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MODIFY A SMALL MACHINE FOR FLAX THRESHING AND CLEANING SEEDS

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ABSTRACT

Flax threshing and cleaning prototype was identified upon the mechanical and aerodynamic separation cleaning theories. The aim of this study is develop a small prototype machine for threshing and cleaning a manual feeding of flax capsules. The performance of the manufacture prototype was test at four peripheral tooth cylinder speeds of 0.40, 0.44, 0.48 and 0.51 m/s; cylinder concave clearance of 2, 4, 6 and 8 mm and air velocity of 1.5, 2.5, 3.5 and 4.5 m/s at recommended seed moisture content of about 14 % d.b. The performance of the modified machine was determined by threshing efficiency, un-threshing capsules, seed damage (visible and invisible), seed losses, seed cleanliness, total seed losses and seed germination ratio. The results showed that the suitable drum speed, concave clearance and air velocity are 0.44 m/s, 2 mm and 4.5 m/s respectively to obtain the best threshing efficiency of 98.45%, seed cleanliness of 92.3% and germination ratio of 91%. Then the modified machine can be used to threshing and cleaning the flax and it can applied the modified machine specifications on the large scale machines.

INTRODUCTION

Flax is considered as one of the most important economic yarn crops. In Egypt the total annual cultivated area is about 12784 feddans producing about 4 ton fibers/feddan and 825 kg seeds/feddan approximately (Economic affairs sector 2010). Flax seed is the source of linseed oil, which is used as an edible oil, as a nutritional supplement and as an ingredient in many wood finishing products. In Egypt, the conventional flax threshing method is done manually by beating the capsules over stones or passing the tractor several times over the plants. Then, flax seeds are winnowed using manually operated stationery cleaning machine. The objective of threshing operation is to separate capsules from plant then separate seeds from the capsules and clean the seed from the capsules leftover. The flax is harvested manually by hand pulling and left for natural drying for about 7 – 10 days and transported to the factories for industrial production (stripping, deseeding and threshing). Handling losses and damage to capsules and stalks. Arafa *et al*. (2009) studied that some physical and mechanical properties of flax seeds. They found that the seed length, width, and thickness were 4.38, 2.2, and 0.72 mm, respectively, volume of 3.631 mm^3, geometric diameter of 1.906 mm, arithmetic diameter of 2.44 mm, percentage of sphericity of 43.52 %, bulk density of 0.640 kg/m^3, flat surface area of 7.56 mm^2 transverse surface area of 1.24 mm^2, mass of 1000-seeds of 10 g and optimum moisture content of 12.5 % for flax seeds. The mechanical properties of flax seeds were the friction angle between stainless, metal and wood surface and flax seeds was 22, 34, and 40 degree, respectively, the angle of repose was 30 degree, the terminal velocity value to suspended flax grain (Sakha 2 – variety) was 22 m/s and hardness of flax seeds was 11.02 N. This capsules and seed specifications can be used as a source to design the active threshing units.

Kawamura (1996) the flax harvesting works of including manual operations cutting stalks with using sickles and threshing by hilling or grinding on the ground. This operations of cutting stalks, binding to make bundles for easy handling, sun drying and threshing which is to separate seeds from capsules.

Klenin *et al*. (1985) conducted that threshing performance are largely affected with design factors such as concave length, diameter, cylinder speed, feed rate and moisture content of harvesting crops. Many practices have been done to over come these problems. Several researches got promising results on flax threshing and cleaning using rice and wheat combine harvesting (Erugin, 1987; Kromer *et al*., 1995; Szarszunow *et al*., 1998; Khatab, 1998; Badawy, 2002 and El-Gayar, 2005) and others researches developed and designed some machines for threshing some crops such as flax, canola, wheat and lentil (Hall *et al*., 1980; Klenin *et al*., 1985; Abdel-Mageed, 1989; Szarszuno *et al*., 1998; Ghonimy and Rostom, 2004 and El-Gayar, 2005). El-Ashary *et al*. (2003) studied the effect of flax threshing systems partial mechanized, complete mechanized and conventional at seed moisture content 18.15, 16.85, 14.32 and 12.05% on flax specification. The results cleared that the unthreshed seed losses decreased by decreasing seed moisture content and the lower values were obtained at seed moisture content of 12.05% were 6.62, 8.35 and 1.05 % for complete, partial mechanized and conventional system respectively. Dudarev (2010) reported that the machine for flax collecting oil flax, forms the stem band and spreads it on the field. After drying and ripening of the seeds, the band is collected with the machine for flax collecting and threshing, which cuts the flower heads with seed capsules from the stems, spreads flax straw and threshes the seeds, and the machine peels the seeds.

