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DEVELOPMENT AND EVALUATION PERFORMANCE OF A LOCAL SUNFLOWER SEEDS HULLING MACHINE

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ABSTRACT

A local sunflower seeds hulling machine was designed and fabricated at a private workshop in Banha city, Egypt at 2002 for producing sunflower kernels for oil industrial and other purposes. The hulling machine performance indicated low hulling efficiency, high kernels breakage and low production. The aim of this research is to develop and evaluate the previous machine for hulling sunflower seeds at the Agricultural Engineering Workshop, Faculty of Agriculture, Minoufya University. Experiments were conducted to optimize the operating parameters of sunflower hulling machine for maximum hulling efficiency with minimum breakage kernels and increase the production . Different attempts were made to adopt the sunflower to improve the hulling machine performance

The hulling was performed using a range of hulling rollers speed ratio(1.2, 1.4, 1.6 and 1.8), clearance between hulling rollers(2, 3, and 4 mm) and feed rates(300 and 500 kg/h) at different levels of moisture contents(6, 8 and 10% d.b.).

The operational parameters for the optimum operational efficiency are: 3mm clearance, 1.6 speed ratio, 500 kg/h, and (6-8%) moisture content

Mathematical equations based on linear regression were developed to describe the hulling efficiency, the broken percentage and the energy consumption of the hulling machine as a function of roll clearance, roll speed ratio, sunflower seeds feeding rate and moisture content

INTRODUCTION

Sunflower seeds crop are one of world's leading oilseed crops, it followed the soybean crop for total oil production. The oil production in Egypt has a great problem due to high gap between production and consumption. The production of both cotton and soybean crops, which considered the main source of oil production. Therefore, the direction toward untraditional oil crops such as sunflower seeds becomes more intended. Otherwise, sunflower seeds deem to replace sesame in the production of halawa tehineia and tehina. From the economical, technological and nutritional point of view in food industry (Radwan, 1987), the use of sunflower seeds tahina as fresh tahina or in suitable sunflower halawa manufacture is more reasonable.

Sunflower seed has a dry brittle hull enclosing a whitish kernel with a thin translucent skin coat. Sunflower seed (Vodic variety) contains 37.5% oil.

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The high fiber, low protein, low oil (1%), high wax and coloring matter content of the hull are major constrains in getting a better yield of oil and good quality of protein. An integrated cost effective process is now available to obtain superior quality oil as well as meal.

Sunflower seeds need to hull, therefore an efficient hulling machine is needed. The sunflower husker used either for direct seeds consume or for hulling before oil pressing.

Allen et al., (1983). mentioned that Sunflower is the second most important source of vegetable oil in the world, second only to soybeans. Sunflower was developed

as the primary oilseed crop in the Russia and has been widely in Europe, Argentina and Australia, since 1966. Oil seed of sunflower has become an important economic crop in the U.S.A. and Canada. It represents a vital source of vegetable oil. However, it plays a vital rule in oil production in the world, it produce about 15.5% of world oil production.

Hulling is a process of removing hulls from the oil bearing seeds for obtaining high quality edible oil by the processing of kernels, this reduces fibrous content of meal and increases the marketability as stock feed. About 99% of oil is stored naturally in kernels and the hulls contain not more than 1% oil. If the hulls are not removed they reduce the total yield of oil by absorbing or retaining oil in the pressed cake. In addition to this the wax and coloring matters present in the hulls get mixed with the expressed edible oil. This necessitated the refining process, and therefore, increase the production cost of edible oil, moreover, processing oilseeds without hulling reduces the capacity of the extraction equipment in addition to more repair and maintenance charges. A large proportion of oil is retained by the high percentage of hull of oilseeds. If the hulls are removed from the seed before processing, it would yield comparatively more volume of oil. Approximate sunflower hulls: Kernel percentage is 25% : 75% and the percentage of oil in whole seeds, kernels and husk are 22–36, 36–55 and 1–2 respectively, (Canada, 1998).

