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Development and Performance Evaluation of a Rubbing Thresher for Sunflower Crop

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ABSTRACT

The main objective of the present study was to develop and evaluate a rub threshing machine to suit threshing of sunflower crop, and applies the theory of frictional rubbing and impacting force, and also to evaluate the threshing machine at different factors which affecting the threshing operation such as, (drum speed, impact plates numbers, the clearance between the impact plates and the bottom of the feeding chute "concave clearance" and moisture content). The performance of the threshing machine was evaluated with consideration of the items of the threshing loss, the efficiency of the threshing, the damage of the seeds (visible and invisible), the productivity of the threshing machine, the required power, the energy-specific consumption, and the total cost. The results showed that, the optimum conditions for threshing sunflower by the modified thresher were 10.12 m/s, 24 plates, 2.5 cm, and 11.28% w.b of drum speed, drum knife numbers, and moisture content respectively.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the world's most important oilseed crops . Sunflower oil consider to be very high quality (Downey *et al.*, 1989).

The effectiveness of bond rupture and plant deformation depends on the mode of action of threshing plant. The search for an optimal mode of action to break this plant is one of the most important aspects of the theory of the threshing equipment can be developed. (Klenin *et al.* 1985)

Kepner *et al.* (1978) stated that threshing might be accomplished by : impact of a fast-moving member upon the material , rubbing, squeezing pods, a combination of two or more of these actions , or some other method of applying the required forces . Khan *et al.* (1992) stated that the threshing drum is mounted on two bearings and rotates in a perforated trough-like member called the concave . During threshing crop is fed between the threshing drum and the concave , where it is subjected to a high degree of impact and frictional forces , which detach grain from panicles . El-Sheikha (1994) stated that threshing action could be performed by one or more of the following methods : Friction, Squeezing, Impact, Tension and Chopping . Bolaji (2000) cleared that the un-threshed grain losses and the total grain damage were affected by the cylinder velocity , feed rate and moisture content . 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 speed can give unthreshed heads . Aban *et al*. (1989) concluded that the capacity of the thresher is increased by increasing its threshing drum velocity . El-Haddad (2000) stated that the threshing efficiency increased with increasing drum speed and decreasing feed rate . Ajav and Adejumo (2005) mentioned that the threshing efficiency increased with increase in cylinder velocity at a given level of concave clearance and moisture content . They added that the total losses were influenced significantly by the cylinder velocity , where the total losses was the least at the lowest cylinder velocity of 4.2 m / s and increased with increasing it . Askari *et al.* (2008) during the test of a power tiller operated small thresher concluded that grain damage increased with increasing peripheral speed and decreasing crop moisture content . Ismail and Elhenawey (2009) tested is inducted on a pedal-operated sunflower thresher was designed and constructed for determine the optimal operating design via three level of the pressure surface press on friction drum (2.0, 4.0 and 6.0 kg/cm^2) for levels of friction drum speed (2.2, 3.7, 4.9 and 6.9 m/s), different radial curves of pressure surface (330,345 and 365 mm) and different resting times of sunflower head inside threshing chamber (5, 10 and 15 sec). Also Ismail (2011) conformed in experiments based on relevant physical properties of the corneas the investigated is designed to achieve conshelling with lowest losses and powers . 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 . Khater (2000) indicated that the threshing efficiency and seed damage increased by decreasing moisture content . He indicated also that the moisture content percent of 14 is the preferred ; forasmuch giving the lowest seed damage , seed losses , and highest threshing efficiency . Simonyan and Oni (2001) reported that there is an increase in threshing efficiency and extractor efficiency of locust bean with decrease in moisture content . Threshing effectiveness was also found to be affected by the cylinder speed . Schild *et al.* (1991) showed that with respect to sunflower threshing , the cylinder must be slow enough to avoid cracking the seed , approximately 300 rpm . The concave must be open enough to avoid grinding up the head . Khater (2000) concluded that the optimum working condition of the tested corn sheller machine , used for sunflower threshing occurred at 7.2 m/s drum speed , 14% seed moisture content and 4.0 cm concave clearance . The criterion cost of the tested machine working in optimum condition was 280 L.E. / fed . EL-Beba (2001) concluded that the optimum condition for sunflower threshing can be achieved at 13.6 m / s drum speed , 15 % seed moisture content and 4/2 (front / rear) drum – concave clearance ratio . Mesquita and Hanna (1993) compared two devices to thresh soybean , the first was conventional combines and the other was an experimental rubbing belt device . The energy used by conventional combines to thresh soybean was 4 times the energy required by the rubbing belt device

The main objectives of this study was the following

- Modifying and testing a thresher suiting for sunflower crop and applying the theory of combination of impact and frictional rubbing force.
- Studying the effect of some threshing conditions on threshing efficiency and energy required.