From the above references; the traditional method for flax threshing and cleaning required much labour, time, high losses and damage from seeds and stalks and its costly. To overcome above problems, this study is to investigate a small prototype machine for small holdings area. This practices include two steps are mechanically, the first is to thresh the seeds from capsules and the second step is to separate the seeds from the trash straw provided.

MATERIALS AND METHODS

The prototype machine was modified at Agric. Mech. Division, as shown in Fig. (1) and photographed at Fig. (2). The experiments were conducted in season 2009-2010 in the Gemmeza Agric. Res. Station in Gharbia Governorate, Egypt. The prototype consists of:

- **Feeding hopper:** interrupted pyramid shaped, the top and the bottom were rectangular shape 150 × 150 and 80 × 80 mm respectively, and the height of feeding hopper is 120 mm.
- **Drum:** constructed from steel sheet of 3 mm thickness fixed on the peripheral of the drum as shown in Fig. (1). The drum is mounted on a shaft with 19 mm outer diameter and its length of 400 mm. It is supported by two ball bearing on the main frame. The drum diameter is 140 mm and 170 mm length. The 10 teeth row on drum each row contain 3 teeth. The tooth dimension is 25 mm length and 5 × 5 mm square cross section shape.

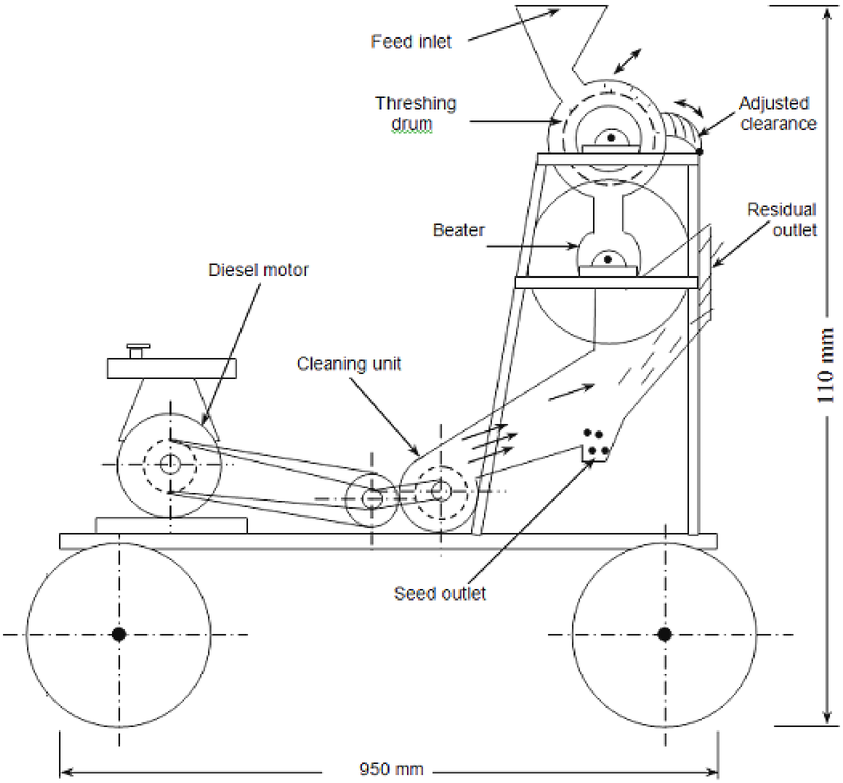

Fig. 1: Sketch of the prototype threshing and cleaning machine.

