housed in the concave and drum cover which were made from a horizontal cylinder of 600 mm in diameter and 600 mm long. The concave is the lower half of the cylinder perforated with 3.5 mm in diameter to serve as discharge holes for the threshed materials. The clearance between threshing drum and concave was 130, 100 and 70 mm at inlet, center and outlet, respectively.

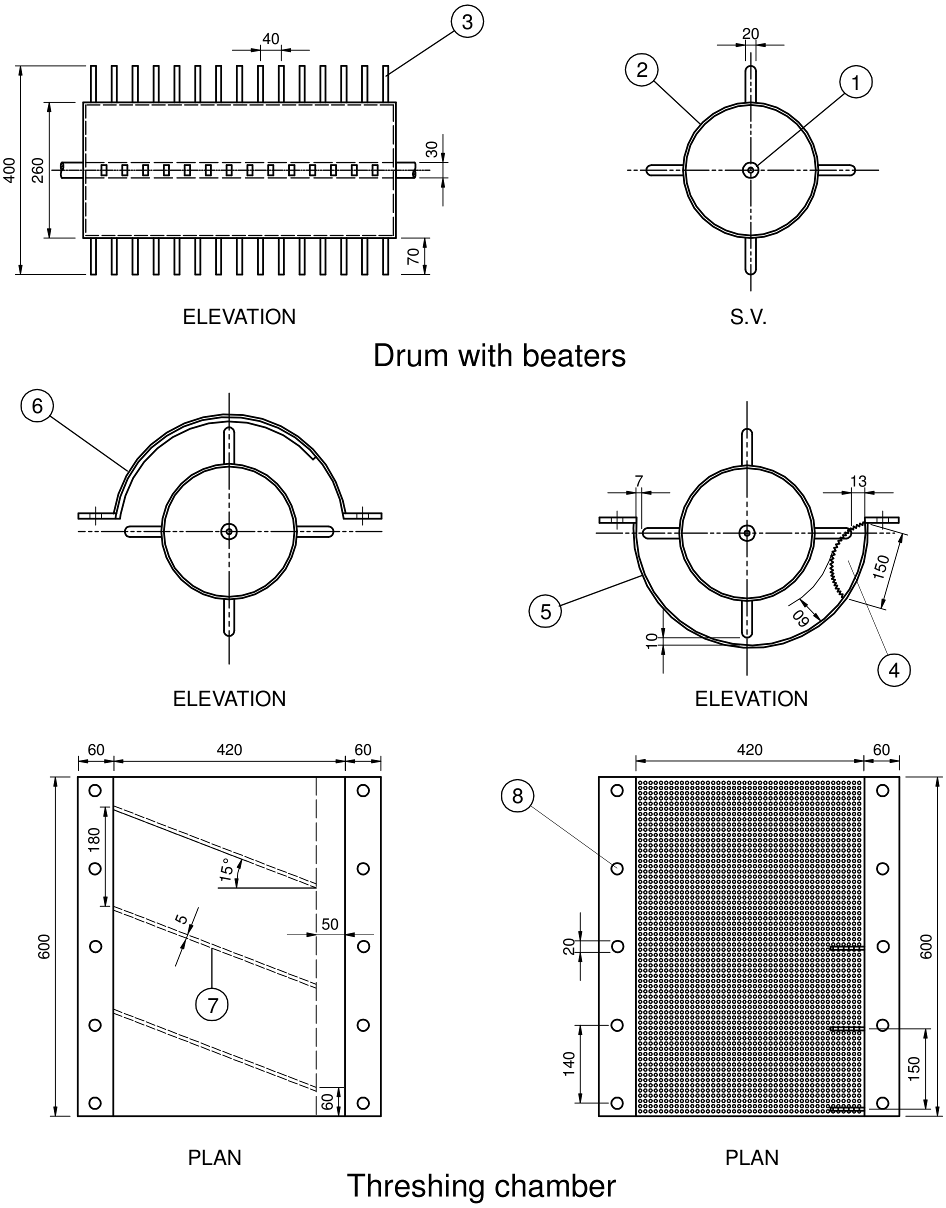
2- The upper half serves as the cover. Three semi circular folds of the same diameter with inclination of 15° were made from metal as shown in Fig. (3) to serve as a cover of the concave and help the crop material to move from inlet to outlet without accumulation.



No.	Part name	No. off
1	Travelling chain	1
2	Chain sprocet	1
3	Flexible rail	1
4	Spring	6
5	Rail	1
6	Blower	1
7	Screen	1
8	Discharge chute	1
9	V-Belt	2
10	Feeding pulley	1
11	Cover	1
12	Concave	1
13	Hanger	2
14	Reduction pulleys	3
15	Engine	1
16	Machine wheel	4
17	Blower pulley	1
18	Belt tensioner	1

All dimensions in, mm

Fig.(2): The elevation and side view of the black seed threshing machine after development.



No.	Part name	No.off	No.	Part name	No.off
1	Drum shaft	1	5	Concave	1
2	Threshing drum	1	6	Cover	1
3	Beater	48	7	Crop guide	3
4	Special knife	3	8	Bolt hole	10

All dimensions in, mm

Fig. (3): The developed threshing drum and its chamber.

3- Three special knifes made of stainless steel with 150 mm in diameter were fixed as shown in Fig.(3) in the initial half on the concave at distance of 100 mm between them starting from the entrance to the middle of the concave. The action of these knifes interacted between the actions of beaters to help in cut the crop materials easily, reduce the impact force by the beaters and prevent the accumulation and rotation the straw around the drum.

B- The development of cleaning system:

The threshed capsules fall on the sieve as shown in Fig. (3), the air blast of the blower push the straw out of the machine and the seed fall on the slippage surface to the seed discharge duct. The slope angle of sieve toward the horizontal plane was equal 5˚. The sieves specifications were selected according to the maximum dimension for the seed (length) as follows; diameter of sieve hole was 3.5 mm, total area of sieve holes was 0.99 per 1 m^2 and the distance between two neighboring holes is 1.29 mm. **(Ebiad, 2005)**.