MATERIALS AND METHODS

The modified threshing machine

The modifications of the local threshing machine were carried out at the workshop of El-Gemeza Agricultural Research Station El-Gharbia Governorate during 2015 to 2017 by adding a new part as shown in Fig.(1). The specification for the new part were as follows

1. Adding a part above the original threshing unit. This part consists of a continuous feeding chute, and a unit for impact and tearing the sunflower heads. The impact unit consist of a drum shaft provided with plates. Fig. (2).

Two levels for the impact plates are used as follows:-

- A drum shaft of 12 fixed plates in 2 row.
- A drum shaft of 24 fixed plates in 4 row.

2. Adjusting the clearance in three levels for the clearance between the impact plates and the bottom of the feeding chute were 2.5 ‹3.5 and 4.5 cm. and the clearance between the drum and the belt was 2.5 cm.
3. Adjusting the speed of impact plates shaft by using four pulleys of different diameter to achieve in four speed levels of 250 rpm (4.58 m/s), 350 rpm (6.41 m/s), 450 rpm (8.24 m/s), and 550 rpm (10.07 m/s).
4. Threshing system consist of one upper drum covered with a rubber layer has diameter of 35 cm, and lower rubber belt of 51 cm in width and 0.4 cm in thickness.
5. Electric motor of 7.36 kW with a rotating speed of 970 rpm and a potential difference 380 v.

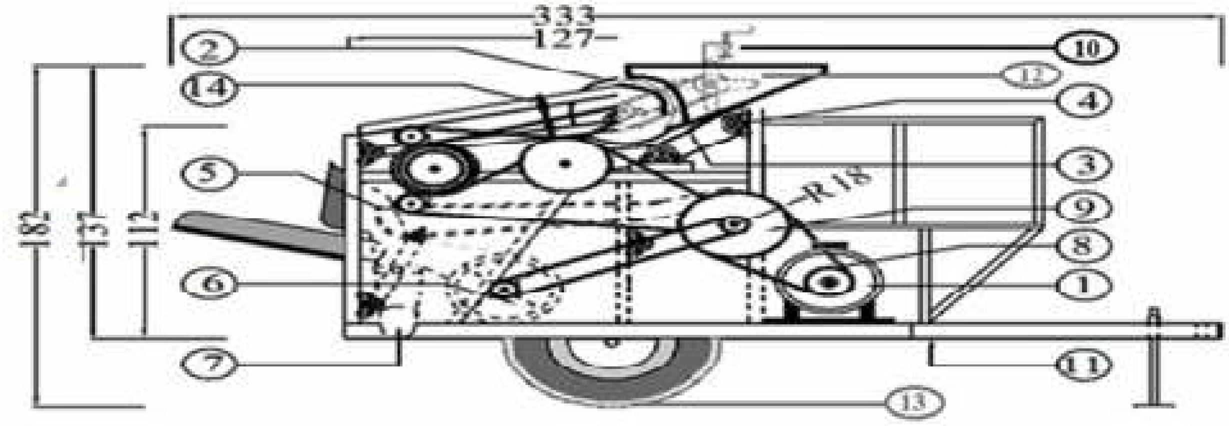

Fig.1.Threshing machine after modifying

1	Electric motor	2	Threshing drum	3	Threshing belt
4	Belt roller	5	Shaker	6	Fan
7	Seed outlet	8	Motor pulley	9	Drive pulley
10	Clearance arm	11	Frame	12	Impact plates
13	Machine wheel	14	Regulate bolt		

Fig.2. Adding upper part for the threshing system

Experimental crop

Sunflower crop variety (Sakha 53) was used in this study. The average physical properties and characteristics of the sunflower plants, heads and seeds are summarized in Tables (1).

The tested sunflower heads were at three levels of moisture content. These levels were 11.28,15.67,and 19.09 % w.b

Table 1. The measured physical properties and specifications of sunflower crop (Sakha 53)

The technical characteristic	Mean value	The technical characteristic	Mean value
Head diameter, average, cm	22.76 ± 6.5	Seed length, cm	1.087 ± 0.15
Head thickness, cm	3.8 ± 0.43	Seed width, cm	0.632 ± 0.75
1000 seed mass, average, g	58.4 ±15	Seed thickness, cm	0.426 ± 0.61
N. of seed/head	365.2 ± 130	Seed yield, g/fed.	0.820 ± 0.20

Measurements

- **Threshing and unthreshing efficiency**

No invisible seed damage was remarked with sunflower seeds by the germination test, this is due to the invisible seed damage is occur as a result to the impact action, in addition to, all the damage has occurred in the seed base not on the sides as a result to the effect of friction.