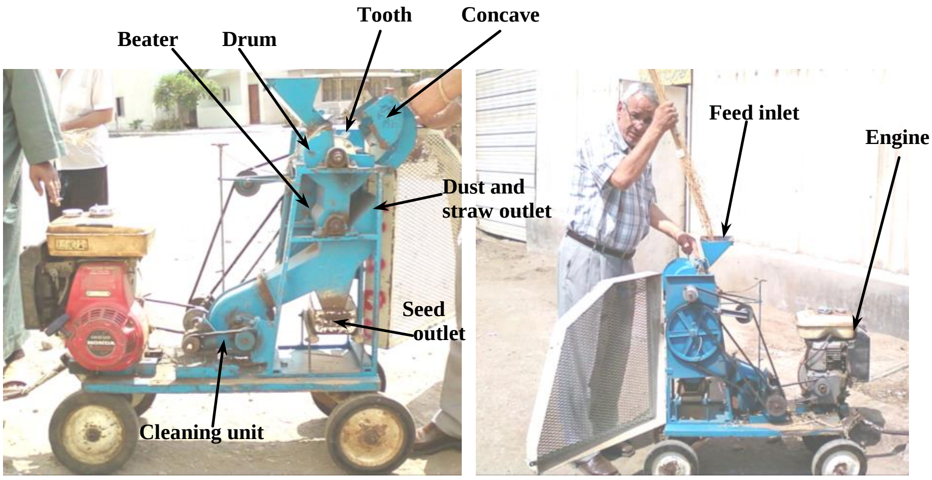

Fig. 2: Prototype threshing and cleaning machine.

- **Cover:** is constructed as semi-cylinder shape from steel sheets of 3 mm thickness with 300 mm length, 17 mm width and 3 mm thickness. The sheet are fitted to make have a shape of rectangular cross section, the tooth is fixed on the steel sheets with 50 mm apart between. The 3 teeth row on drum each row contain 3 teeth. The tooth dimension is 25 mm length and 5 × 5 mm square cross section shape. The clearance between the drum and the cover front edge can be adjusted by raising or lowering the concave board upper the drum.

- **Beater:** is located directly behind and usually slightly under the drum. Its diameter is 100 mm with the same drum length of 170 mm.
- **Cleaning unit:** the design of cleaning unit based upon the determination of terminal velocity of flax seeds and its capsul's cover. A fan with four straight blades rotating in a volute casing was constructed. The fan was used to supply the air stream for separating.
- **The fan air chest:** a shallow interrupted pyramid shape, the start vent is square cross section 80 × 80 mm and the end vent is rectangular cross section 60 × 180 mm and with 180 mm shaft length and 130 mm fan diameter. The air path diameter at start vent was determined using the following Eq.:

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

Where:

d : air path diameter, m

q : air flow rate, m^3/sec

V_t : air velocity, m/sec

The air velocity should be less than flax seeds terminal velocity at outlet air to avoid seeds terminal velocity to cause a dragging force for flax-seeds toward exit hole. Therefore, the manually adjustable door is used for controlling air velocity at the exit hole section. The cleaning seeds outlet gate has 60 × 180 mm rectangular cross section.

- **Transmission system:** the transmission system consists of some pulleys and V belts to transmit the motion from the source of power to the threshing drum, beater and cleaning units. The diameter of driving and driven pulleys for each transmission stage were determined according to the rotating speed of driving and driven pullets. V belts are used to transmit the motion between driving and driven pulleys.
- **Power source:** the power source is driven by the diesel engine 3 kW, at rotating speed of 3600 rpm, WBK 30T Honda, Thailand.
- **Main frame:** made of L section steel of 50 × 50 mm. All parts are connected to the frame by bolts and nuts and some parts welding with the frame. The frame dimensions are 950, 850 and 350 length, height and width respectively.