The present investigation was carried out with the aim of develop and evaluate the machine for hulling sunflower seeds. A series of experiments were conducted to specify the optimum conditions of hulling operation, which insure the highest grade of hulling efficiency with minimum percentage of broken kernels and net energy consumption

REVIEW OF LITERATURE

Sunflower is considered as one of the most Egyptian leading oilseed crops. It could be planted in several soil types under varied climatic condition. It needs a short growing period and can be harvested at moisture content ranged from 17 to 20 % (w.b.). (Gomaa et al., 2000).

Herdish (2000). mentioned that, sunflower can be store at 10% moisture content or below. Aeration can be helpful in drying seed down to 10% or below. A moisture level above 10% resulted in crusting and mold on the top layer in the bin. Long-time storage is usually 12 months or less and no need to store sunflower longer than a year.

Many investigations reported that physical characteristics of seeds such as shape, size, volume, and surface area important in solving many problems associated with design or development of specific machines besides used in analysis the behavior of the product in handling of the material

Generally, hulling process efficiency is dependent upon seed variety, purity, percentage of mature kernels, moisture content, crackage, duration of storage, hulling techniques, pre-milling procedures (harvesting, cleaning and drying methods) and degree of polishing (Takai and Barrdo, 1981).

Hulling of sunflower seeds are carried out by using various kinds of equipment, ranging from simple to modern equipment. In Egypt, three types of rubber roll huskers are being used a great deal in the milling industry. One type has two rolls that rotate in opposite directions at the same angular speed but their diameters are different. The other type has two rolls of the same diameter but they rotate at different angular speeds. The clearance between rolls in these two types are adjusted manually by a hand wheel. A third and more modern type differs from the two other types. It has a pneumatic pressure control by which the clearance is automatically adjusted according to the feed rate.

Many investigation designed and tested various forms of milling and shelling machines.

Soliman (1987). studied the hulling characteristics of two types of rubber roll huskers using short grain rough rice reported that, hulling efficiency, broken percentage and power consumption for a husker machine are affected significantly by roll clearance, feeding rate and speed ratio adjustments. Proper selection of clearance adjustments speed ratio and feeding rate plays a major role in the effectiveness of the milling process as it improves the hulling efficiency. The operational parameters for optimum operational efficiency were 1 mm clearance, 1.5 speed ratio, 1 kg/min feeding rate for the husker machine(THU-35A) and 3.5 kg/cm^2 pneumatic pressure and 90 kg/min feeding rate for the Husker machine (HR-10MPC) at constant speed ratio of 1.25. Soliman (1987), concluded that, the power requirement for process of paddy husking and the types of energy affecting the paddy kernels in the hulling zone was derived for all operational parameters as the huskers. Ibrahim (1987), studied the feasibility of using the rubber roller husker machine in shelling Egyptian peanuts. He used different clearances, speeds and moisture contents for peanut. He found that rubber roller husker machine provides satisfactory levels of shelling Egyptian peanuts.

Tayel and Khairy (1988), designed and tested a sunflower prototype-shelling machine. They studied the effect of spinning disc speed, diameter and coefficient of friction between seeds and the impact surface on shelling efficiency. They concluded that, sunflower seeds could be shelled by impact method with reasonable efficiency reaching 90%, the speed of spinning disc should range between 4000 to 5000 r.p.m with 2mm clearance which gave the best shelling efficiency. The impact surface must be made frame rough and hard materials. The roughness needed for the rubbing action tends to separate hulls from sunflower seeds, while the broken kernels reached 40% at recommended speeds.

Abd el-Magieed (1989), carried out experiments to determine the suitability of rubber roller husker (with speed ratio between the rollers 1.2)for lentil hulling. He indicated that using a rubber roller husker for hulling lentil grains is more economical than the traditional.

Ibrahim (1992), study and asses parameters affecting rice grain broken percentage during milling process on local rice husker machine. He found that the improvements which were made on the local machine increased the milling efficiency by 10% and 15% and decreased the damage percentage by 7% and 22% for G-173 and IR-28 rice varieties respectively.

Ismail (1994), studied the possibility of utilizing and developing a local rice husker machine for lentil hulling. He concluded that the hulling efficiency may be influenced by different parameters like drum speeds, types of drum , coefficient of friction, diameter and the length of hulling impact zone.

Many investigators designed and developed a peanut Sheller machine for the small farms (Farag, 1996 and Helmay, 1999), they concluded that the shelling and breakage percentage efficiency, depending on drum types, drum speed, concave type and clearance between drum and concave, moisture content of grains.