The percentage of unthreshed seed was calculated as follows:

$$Ut_L = \frac{Ut_m}{Ut_m + S_{outlet}} \times 100$$

Where:-

Ut_L = The percentage of unthreshed seed;
Ut_m = unthreshed seed mass, g;
S_{outlet} = mass of threshed seeds at the main seed outlet, g

Visible seed damage

The seed damage percentage was determined as follows:

$$D = \frac{d}{t} \times 100$$

Where:

D = The percentage of seed damage;
D = amount of seed damage, g
t = total mass of sample, g

Threshing efficiency

The threshing efficiency % was calculated from the following expression = 100 - Losses,%

- **Threshing productivity**

The threshing time was estimated, and the mass of sunflower seed were estimated. The threshing productivity per Mg/h was calculated from the following expressions:

$$\textbf{Sunflower threshing productivity (Mg/h):-} = \frac{S_w \times 3.6}{T}$$

Where:-

S_w = weight of the outputted seeds of sunflower crops; kg

T = time of treatment; sec

- **Power and energy requirements**

The power requirement was estimated using the measured line current in Amperes and potential difference in volts. The required power for the machine (P) was estimated according to the following equation (Lockwood and Dunstan, 1971):

$$p = \frac{\sqrt{3}.\text{I}.\text{V}.\eta.\cos\theta}{1000}$$

Where:-

P = total required power; kW,

I = line current strength in amperes,

V = potential difference (voltage); equal to 380 v,

η = mechanical efficiency; assumed (95 %),

cos θ = power factor (was taken as 85 %),

$\sqrt{3}$ = coefficient of consumed three phase current.

The specific consumed energy (kW.h/Mg) was calculated by dividing the required power (kW) by the threshing productivity (Mg/h).

- **Total cost**

Total cost was estimated according to the assumption and procedures given by Kepner, R.A.; R. Bainer and L.E. Barger. 1982.

RESULTS AND DISCUSSION

The effect of the added new part on the threshing of sunflower heads was evaluated from the technological and economical point of view. The obtained results were presented and discussed under the following headings:

1. Threshing losses

From the obtained data, it is clear that threshing losses of sunflower crops were increased by increasing the concave clearance and the moisture content, and decreased by increasing the impact plate numbers and the drum speed, Fig. (3).

The lowest value for threshing losses was 0.31%, which obtained at 10.07 m/s of drum speed, 11.28% of moisture content, concave clearance 2.5 cm, and the impact plate numbers were 24 plate. Whereas the highest value was 36.16%, which obtained at 4.58 m/s of drum speed, 19.09 % of moisture content, concave clearance 4.5 cm, and the impact plate numbers were 12 plate.