Flax seeds and capsules specifications:

The flax (Linum Ustatissimum L.) variety is Giza 4. Samples of flax crop of 2009-2010 seasons were taken to measure the basically of physical, mechanical and airo-dynamical properties can used to modifying the threshing unit and adjust the cleaning unit. The average of capsules diameter is 6.5 mm and the number of seeds/capsule is 7. The average of main seed dimensions are 4.56, 2,29 and 1.01 mm for length, width and thickness respectively. The average of seed volume is 3.96 mm^3, 1000 seed weight is 7.2 g, bulk density is 0.479 g/cm^3, moisture content is 14.03 % and terminal velocity is 25.4 m/s.

The experiments design in split plot design in three replicates. The amount of flax stalks are held by hand and their head part are fed to the drum. It has the cleaning device of fan which the small seeds; un-matured seed and chaffs are separated with air stream. To achieve the aim of the research the machine tested at the variables of drum speed levels of 0.40, 0.44, 0.48 and 0.51 m/s, concave clearance levels of 2, 4, 6, and 8 mm and the air velocity levels of cleaning unit of 1.5, 2.5, 3.5 and 4.5 m/s.

Measurements and calculations:

1- Threshing efficiency (Th_e)

Threshing efficiency (%) of flax capsule was estimated as follows:

$$Th_e = \frac{Th_s}{T_s} \times 100$$

Where

Th_s: threshed seed

T_s : total seed in put

2- Un-threshed capsules (Th_u)

The un-threshed capsules percentage was estimated as follows:

$$Th_u = 100 - Th_s$$

3- Seed Damage

a- Visible seed damage

The damaged seeds were separated by hand and weighted, and then visible seed damage (%) was estimated as a percentage of total seed mass as follows:

$$D_{sv} = \frac{W_d}{W_s} \times 100$$

Where

D_{sv}: seed damage, (%)

W_d: mass of damage seeds, (g)

Ws: total seed mass (100 g)

b-Invisible seed damage (D_{si})

The germination test was used to estimate, the percentage of the invisible seed damage as follows:

$$D_{si} = \frac{a}{b} \times 100$$

Where

a: number of un-germinated seeds from the samples taken after threshing operations.

b: total number of seeds in the sample.

4- Germination ratio (G_r)

The germination ratio was determined as the following equation:

$$Gr = \frac{c}{b} \times 100$$

Where

c: number of germinated seeds from the samples taken after threshing operations.

b: total number of seeds in the sample.

5- Seed losses (L_s)

After threshing operations, the un-threshed capsules were threshed manually from the capsules and weighted then seed loses percentages was calculated as follows:

$$L_s = \frac{W_2}{W_1 + W_2 + W_3} \times 100$$

Where

W_1: mass of threshing seeds, kg

W_2: mass of un-threshed capsules, kg

W_3: mass of threshing seeds and received at the outlet, kg

6- Seed cleanliness (N_s)

A randomized sample of 500 g seeds were taken to calculate the percentage of seed cleaning as follows:

$$N_s = \frac{S_1 - S}{S_1} \times 100$$

Where

S_1 : mass of sample, g.

S : mass of impurities

Statistical Analysis:

SAS computer software package was used to employ the analysis of variance and the LSD tests for data of threshing and cleaning flax seeds.

Regression and correlation analysis:

Microsoft Excel 2007 computer program was used to carry out the multiple regression analysis to represent:

1. The relation between threshing efficiency, un-threshing capsules, seed visible and invisible damage, seed losses, seed cleanliness and both drum speed and concave clearance.
2. The relation between seed losses, seed cleanliness and both drum speed and air velocity.

RESULTS AND DISCUSSION

1- Threshing and un-threshing efficiency

Figs. (2 and 3) illustrate the effect of drum speed and concave clearance on threshing and un-threshing efficiency. From Fig. (2) the threshing efficiency slightly increased from 97.19 to 98.24 % by increasing the drum speed from 0.40 to 0.51 m/s. Consequently, the threshing efficiency increased from 98.86 to 96.09 % at increase the concave clearance from 2 to 8 mm. This result guide that the concave clearance is the higher effect on the threshing efficiency than the drum speed. From the result the highest value of threshing efficiency 99.20 % at 0.51 m/s drum speed and 2 mm concave clearance. On the other side, Fig. (3) explains, the un-threshed capsules decrease from 3.31 to 2.39 % at increase the drum speed from 0.40 to 0.51 m/s. Therefore, the un-threshed capsules increased from 1.08 to 4.85 % by increasing the concave clearance from 2 to 8 mm. These results clear that the concave clearance is the higher effect on the un-threshed capsules than the drum speed. While, the result show that the lowest value of un-threshed capsules 0.85 % at 0.51 m/s drum speed and 2 mm concave clearance.