• DESIGN CALCULATIONS:

1- Threshing Drum:

The principal parameters of the threshing drum are the drum length, the drum diameter, number of beaters on the drum and the drum speed. **(Soja *et al.* 2004).** The drum length was obtained from the following equation as reported by **(Kepner *et al.* 1978 and Resnikov, 1991).**

$$q = q_o \cdot L \cdot M \quad \text{.............................. (7)}$$

Where:

L = Drum length (m), q = Feed rate of thresher (kg/s), q_o = Permissible feed rate (kg/s) and M = Number of (rows of) beaters. Therefore for a q of 0.4 kg/s and q_o of 0.17 kg/s, the drum length (L) for 4 rows of beater was approximately 600 mm.

2- The Drum Shaft:

The shaft is supporting by two bearing. Assuming that the load (F_1 = 240.4 N) due to the weight of the threshing drum with beaters (W_1 = 200 N), weight of threshing drum shaft (W_2 = 40 N), and crop materials (W_3 = 0.40 N) is uniformly distributed along the section of the shaft as shown in Fig. (4). Leaving an allowance of 0.1 cm between ends of drum and concave (for free rotation of drum) on both sides of the drum, and 17.5 cm on the right sides for the pulley, then, a threshing shaft length of 600 mm was obtained.

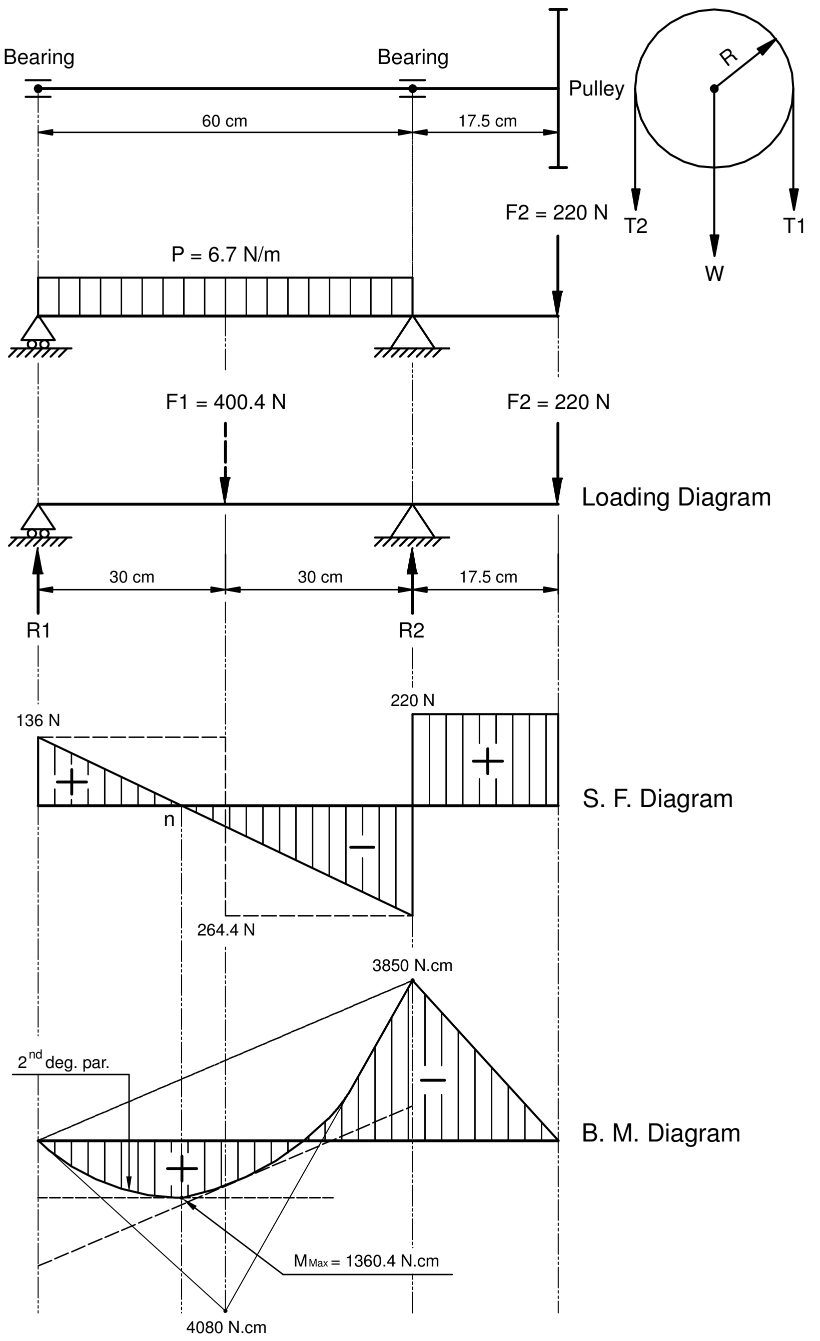


Fig.(4): The bending moment diagram of the drum shaft.

Placing pulley (W = 5 N) of diameter of 200 mm on the right end of the threshing drum shaft as point loads (F_2 = 220 N), the pulley is subjected to the tension by the belt of V-shape on the tight side (T_1 = 211.4 N) and the slack side (T_2 = 3.5 N) by the belt. The belt has area of 0.76 cm^2, weight of 0.106 kg per meter and allowable tension stress of 280 N/cm^2. From the previous, the shaft is subjected to combine torsion and bending stress through two loads in the same plan and direction. The diameter of threshing shaft can be calculated according to the theory of maximum shear stress according to (**Khurmi and Gupta 1984).**

$$d^3 = \frac{16}{\pi S_s} \sqrt{[K_b M_b]^2 + [K_t M_t]^2} \quad \ldots\ldots\ldots\ldots(8)$$

Where:

d = Shaft diameter, Ss = Allowable shear stress for shaft = 5000 N / cm^2, Kb = Shock factor for bending moment = 2, Kt = Shock factor for torsional moment, = 1.5., M_b = Maximum bending moment (Kg.cm), M_t= Maximum torque (Kg.cm).To determine both M_b and M_t , the forces (F_1 and F_2) acting on the shaft must be calculated as follows;

$F_1 = W_1 + W_2 + W_3$ (N)……………………..…………..…..(9)

$F_2 = T_1 + T_2 + W$ (N)…………………………….....…..(10)

The tension force on the pulley must be calculated according to the following equations **(Khurmi and Gupta, 1984)**.