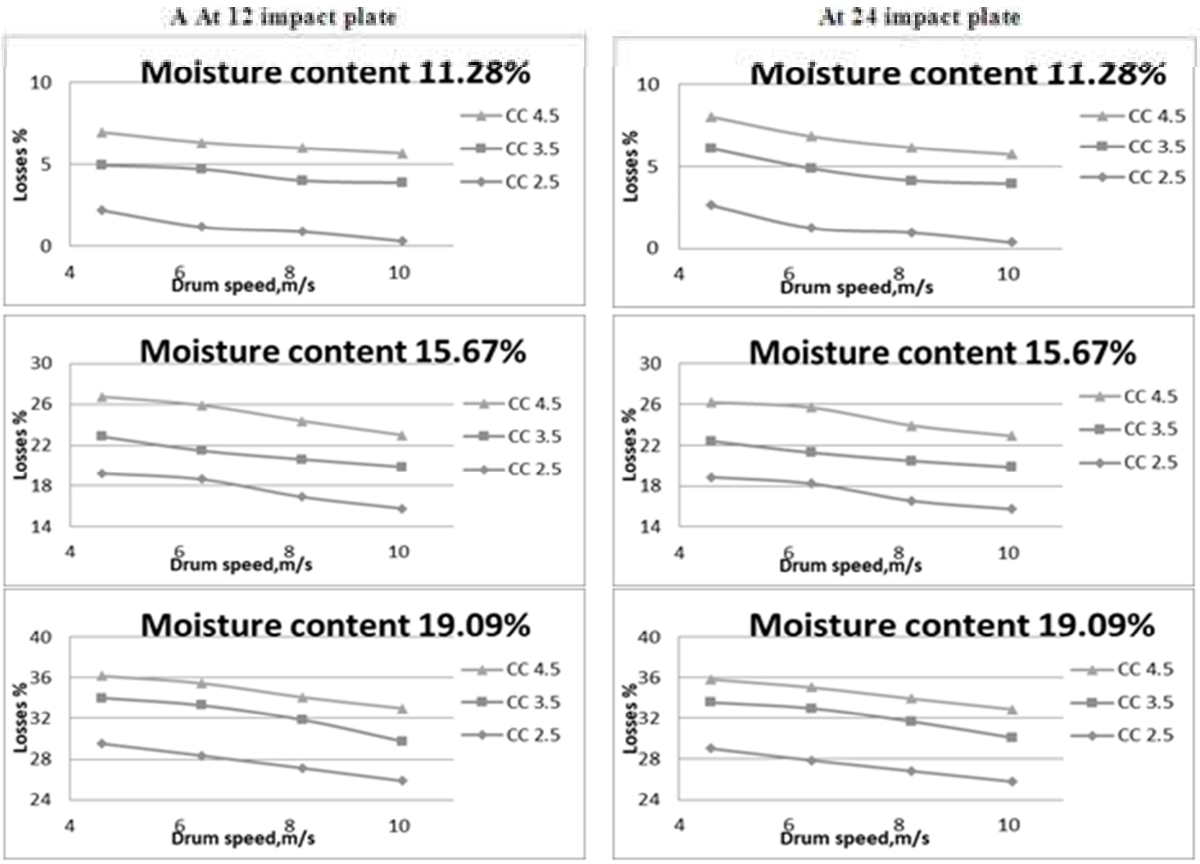

Fig. 3. Effect of drum speed, concave clearance (CC), and moisture content on sunflower threshing losses for both 12 and 24 impact plate numbers.

2. Threshing efficiency

The data clarified that the threshing efficiency of sunflower crops were increased by increasing the impact plate numbers and the drum speed, and decreased by increasing the concave clearance and the moisture content. Fig.(4).

The lowest value for threshing efficiency was 63.84%, which obtained at 4.58 m/s of drum speed, 19.09 % of moisture content, concave clearance 4.5 cm and the impact plate numbers were 12 plate. Whereas the highest value was 99.69%, which obtained at 10.07 m/s of drum speed, 11.28% of moisture content, concave clearance was 2.5 cm, and the impact plate numbers were 24 plate

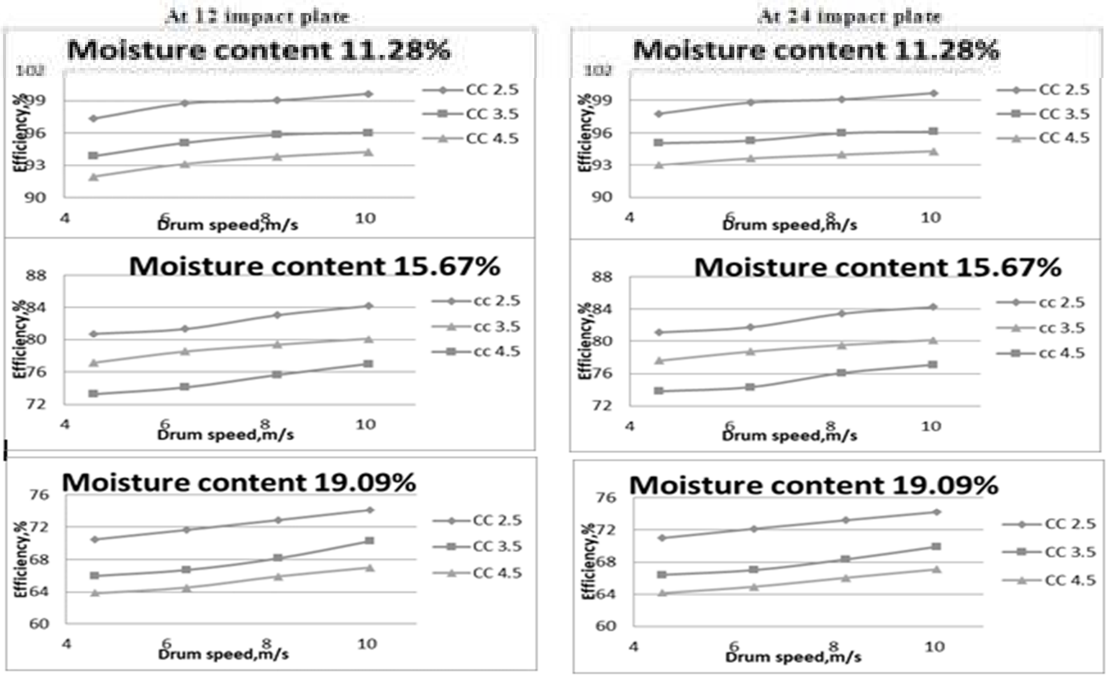

Fig. 4. Effect of drum speed, concave clearance (CC), and moisture content on sunflower threshing efficiency for both 12 and 24 impact plate numbers.