The multiple regression analysis reveal that there is a highly significant between each of threshing efficiency (Th_e) and un-threshed capsules (Th_u) on drum speed (d_S) at different concave clearances (C_C) of 2, 4, 6 and 8 mm as follows:

$$Th_e = 95.416 - 0.471\, C_c + 10.059\, d_s \qquad R^2 = 0.9462$$

$$Th_u = 3.651 + 0.622\, C_c - 8.537\, d_s \qquad R^2 = 0.9689$$

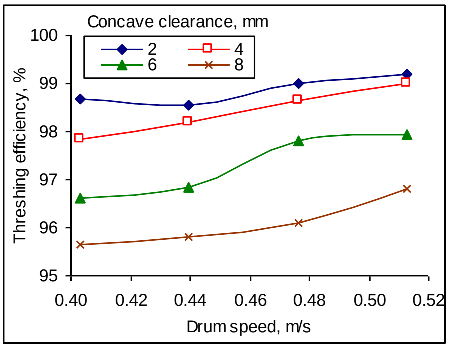

Fig. 2: The effect of drum speed on threshing efficiency.

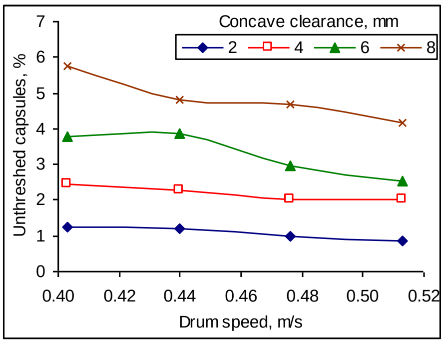

Fig. 3: The effect of drum speed un-threshed capsules.

2- The seed damage

Figs. (4 and 5) illustrate the effect of drum speed and concave clearance on seed damage. From Fig. (4) the seed visible damage increased from 1.85 to 3.33 % by increasing the drum speed from 0.40 to 0.51 m/s. Also, the visible seed damage has a slightly increment at the slow drum speed but it high increase at the high drum speeds. Therefore, the seed visible damage decreased from 3.36 to 1.67 % by increase the concave clearance from 2 to 8 mm. On the other hand, Fig. (5) clears that the seed invisible damage increase from 1.10 to 2.03 % by increasing the drum speed from 0.40 to 0.51 m/s. Then, the invisible seed damage has a slightly increment at the slow drum speed but it high increase at the high drum speeds. Therefore, the seed invisible damage decreased from 1.88 to 1.17 % by increase the concave clearance from 2 to 8 mm. This result may be due to the seed centrifugal force especially at the high speeds and the impact between the seeds at the high clearance.

The multiple regression analysis reveal that there is a highly significant between seed damage (D_S); visible (D_{Sv}) and invisible (D_{Si}); and drum speed (d_S) at concave clearance (C_C) of 2, 4, 6 and 8 mm as follows:

$$D_{Sv} = -2.361 - 0.284\ C_c + 13.533\ d_s \qquad R^2 = 0.8811$$

$$D_{Si} = -1.754 - 0.117\ C_c + 8.401\ d_s \qquad R^2 = 0.9527$$

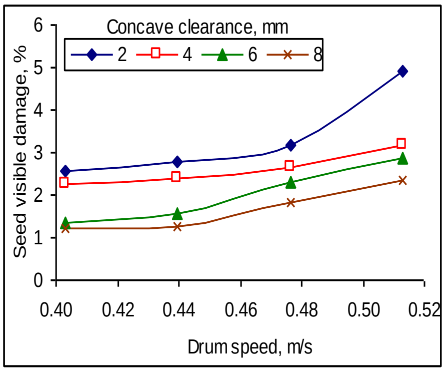

Fig. 4: The effect of drum speed seed visible damage.