$T_c = w.\ v^2 / g$ ……………………………………………..…..(11)

T = F. A ………………………………………….....…..…..(12)

$T_1 = T - T_c$ …………………………………….…..…..(13)

$$\mu = 0.54 - \frac{42.6}{152.6 + N_{rpm}} \quad \ldots\ldots\ldots\ldots(14)$$

2.3 log $T_1 / T_2 = \mu\Phi$ cosec α …………………………......….(15)

$\Phi = (180 - 2\alpha).\ \pi/180$, radian ……………………….....…(16)

Where:

T_c: Centrifugal tension force(kg), V: Belt speed (m/s), T: Maximum tension in the belt (N), allowable tension stress (280 N /cm^2 or less), T_1: Tension on the tight side of belt (N), T_2: Tension on the slack side of belt (N), 2α: groove angle of the pulley (30–40°), Φ: Angle of lap on the pulley (radian), μ: Coefficient of the friction, and g: Acceleration gravity (m/s^2). By applying and using loading diagram (Fig.3), the reactions R_1 = 136 N and R_2 = 484.4 N. From the bending moment diagram in (Fig.3), the maximum bending moment (M_b) was found to be M_b = 3850 N.cm. The maximum torque (M_t) can be calculated using the following equation:

$$T = \frac{71640.HP}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

$$HP = \frac{2\pi NT}{75} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

$T = (T_1 - T_2) . R$, **Khurmi and Gupta (1984)**…..…..(19)

Where:

T: Torque (N.cm), HP: Require power (hp) and N: Number of drum rotations, rpm. By compensation, then the maximum torque equal 2079 N.cm, required power equal 1.02 hp (0.75 kW) and diameter of threshing drum shaft equal 20.3 mm. So the diameter of the threshing drum shaft was designed to be 25 mm.

3- Bearing selection:

The bearings were designed using the loads resulting from the belt tension and the appropriate sizes and strength of bearings to withstand such loads selected. A ball bearing that will withstand the load was selected from codes.

●CALCULATIONS:

The following criteria by **FAO (1994)** were used to evaluate the performance of the threshing machine on stripping efficiency (S_tE), threshing efficiency (TE) and cleaning efficiency (CE):

A - Efficiencies:

1. Stripping efficiency (S_tE):

It was calculated according to the following equation:

$$S_tE\,(\%) = \frac{\text{Weight of stripped seed (g)}}{\text{Total weight of seed on stalks (g)}} \times 100 \ldots\ldots(20)$$

2. Threshing efficiency (TE):

It was calculated according to the following equation:

$$TE\,(\%) = \frac{\text{Weight of threshed seed (g)}}{\text{Total weight of seed (g)}} \times 100 \ldots\ldots\ldots(21)$$

3. Cleaning efficiency (CE):

It was calculated according to the following equation:

$$CE\ (\%) = \frac{\text{Weight of chaff collected at the chaff outlet (g)}}{\text{Total weight of chaff (g)}} \times 100 \text{ ..(22)}$$

4. Separation efficiency (SpE):

It was calculated according to the following equation;

$$S_pE\ (\%) = \frac{S_1 + S_2}{S} \times 100 \text{ ....(23)}$$

Where:

S_1: weight of seed from the out let (g), S_2: weight of seed from the straw outlet (g), and S: Total weight of seed (g).

<u>B - Seed losses:</u>

1. Drum losses (D_L):

It was calculated according to the following formula:

$$D_L(\%) = \frac{W_{unstripped} + W_{unthreshed}}{W_t} \times 100 \text{ …....(24)}$$

Where:

$W_{Un\text{-}stripped}$: Weight of un-stripped seed (g), $W_{Un\text{-}threshed}$: Weight of un-threshed seed (g), and W_t : Total weight of input seed (g).

2. Separation losses (S_L):

It was calculated according to the following formula;

$$S_L(\%) = \frac{W_{Un-separated}}{W_t} \times 100 \text{ ……………….……(25)}$$

Where:

$W_{Un\text{-}separated}$: Weight of un-separated seed (kg).

3. Total seed losses (TL):

It was calculated according to the following formula;

$$TL\ (\%) = \frac{D_L + S_L}{W_t} \times 100 \text{ …………………….....(26)}$$

<u>C – Energy requirements:</u>

Estimation of the required power was calculated using the following formula **(Barger *et al*. 1982):**

$$EP = [f.c.(1/3600)\rho_E \times L.C.V. \times 427 \times \eta_{thb} \times \eta_m \times 1/75 \times 1/1.36],\ kW \text{ .(27)}$$

Where:

f.c. = The fuel consumption, (*l*/h).
ρ_E = The density of fuel, (kg/*l*), (for Gas oil = 0.85).
L.C.V. = The lower calorific value of fuel, (11.000 k.cal/kg).
η_{thb} = Thermal efficiency of the engine (35 % for Diesel).
427 = Thermo-mechanical equivalent, (Kg.m/k.cal).
η_m = Mechanical efficiency of the engine (80 % for Diesel).
Hence, the energy requirements can be calculated as follows:-

$$\text{Energy requirements} = \frac{Required\ \ power\,(kW)}{Feed\ \ rate\ \ (ton/h)}\,,kW.h\,/\,ton \,\ldots\ldots\ldots(28)$$