3. Visible and invisible seed damage

The invisible seed damage wasn't remarked with sunflower seeds by the germination test, this is due to the invisible seed damage is occur as a result to the impact action, in addition to, all the damage has occurred in the seed base not on the sides as a result to the effect of friction. Fig. (5)

The data clarified that the visible seed damage of sunflower were increased by increasing the impact plate numbers, the drum speed, and the moisture content, and decreased by increasing the concave clearance.

The lowest value of the visible seed damage for sunflower was 0.09%, which obtained at 4.58 m/s of drum speed, 11.28 % of moisture content, concave clearance 4.5 cm, and the impact plate numbers were 12 plate. Whereas the highest value was 9.41%, which obtained at 10.07 m/s of drum speed, 19.09 % of moisture content, concave clearance 2.5 cm, and the impact plate numbers were 24 plate.

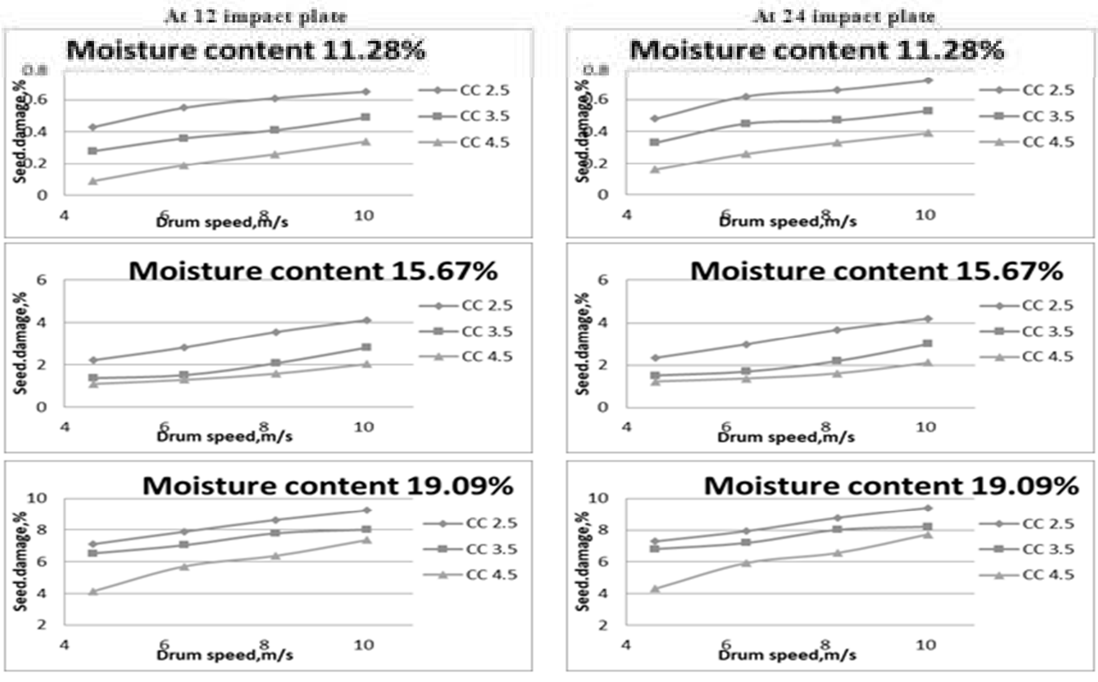

Fig. 5. Effect of drum speed, concave clearance (CC), and moisture content on sunflower seed damage for both 12 and 24 impact plate numbers.

4. The threshing machine productivity

The productivity for the threshing machine increased by increasing the impact plate numbers, the drum speed, and the concave clearance, and decreased by increasing the moisture content, Fig. (6)

The lowest value of the threshing machine productivity was 0.26 Mg/h, which obtained at 4.58 m/s of drum speed, 19.09 % of moisture content, concave clearance 2.5 cm, and the impact plate numbers were 12 plate. Whereas the highest value was 0.669 Mg/h, which obtained at 10.07 m/s of drum speed, 11.28 % of moisture content, concave clearance 4.5 cm, and the impact plate numbers on drum were 24 plate.