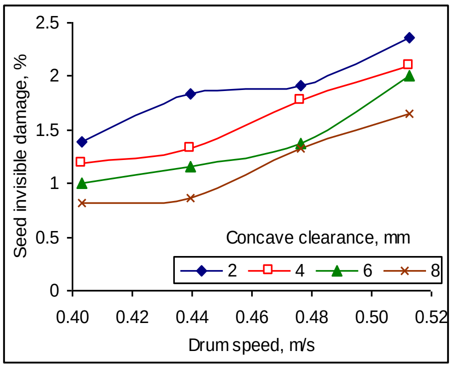

Fig. 5: The effect of drum speed seed invisible damage.

3- The seed germination ratio

Fig. (6) indicates the effect of drum speed and concave clearance on seed germination ratio. From figure can seen that the seed germination ratio decrease from 91.53 to 86.98 % by increasing the drum speed from 0.40 to 0.51 m/s. Therefore, the seed germination ratio increased from 88.75 to 89.08 % at increase the concave clearance from 2 to 8 mm. This results due to decrease the seed damage at the low drum speed.

4- The seed losses

Figs. (7 and 8) explain that the effect of drum speed on seed losses at different concave clearance and air velocity. From Fig. (7) seed losses decreased from 0.81 to 0.72 % at increase the drum speed from 0.40 to 0.51 m/s. Hence, the seed losses increased from 0.66 to 0.85 % by increasing the concave clearance from 2 to 8 mm. This result may be due to the seed centrifugal force especially at the high speeds and the impact between the seeds at the high clearance. On the other hand, Fig. (8) indicates that the effect of drum speed on seed losses at different air velocity. From the figure the seed losses increase from 2.51 to 3.75 % by increasing the drum speed from 0.40 to 0.51 m/s. Therefore, the seed losses increased from 1.45 to 5.18 % at increase the air velocity from 1.5 to 4.5 m/s. These results clear that the increase seed losses at the highest value of air velocity may be due to some fine seed losses with the capsules scrape. Moreover, the results clear that the slightly differences in seed losses effecting on the drum speed.

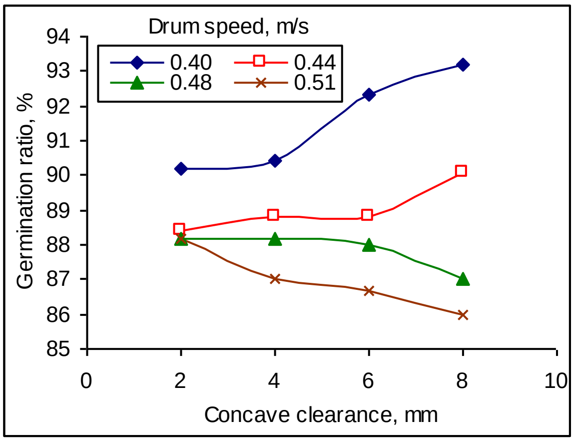

Fig. 6: The effect of drum speed on seed germination ratio.

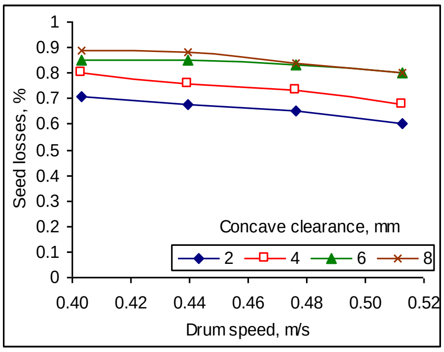

Fig. 8: The effect of drum speed on seed losses.

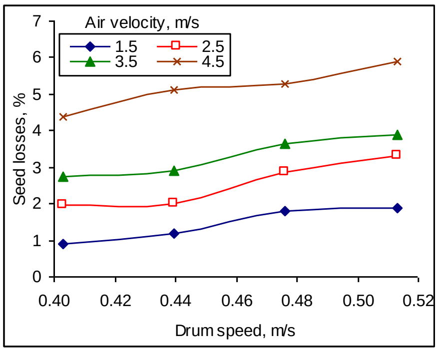

Fig. 9: The effect of drum speed on seed losses.