D - Cost analysis:

Machine cost was determined using the following equation **(Awady *et al.* 1982):**

$$C = \frac{P}{h}\left(\frac{1}{a}+\frac{i}{2}+t+r\right)+\left(0.9W.S.F\right)+\frac{m}{144}\,\ldots\ldots\ldots\ldots\ldots\ldots\ldots(29)$$

Where:-

C = Hourly cost, L.E/h.
P = Price of machine, L.E.
h = Yearly working hours, h/year.
a = Life expectancy of the machine, h.
i = Interest rate/year.
F = Fuel price, L.E/*l*.
t = Taxes, over heads ratio.
r = Repairs and maintenance ratio.
m = Monthly average wage, L.E
0.9 = Factor accounting for lubrications.
W = Engine power, hp.
S = Specific fuel consumption, *l*/hp.h.
144 = Reasonable estimation of monthly working hours.

The operational cost was determined using the following equation:

$$Oprating\ cost = \frac{Machine\,cost\,(\,L.E/h)}{Feed\ rate\,(ton/h)}, \quad L.E\,/\,ton \,\ldots\ldots\ldots\ldots\ldots\ldots(30)$$

$$Criterion\ cost = Operating\ cost\ (L.E/ton) + losses\ cost\ (L.E/ton\ )\ldots\ldots(31)$$

● **TESTING AND EVALUATION:**

Tests were conducted on the machine to ascertain its performance. The black seed plants (*nigella sativa*) were fed into the machine. The output from the seed outlet and the chaff outlet were collected and weighed. Unthreshed capsules were broken open and the seeds taken out and weighed using an electronic weighing balance. Four cylinder speeds of 200 rpm (4.19 m/s), 250 rpm (5.23 m/s), 300 rpm (6.28 m/s), and 350 rpm (7.32 m/s) were used and these were obtained by changing the size of the pulleys on the blower shaft to give drum speeds of 450 rpm (9.18 m/s), 550 rpm (11.23 m/s), 650 rpm (13.27 m/s) and 750 rpm (15.31 m/s). The speed out from blower shaft was transmitted to a pulley of 10 cm and transmitted to threshing drum pulley of 20 cm to give the previous speeds of threshing drum. Four feed rates of 600 kg/h, 700 kg/h, 800 kg/h and 900 kg/h; four capsules moisture content of 11.82, 13.63, 15.72 and 17.61 % on the W.b. were selected. Each combination of speeds, feed rates and moisture contents were replicated three times and the representative value taken as the mean of the three readings resulting in a total of 192 observations (4 feed rates × 4 speeds × 4 moisture content × 3 observations). Means of the observations were taken and a split block design in Randomized Complete Block Design was used with a total of 46 observations (4 drum speeds × 4 feed rates × 4 moisture contents).

RESULTS AND DISCUSSIONS

1 - Effect of some operating parameters on seed losses:

The threshing losses are affected directly by different operating parameters such as feed rate, threshing drum speed, seed moisture content…..etc.

a - Drum losses:

Generally, the threshing losses as expressed drum losses which represent un-stripped and un-threshed seed losses increased by increasing both feed rate and seed moisture content and decreased by increasing threshing drum speed. Data in Fig (5) show that increasing feed rate from 600 to 900 kg/h at drum speed of 6.28 m/s, increased the drum losses from 1.11 to 2.75, 1.26 to 3.15, 1.78 to 4.38 and 2.17 to 4.95 % at different seed moisture contents of 11.82, 13.63, 15.72 and 17.61 %, respectively. The increase in the percentage of drum losses by increasing feeding rate is attributed to the excessive plants in the threshing chamber. Consequently, plants leave the device without complete threshing that tends to increase drum losses. While the vice-versa was noticed with drum speed. Increasing drum speed from 4.19 to 7.32 m/s at feed rate of 600 kg/h, decreased the drum losses from 2.52 to 0.78, 2.76 to 1.02, 3.28 to 1.44 and 3.73 to 1.78 %, at different seed moisture contents of 11.82, 13.63, 15.72 and 17.61 %, respectively. This decrease is due to the more adequate time to separate seeds from capsules. The same trend was noticed with the seed moisture content. Increasing moisture content from 11.82 to 17.61 % at feed rate of 600 kg/h, decrease the drum losses from 2.52 to 3.73, 1.58 to 2.83, 1.11 to 2.17 and 0.78 to 1.78 %, at different drum speeds of 4.19, 5.23, 6.28 and 7.32 m/s. This is due to the elastic conditions of high moisture content material which resulting in a little impacting forces on the threshing materials.