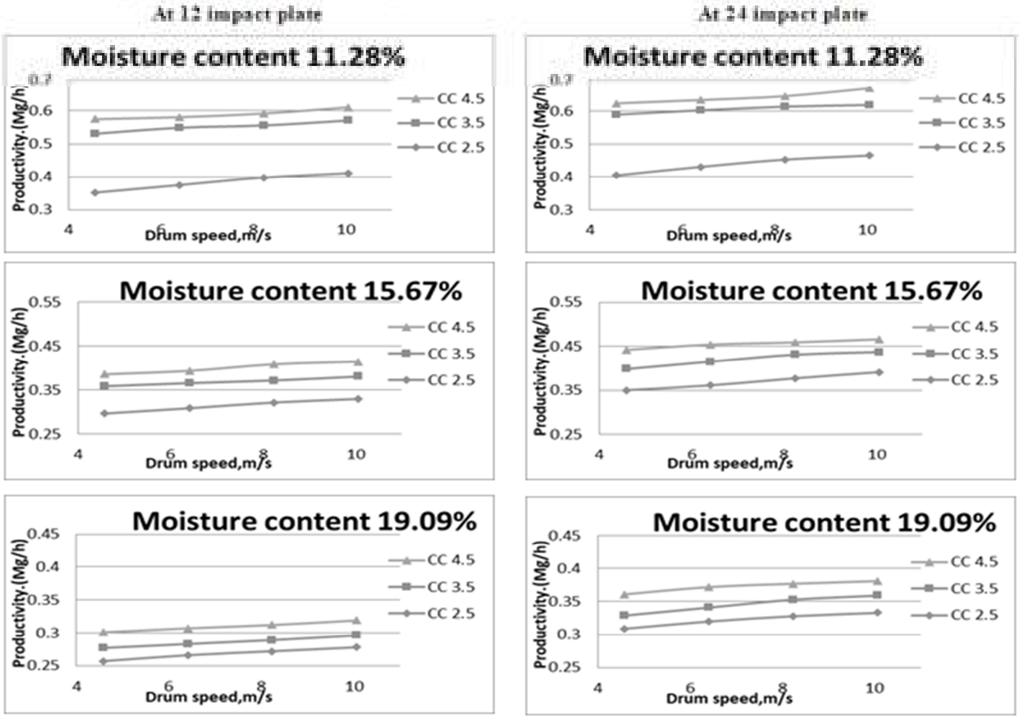

Fig. 6. Effect of drum speed, concave clearance (CC), and moisture content on the machine productivity of sunflower for both 12 and 24 impact plate numbers.

5. The required power for threshing operation

The required power for threshing operation increased by increasing the impact plate numbers, the drum speed, and the moisture content, and decreased by increasing the concave clearance, Fig. (7)

The lowest value of the required power for sunflower was 4.80 kW, which obtained at 4.58 m/s of drum speed, 11.28 % of moisture content, concave clearance 4.5 cm, and the impact plate numbers were 12 plate. Whereas the highest value was 7.53 kW, which obtained at 10.07 m/s of drum speed, 19.09 % of moisture content, concave clearance 2.5 cm, and the impact plate numbers were 24 plate