The multiple regression analysis reveal that there is a highly significant between on seed losses (L_S), drum speed (d_S) and air velocity (A_v) at concave clearance (C_C) of 2, 4, 6 and 8 mm as follows:

$$L_s = 0.989 + 0.033\ C_c - 0.839\ d_s \qquad R^2 = 0.9373$$

$$L_s = -5.865 + 1.196\ A_v + 11.772\ d_s \qquad R^2 = 0.9599$$

5- The seed cleanliness

Figs. (10 and 11) explain that the effect of drum speed on seed cleanliness at different concave clearance and air velocity. From Fig. (10) seens that the seed cleanliness decrease from 92.72 to 89.99 % by increasing the drum speed from 0.40 to 0.51 m/s. While, the seed cleanliness has decreased from 92.34 to 90.21 % by increasing the concave clearance from 2 to 8 mm. This result may be due to the seed centrifugal force especially at the high speeds and the impact between the seeds at the high clearance. Fig. (11) clears that the effect of drum speed on seed cleanliness at different air velocity. From the figure the seed cleanliness decrease from 94.00 to 92.83%

by increase the drum speed from 0.40 to 0.51 m/s. Meanwhile, the seed cleanliness increased from 90.91 to 96.94 % by increase the air velocity from 1.5 to 4.5 m/s. These results are logical at the air velocity increased and drum speed decreased.

The multiple regression analysis reveal that there is a highly significant between on seed cleanliness (CL_s), drum speed (d_S) and air velocity (A_v) at concave clearance (C_C) of 2, 4, 6 and 8 mm as follows:

$$CL_s = 104.386 - 0.330\, C_c - 24.813\, d_s \qquad R^2 = 0.9531$$

$$CL_s = 92.243 + 1.996\, A_v - 10.407\, d_s \qquad R^2 = 0.9520$$

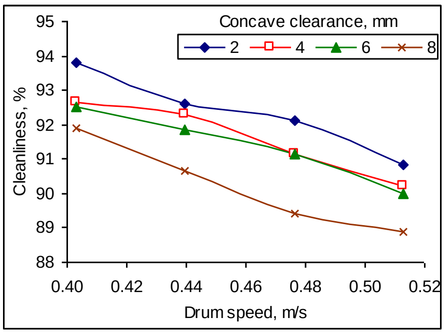

Fig. 10: The effect of drum speed on seed cleanliness.

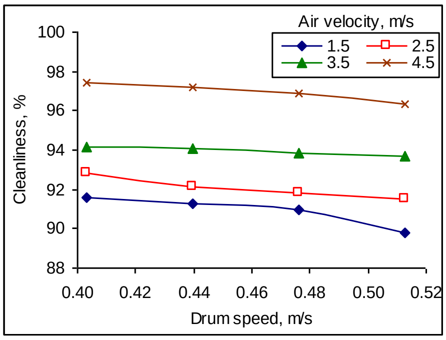

Fig. 11: The effect of drum speed on seed cleanliness.

CONCLUSION

The results showed that the suitable drum speed, concave clearance and air velocity are 0.44 m/s, 2 mm and 4.5 m/s respectively to obtain the best threshing efficiency of 98.45%, seed cleanliness of 92.3% and germination ratio of 91%. Then the modified machine can be used to threshing and cleaning the flax and it can applied the modified machine specifications on the large scale machines.

REFERENCES

Abdel-Mageed, H.N. (1989). Lentil hurtling as affected by grain treatments and husking machine. Misr.J. Ag. Eng., 6(2): 293-302.

Arafa, G.K.; M.T. Ebaid and H.A. El-Gendy (2009). Development of local machine for winnowing and grading flax seeds. Misr, J. of Agric. Eng. Vol. (26), No. (1)

Badawy, M .E. 2002. Modification and evaluation of paddy rice thresher to suit flax deseeding. Misr J. Ag. Eng., 19(4): 881– 900.