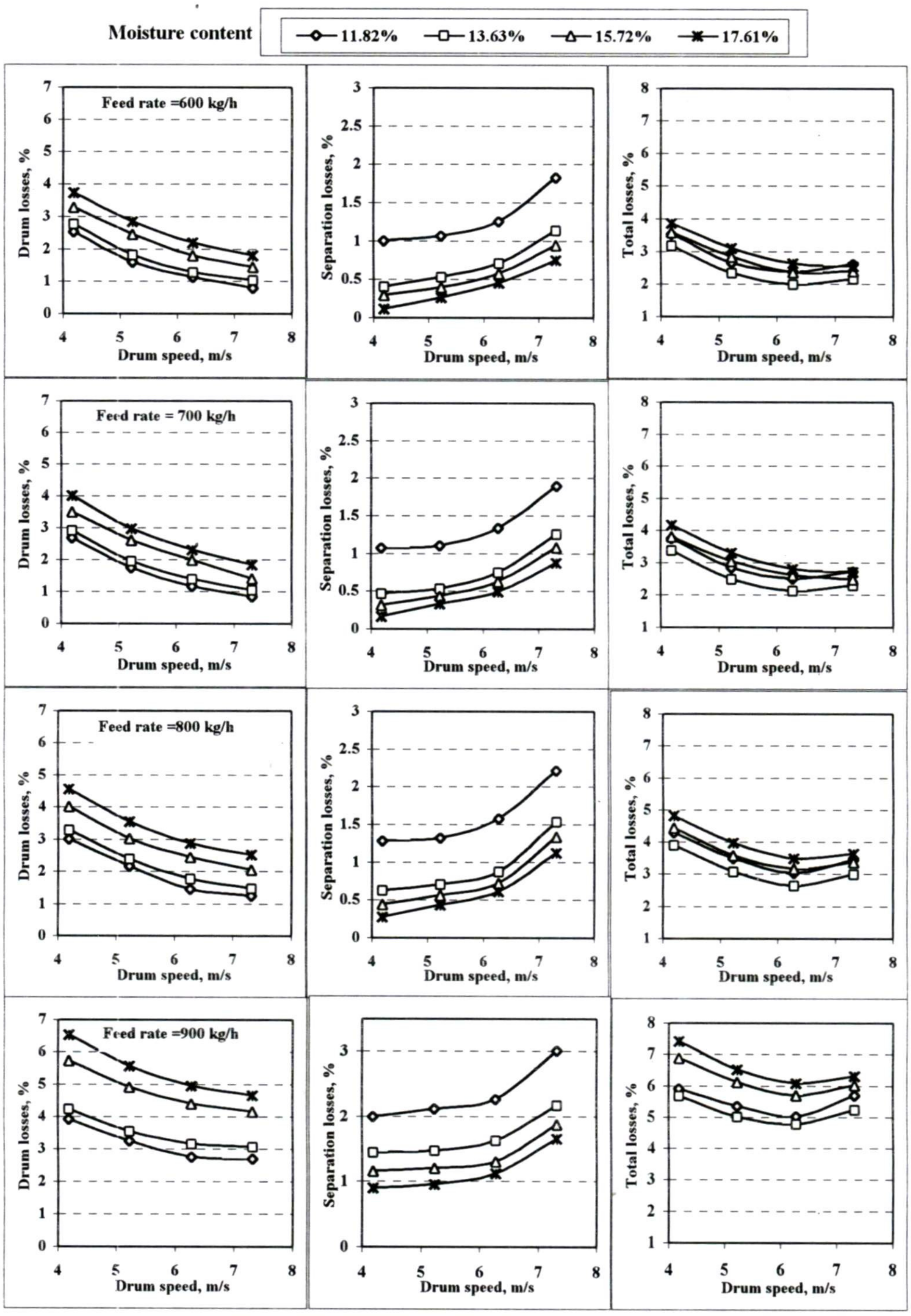


Fig.(5): Effect of drum speed on threshing, separation and total seed losses of black seed crop at different conditions of feed rates and seed moisture contents.

b - Separation losses:

The separation losses increased by increasing both feed rate and drum speed and decreased by increasing seed moisture content. Fig (5) show that, increasing feed rate from 600 to 900 kg/h at drum speed of 6.28 m/s, increased the separation losses from 1.25 to 2.26, 1.70 to 1.62, 0.57 to 1.30 and 0.45 to 1.11 % at different seed moisture contents of 11.82, 13.63, 15.72 and 17.61 %, respectively. This increase is attributed to the excessive plants in the threshing chamber, so the capsules leave the device without complete threshing that tends to increase un-separated seeds.

Also, increasing the drum speed from 4.19 to 7.32 m/s at feed rate of 600 kg/h, increased the separation losses from 1.00 to 1.82, 0.40 to 1.13, 0.29 to 0.94 and 0.11 to 0.75 %, at different seed moisture contents of 11.82, 13.63, 15.72 and 17.61 %, respectively. The increase in the percentage of separation losses by increasing drum speed was attributed to the high stripping and impacting forces applied to the plants. While, Increasing seed moisture content from 11.82 to 17.61 % at feed rate of 600 kg/h, decrease the separation losses from 1.00 to 0.11, 1.06 to 0.26, 1.25 to 0.45 and 1.82 to 0.75 %, at different drum speeds of 4.19, 5.23, 6.28 and 7.32 m/s, this results was due to good conditions of threshing operation which gave the optimum impacting force on the plants resulting in more separation seeds from capsules and stalks.

c - Total losses:

From the previous analysis and results obtained, the total seed losses including both drum losses and separation losses were illustrated in Fig. (5). It can be noticed that the minimum total seed losses of 1.97 % will be achieved at seed moisture content of 13.63 %, drum speed of 6.28 m/s and feed rate of 600 kg/h.

2- Effect of some operating parameters on efficiencies:

a - Stripping efficiency:

The stripping efficiency affected by different operating parameters such as seed moisture content, feed rate and threshing drum speed. From Fig (6), it is clear that increasing feed rate from 600 to 900 kg/h at constant drum speed of 6.28 m/s and seed moisture content of 13.63 %, decreased the stripping efficiency by 0.97 %. The decrease in the percentage of stripping efficiency by increasing feed rate is attributed to the excessive plants in the threshing chamber. Consequently, the seeds leave the device without complete stripping from the capsules.