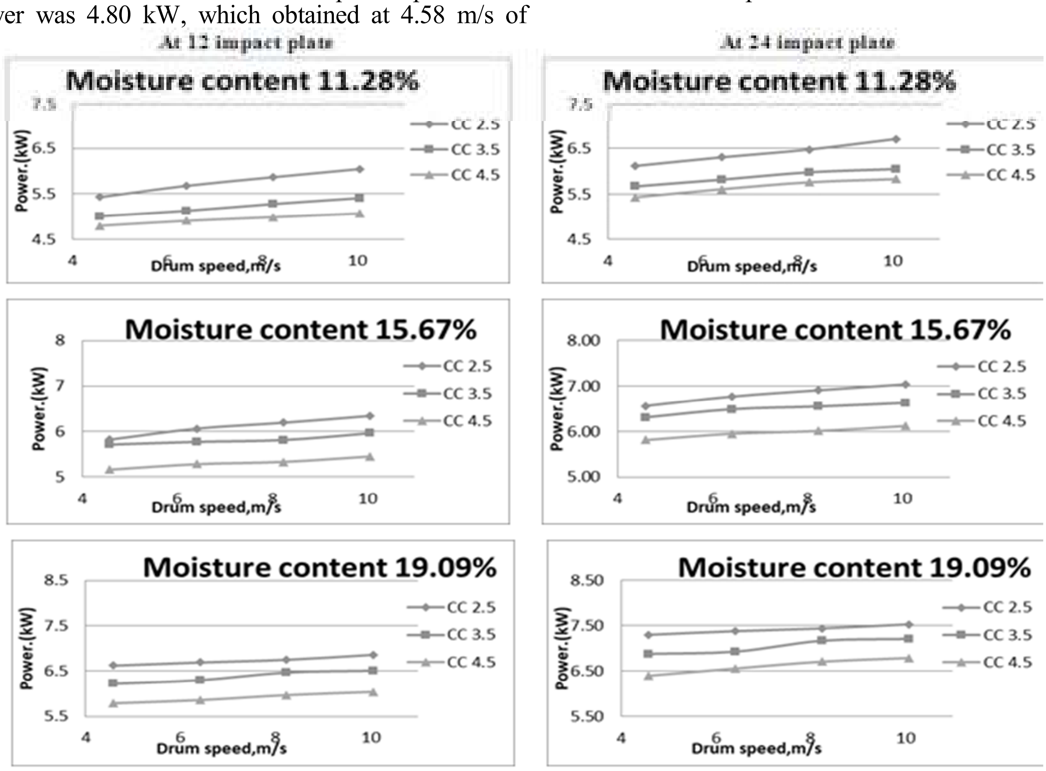

Fig. 7. Effect of drum speed, concave clearance (CC), and moisture content on the required power for both 12 and 24 impact plate numbers.

6.The specific energy requirement for threshing machine

The consumed specific energy increased by increasing the moisture content, and decreased by increasing the impact plate numbers, the drum speed, and the concave clearance, Fig. (8)

The lowest value of the consumed energy was 8.3 kW.h/Mg, which obtained at 10.07 m/s of drum speed, 11.28 % of moisture content, concave clearance 4.5 cm, and the impact plate numbers were 12 plate. Whereas the highest value was 25.76 kW.h/Mg, which obtained at 4.58 m/s of drum speed, 19.09 % of moisture content, concave clearance 2.5 cm, and the impact plate numbers were 12 plate.