Bainer *et al*., 1982

Dudarev I.M (2010). Oil Flax Combine Harvester. Patent № 93019 Ukraine, IPC A01D45/00, A01D34/00, A01F11/00; application 08.10.2009; issued: 27.12.2010; Bulletin.

Economic affairs sector (2010): Bulletin of the agricultural statistics, Ministry of Agricultural and land reclamation, A.R.E. Vol.1:61.

EL-Ashary A.S., A.EL-Rayes, and G.R.Gamea (2003). A comparative study of Flax threshing systems and their efects on yield components quality. Misr. J. Ag. Eng., 20(3): 691-701.

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

Erugin, A.F. (1987). Threshing of flax from experimental plots. Konoplya No 6. Russia: 28-29.

Ghonimy, M.I. and M.N. Rostom (2004). Design and performance evaluation of canola-seed cleaning machine. Misr.J. Ag. Eng., 21(3): 869-884.

Hall, A.; A.R. Holowenko and H.G. Laughlin (1980). Schaum's outline of theory and problems of machine design. Schaum's outline series, Mc Graw-Hill Book Company.

Kawamura, R. (1996). Rice machinery. Text Book of Japan International Cooperation Agency (JICA) Kyoto Univ. Japan.

Khatab, M.K. (1998). Development of a simple flax thresher. Ph. D. Thesis, Agric. Eng. Dept., Fac. of Agric., Zagazig Univ: 88-105.

Klenin, N. I; I. F. Popov, and V. A. Sakun (1985). Agricultural machines, theory of operation, combination of controlling parameters and the conditions of operation. Amerid Publishing C., Pvt. Ltd., New Delhi, India.

Kromer, K.H.; H. Gottschalk and A. Beckmann (1995). Technically usable flax fiber, a new short fiber flax technology. Land Tech., 50: 6, 340-341.

Szarszunow, W.A.; W.E. Kruglenja, A.N. Kudrjawcen, S.W. Kurzenkow. (1998). Selection of design parameters of a roller assembly for flax threshing Problem. Inzynieri – Roiniczej 6(4): 63-73.

تعديل آلة صغيرة لدراس وتنظيف بذور الكتان

يحى عبد السلام الفوال ، ناهد خيرى إسماعيل و محمود أحمد العطار
معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقى - جيزة

يهدف البحث تطوير آلة بسيطة لدراس وتنظيف كبسولات الكتان تناسب المساحات الصغيرة ويتم تغذيتها يدوياً. حيث تم تعديل درفيل الدراس وتزويده بأصابع يمكن التحكم فى المسافة بينها وبين أصابع صدر الدراس لتناسب كبسولات الكتان. وتم إختبار الآلة تحت سرعات لدرفيل الدراس 0.40، 0.44، 0.48، 0.51 م/ث، وخلوص بين درفيل وصدر الدراس 2، 4، 6، 8 مم، سرعة هواء التنظيف 1.5، 2.5، 3.5، 4.5 م/ث. ولتقييم الأداء الآلى للآلة تحت الدراسة تم قياس كل من كفاءة الدراس ونسبة الكبسولات غير المدروسة ونسبة الكسر الظاهرة وغير الظاهرى والفقد فى البذور ودرجة نظافة البذور والفقد الكلى للبذور ونسبة الإنبات. وأعطت الدراسة أفضل النتائج عند سرعة درفيل 0.44، م/ث، خلوص 2 مم، وسرعة هواء 4.5 م/ث. حيث أعطت أفضل كفاءة دراس 98.45%، وأفضل نظافة للبذور 92.3% وأفضل نسبة إنبات 91%. وعليه فإنه يمكن إستخدام الآلة المعدلة فى دراس وتنظيف بذور الكتان، كما ينصح بإمكانية تطبيق نفس النظام الآلى للدراس فى آلات ذات سعة إنتاجية مختلفة.

قام بتحكيم البحث

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أ.د / محمود على محمد	**كلية الزراعة – جامعة شبين الكوم**