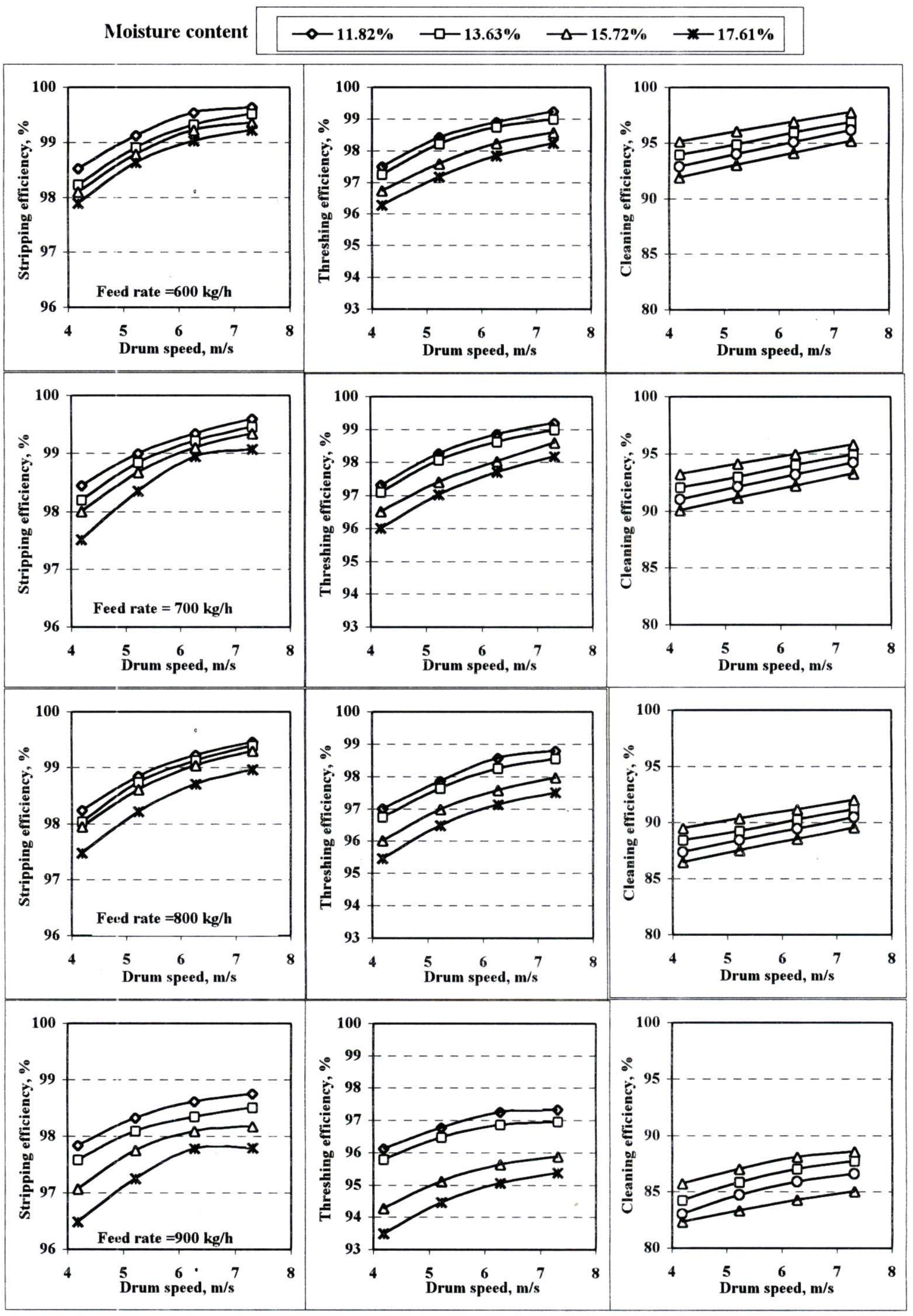


Fig.(6): Effect of drum speed on stripping, threshing and cleaning efficiencies of black seed crop at different conditions of feed rates and seed moisture contents.

While, increasing drum speed from 4.19 to 7.32 m/s at constant feed rate of 600 kg/h and seed moisture content of 13.63 % increased the stripping efficiency by 1.31 %. This increase is due to knock plant capsules more times that tends to improve the stripping operation along the drum which reduce un-stripped capsules from stalks. Also, increasing the seed moisture content from 11.82 to 17.61 % at feed rate of 600 kg/h and drum speed of 6.28 m/s decreased the stripping efficiency by 0.51 %. This result was due to the elastic conditions of high moisture content of plants which results in a little impacting force on the threshing materials.

b - Threshing and cleaning efficiencies:

Generally, the threshing and cleaning efficiencies increased by increasing the drum speed and decreased by increasing both the feed rate and seed moisture content. Fig (6), show that, increasing the drum speed from 4.19 to 7.32 m/s at constant feed rate of 600 kg/h and seed moisture content of 13.63 %, increased both threshing and cleaning efficiencies by 1.79 % and 3.10, respectively. The increase in the percentage of threshing and cleaning efficiencies by increasing drum speed was attributed to the high stripping and impacting forces applied to the black seed materials, which tend to improve the threshing operation and increase threshing and cleaning efficiencies. On the other side, increasing the feed rate from 600 to 900 kg/h at constant drum speed of 6.28 m/s and seed moisture of 13.63 %, the threshing and cleaning efficiencies decreased by 1.91 % and 9.28 %, respectively. This increase in threshing and cleaning efficiencies was attributed to the excessive plants in the threshing chamber. Consequently, the stalks and their capsules leave the device without complete threshing. While, increasing the seed moisture content from 11.82 to 17.61 % at feed rate of 600 kg/h and drum speed of 6.28 m/s, decreased the threshing and cleaning efficiencies by 1.07 % and 2.87 %, respectively. These results were attributed to the high elastic conditions of high moisture content, which resulting in a little impacting force on the threshing materials.

3- Effect of operating parameters on energy requirements:

Energy requirements for threshing black seed plants depending on some variables as feed rate, drum speed and seed moisture content. Fig (7) show the relation between drum speed and feed rate with energy requirements. Increasing feed rate from 600 to 900 kg/h at drum speed of 6.28 m/s and seed moisture content of 13.63 % the energy increased from 2.85 to 3.20 kW.h/ton.