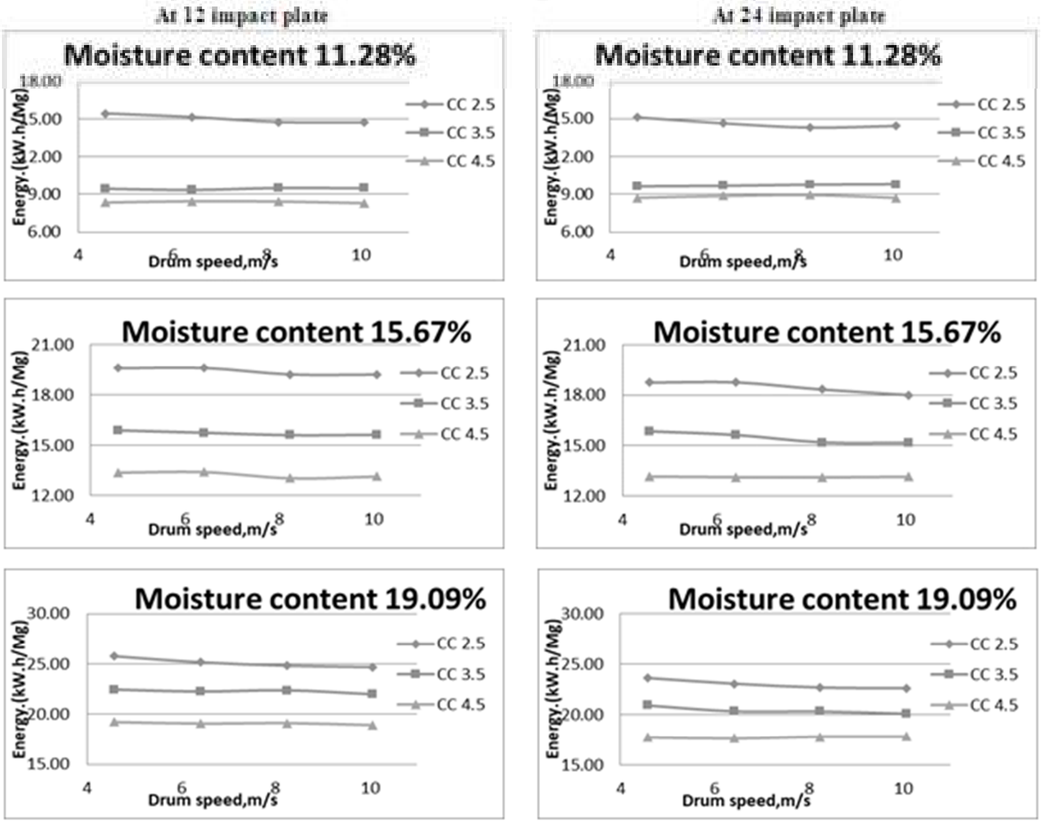

Fig. 8. Effect of drum speed, concave clearance (CC), and moisture content on the required energy for both 12 and 24 impact plate numbers.

6. Economic Evaluation :

The cost of sunflower threshing using the modified thresher was compared with that of the original machine.

The machine cost per hour includes the fixed and variable costs for the machine and the motor. It was found to be 122.5 LE/Mg at the optimum operating conditions (10.07 m/s of drum speed, 11.28 % of moisture content, concave clearance 4.5 cm, and the impact plate numbers were 24 plate)

While for the original machine it was 158.5 LE/Mg.

The decreasing in the operation cost for the modified thresher is due to increasing the threshing machine productivity and decreasing the seed losses.

CONCLUSION

It has been observed that, using modified thresher reduced seed losses.

The optimum operation conditions for the modified thresher were found to be follows (Drum speed about 10.07 m/s, concave clearance about 2.5 cm and impact plate numbers were 24 plate and seed moisture content about 11.28% w.b,) were gave the best result of productivity rate (0.669 Mg/h) and threshing efficiency (99.69%).

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تطوير وتقييم أداء آلة دراس بالاحتكاك لمحصول عباد الشمس

حسني الشبراوي المرسي[1] ، عبده شوقي العشري[2]وأحمد عبد الفتاح الكفراوي[1]

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كانت الأهداف الرئيسية للدراسة هي:1- تعديل وتطوير دراس محصول عباد الشمس وتطبيق نظرية قوة الدراس بالاحتكاك والتصادم2- دراسة العوامل الهندسية لآلة الدرس، والتي تؤثر على كفاءة الدرس والطاقة المطلوبة3- تقييم أداء آلة الدرس المعدلة من وجهة النظر التكنولوجية والاقتصادية. لقد تم تطوير الآلة وتعديلها خلال عامي 2015 إلى 2017 بورشة محطة البحوث الزراعية بالجميزة – بمحافظة الغربية، ثم أجريت الاختبارات على الآلة المطورة على محصول عبد الشمس إنتاج الموسم الصيفي لعام 2017. تقييم أداء آلة الدراس المطورة تم باختبار بعض العوامل التي تؤثر على كفاءة الأداء وهي التالي:1- سرعة درفيل الدراس– حيث تم اختبار درفيل الدراس عند أربع مستويات من السرعة وهي 4.58، 6.41، 8.24 و10.07 م/ث2-الخلوص بين الدرفيل وأرضية جهاز الدراس في الجزء الجديد – حيث تم اختبار الخلوص عند ثلاث مستويات حيث كانت مستويات الخلوص هي 2.5، 3.5 و4.5 سم 3-المحتوى الرطوبي لأقراص عباد الشمس – تم أيضاً اختبار الآلة عند ثلاث مستويات من المحتوى الرطوبي هي 11.28، 15.67 و 19.09٪ على أساس رطب.4- عدد سكاكين التصادم في الدرفيل في الجزء الجديد – حيث تم اختبار الآلة عند مستوين من عدد السكاكين 12 و 24 سكينة في الدرفيل. وتم اختبار العوامل سابقة الذكر من حيث القياسات التالية:- 1- نسبة فواقد البذور 2- كفاءة الدراس 3- الكسر الظاهر وغير الظاهر في البذور4- إنتاجية الآلة5- القدرة المستهلكة6- الطاقة المستهلكة7- تكاليف التشغيل ويمكن تلخيص النتائج الرئيسية المتحصل عليها من الدراسة و صياغة التوصيات التالية:- كان استخدام ماكينة الدراس المعدّلة في دراسة محصول دوار الشمس عند القيم التالية كما يلي:- محتوى الرطوبة حوالي 11.28٪ على اساس رطب.- سرعة الدرفيل حوالي 10.12 م / ث -الخلوص بين الدرفيل و أرضية جهاز الدراس حوالي 2.5 سم.- كانت أعداد السكاكين بالدرفيل 24 سكينة.