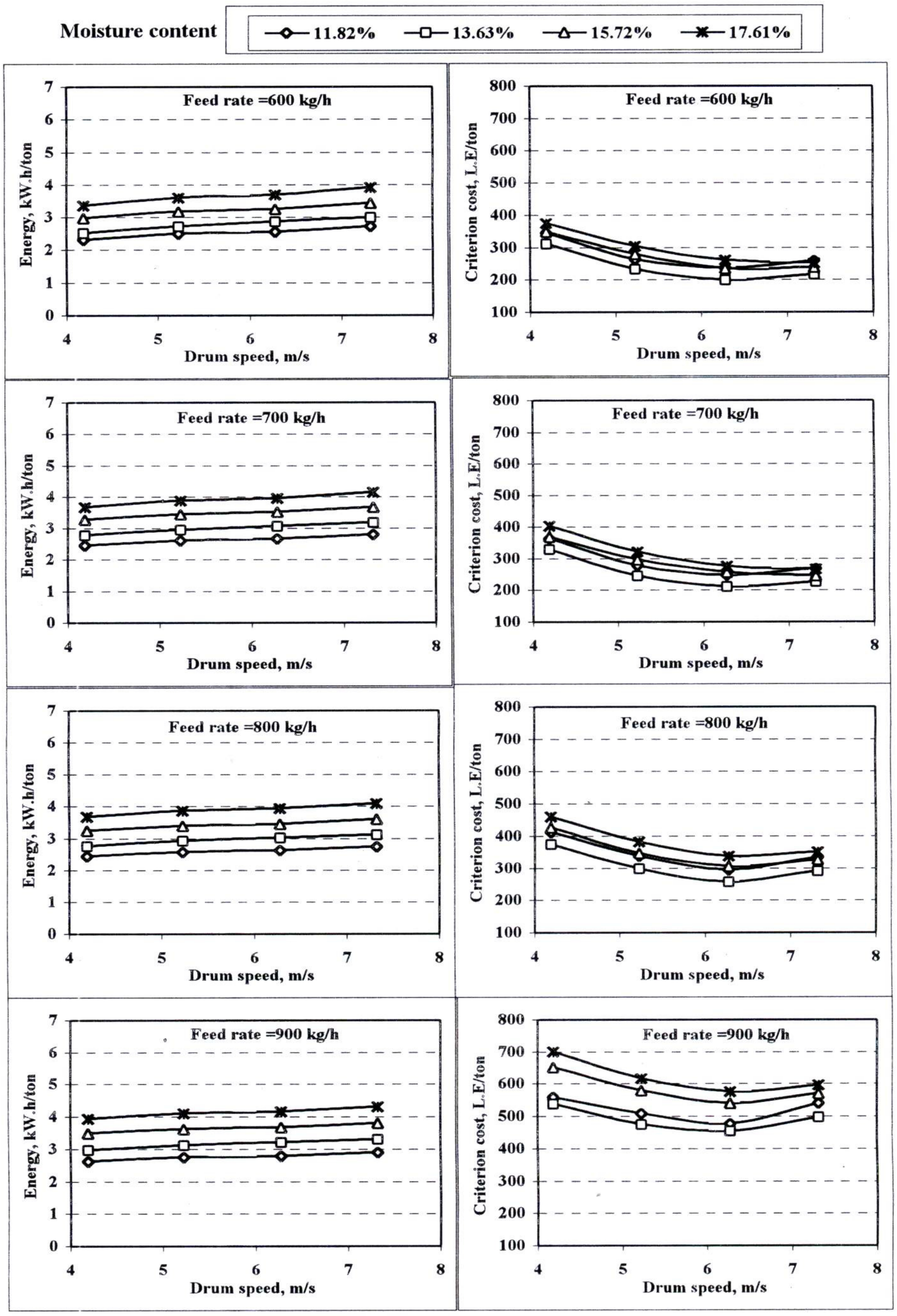


Fig.(7): Effect of drum speed on energy and criterion cost of black seed crop at different conditions of feed rates and seed moisture contents.

Increasing energy required by increasing feed rate is attributed to the excessive plants in the threshing chamber which represent more loads on the drum, resulting in more fuel consumption and energy. On the other side, increasing the drum speed from 4.19 to 7.32 m/s at constant feed rate of 600 kg/h and seed moisture content of 13.63 % increased the energy required from 2.50 to 2.98 kW.h/ton. The increase in the percentage of energy required by increasing drum speed is attributed to the high stripping and impacting forces applied during threshing operation, that tend to consume more fuel and increase energy required. Also, increasing the seed moisture content from 11.82 to 17.61 % at

constant feed rate of 600 kg/h and drum speed of 6.28 m/s increased the energy required from 2.55 to 3.68 kW.h/ton.

This increase was due to elastic condition of the threshing plants which need more force to overcome excessive loads resulting from high moisture of plants.

4- Effect of operating parameters on criterion cost:

The criterion cost is considered the main indicator, which judges the evaluation of the developed machine. Results in Fig (7) show that, increasing drum speed from 4.19 to 6.28 m/s at feed rate of 600 kg/h, decreased criterion cost by 31.44, 35.74, 32.62 and 30.43 % at different seed moisture contents of 11.82, 13.63, 15.72 and 17.61%, respectively. Any further increase in drum speed of 6.28 m/s will increase the criterion cost due to increase seed losses. From this result, the drum speed of 6.24 m/s is considered the optimum value which recorded the minimum criterion cost.

Concerning to the effect of feed rate on criterion cost, results obtained in Fig (7) show that increasing feed rate from 600 to 800 kg/h at drum speed of 6.28 m/s, slightly increased the criterion cost by 24.42, 28.87, 30.07 and 29.32 % at different seed moisture contents of 11.82, 13.63, 15.72 and 17.61 %, respectively. Any increase in feed rate up to 800 kg/h increased criterion cost rapidly. So, the feed rate from 600 to 800 kg/h is recommended to minimize criterion cost.

Also, Fig (7) show that increasing seed moisture content from 11.82 to 13.63 % at drum speed of 6.28 m/s, decreased criterion cost from 15.42, 14.04, 12.39 and 4.69 %, at different feed rates of 600, 700, 800 and 900 kg/h. Any further increase of seed moisture content up to 17.61 %

increased criterion cost rapidly due to increase seed losses. So, the seed moisture content of 13.63% is recommended to minimize criterion cost.

CONCLUSION

A local flax threshing machine was developed and tested to thresh black seed crop with high efficiency. Data from this study led to the following conclusions:-

- Minimum total seed losses of 1.97 % were obtained at feed rate of 600 kg/h, drum speed of 6.28 m/s and seed moisture content of 13.63 %. While the stripping, threshing and cleaning efficiencies of 99.31, 98.74 and 95.88, % were obtained at the same previous conditions.
- The minimum energy requirement of 2.85 kW.h/ton was obtained at feed rate of 600 kg/h, drum speed of 4.19 m/s and seed moisture content of 11.82 %. While, the maximum energy requirement of 4.30 kW.h/ton was obtained at feed rate of 900 kg/h, drum speed of 7.32 m/s and seed moisture content of 17.61 %.
- The minimum criterion cost of 199.18 L.E/ton was obtained at feed rate of 600 kg/h, drum speed of 6.28 m/s and seed moisture content of 13.63 %.

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الملخص العربي

تطوير آلة دراس محلية الصنع لتناسب دراس حبة البركة

د. محمود خطاب عفيفي ** **د. محب محمد أنيس الشرباصي** * **د. محمود مصطفى علي** *

يعتبر نبات حبة البركة من أحد النباتات الطبية التي تدخل في كثير من الصناعات الطبية حيث تتميز بذوره باحتوائها على نسبة عالية من الفيتامينات والأحماض الأمينية التي تستخدم في علاج الكثير من الأمراض. وقد زاد الاهتمام مؤخراً بالنباتات الطبية لما لها من فائدة عظيمة.

وتعتبر طرق الدراس المتبعة لفصل حبوب حبة البركة من النبات مازالت بدائية وتتمثل في الطرق بقطع خشبية على الكبسولات بعد جفافها ثم تبدأ عمليات الغربلة والتنظيف يدوياً مما يؤدي إلى إهدار كمية كبيرة من الحبوب، لهذا اهتم هذا البحث بتطوير آلة دراس محلية الصنع لتقوم بدراس محصول حبة البركة بكفاءة عالية وكفاءة تنظيف جيدة للحصول على جودة حبوب تناسب السوق المحلي. وتتركب آلة الدراس المطورة من الوحدات التالية:-

- **وحدة تغذية نصف آلية:** وهي تتكون من جنزير ناقل مركب على عجلات مسننة تأخذ حركتها من عمود درفيل الدراس عن طريق منظومة تخفيض للسرعة.

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- **وحدة الدراس المطورة:** وهي تتكون من صدر الدراس بقطر ثقوب 3.5 مم ودرفيل الدراس بطول 600 مم وقطر كلي 400 مم مزود بمضارب على 4 صفوف بارتفاع 70 مم . المسافة بين الدرفيل و صدر الدراس 13 مم عند المدخل و 7 مم عند المخرج، كما زودت غرفة الدراس بعدد 3 سكين نصف دائرية بقطر 150 مم المسافة بينها 100 مم من المدخل حتى منتصف غرفة الدراس لتساعد على تقطيع القش وعدم التفافه حول درفيل الدراس أثناء الدوران مما يخفف الحمل الواقع على درفيل الدراس. كما زودت غرفة الدراس بغطاء مزود بعدد 3 خوص حديدية بزاوية ميل 15 درجة لتساعد عل تحريك ودفع القش إلى مخرج الآلة وتمنع تراكمه داخل غرفة الدراس.
- **وحدة التنظيف المطورة**: وهي تتكون من مروحة وغربال تنظيف بزاوية ميل على الأفقي 5 درجات، قطر ثقوب الغربال 3.5 مم، المساحة الكلية للثقوب 0.99 للمتر المربع والمسافة بين الثقوب المتجاورة 1.29 مم

تم دراسة عدد من المتغيرات لتقييم الآلة بعد التطوير والتي تتمثل في معدلات تلقيم مختلفة هي (600 ، 700 ، 800 و 900) كجم/س وسرعات مختلفة لدرفيل الدراس هي (4.19 ، 5.23 ، 6.28 و 7.32) م/ث عند نسب مختلفة لرطوبة الحبوب (11.82 ، 13.63 ، 15.72 و 17.61) %.

تم تقييم أداء الآلة المطورة من خلال القياسات التالية:

- نسبة فواقد الحبوب (فواقد درفيل الدراس، فواقد الفصل والفواقد الكلية).
- كفاءة الآلة (كفاءة نزع الكبسول، كفاءة الدراس وكفاءة التنظيف).
- الطاقة اللازمة لعملية الدراس.
- التكاليف الحدية لعملية الدراس وتشمل (تكاليف تشغيل الآلة + فواقد الحبوب).

وقد أظهرت النتائج المتحصل عليها أن أفضل الظروف لتشغيل هذه الآلة هي معدل تلقيم 600 كجم/س، سرعة درفيل الدراس 6.28 م/ث و نسبة رطوبة للحبوب 13.63 % وذلك للحصول على أفضل كفاءة لنزع الكبسول 99.31 % أفضل كفاءة دراس 98.74 %، أفضل كفاءة تنظيف 95.88 %، فاقد كلي للحبوب 1.97 % ، طاقة مستهلكة 2.85 كيلووات.س/طن و تكلفة كلية لعملية الدراس 199.18 جنيه/طن.

لذا توصي الدراسة باختيار معدل تلقيم يتراوح مابين (600 – 800 كجم/س) عند سرعة درفيل الدراس 6.28 م/ث و نسبة رطوبة للحبوب 13.63 % بتكلفة (199.18 – 256.69 جنيه/طن) لانخفاض الفواقد الكلية للحبوب والتكاليف عن معدل تلقيم 900 كجم/س بتكلفة (454.60 جنيه/طن).