MATERIALS AND METHODS

Sun flower seeds (Vidoc variety), which commonly grown in Egypt, taken from Oil Crops Institute, Ministry of Agriculture and have been used in this study.

Table (1) shows the physical characteristics of the mentioned seeds variety. All measurements were carried out and analyzed at the Agric. Eng. Laboratory in Agricultural Engineering department. Faculty of Agriculture, Minoufiya University.

The moister content of samples was about 10% (d.b.)which were taken without any drying process. With the help of these properties is easy to determine the engineering parameters for the seeds hulling and separation machines suitable work with the sunflower seeds variety under study. The following measuring instruments were used in the present work:

-A caliper electronic gauge used (vernier clippers) for dimensional properties determination such as seeds length, width and thickness.

-Repose angle meter was used to measure the angle between the horizontal base and the inclined side of the formed cone due to a free vertical fall of the seeds (El-Raie, 1998).

Rigidity force of seed was measured by using the digital force gauge apparatus (Effe-Gi, Ravenna, Italy, MT).

-Friction angle for samples was measured against iron and rubber was measured according to the method stated by Mohsenin, (1970).

-Rotational speed of rollers was measured by means of amulti- range hand tachometer (Model: Smith G0 341).

The electric power (P,Watt) was calculated based on current intensity (I, Ampere)and the voltage(V, volt) measurements.(Soliman and Abd El Maksoud, 2001).

$$P = \cos ? . I . V$$

where:

cos ? = power factor (*being equal to 0.85*)

V = Voltage (*220 volt*)

Table 1. Some physical of sunflower seeds characteristics (Vidoc variety)

characteristics	Mean (x')	Standard deviation (δ^{-1})	Coefficient of variation (C.V.)
Length(L)mm	12.22	0.65	5.3
Width(w)mm	5.95	0.46	7.73
Thickness(t)mm	3.83	0.43	11.22
Geometric diameter (G_d)mm	6.4	0.42	6.56
Arithmetic diameter (A_d)mm	7.3	0.38	31.66
Area of flat surface (A_f)mm^2	56.13	5.88	10.47
Area of transfer surface (A_t)mm	17.7	3.02	17.06
Sphericity %	52.44	3.41	6.5
Volume mm^3	144.49	26.98	18.67
Rigidity force (N)			
a - Longitudinal	25.8	4.24	16.43
b- Lateral	18.3	2.67	14.59
c- Transverse	12.9	4.47	34.65
Angle of repose	31.2	1.81	2.59
Friction angle			
a- iron steel	23	0.82	3.56
b- rubber	54.7	3.68	6.72

-The moisture content was determined by the oven method (105° for 24 hrs)

To meet the practical objectives of this paper a series of pre experimental tests were carried out on a local hulling machine which was available in the Public Service Center, Minoufiya University. The modification was carried out in the Agric. Eng. work shop, Faculty of Agriculture, Minoufiya Univ.

The old designed of this machine consists of two horizontal tangential tooth rollers steel (25cm Diameter, 100cm length, and 2 tooth/cm) rotates inside the hulling chamber in apposite direction(350 r.p.m). The rollers driven by electric motor (7.5 H.P. with 700 r.p.m.). A feeding hopper was fixed over the hulling chamber to feed the sunflower seed. It was manufactured from galvanize smooth iron sheets (100x75 cm) and had two adjustable walls to obtain the proper slope for the seeds to slide smoothly between the hulling drums, there was a feeding gate in the hoppers base to control the feeding rate. Inclined smooth groove for receiving the product outlet was fixed under the hulling drums. The pre experimental results of the undeveloped machine after one pass of feeding material (300 kg/h) between the rollers indicated that, the sunflower hulling efficiency was not satisfactory (about 25-50%), broken kernels was very high (about 40-50%) and unregulated feed rate was noticed.

The developed (modified) machine was sketched as shown in Fig.(1) To develop the hulling machine various accessories were fitted to the local machine. Mechanical feeding system was added to feeding hopper to regulate the feeding process. It consists of a feeding sieve (100x75 cm) to move the big chaff and other debris which mixed with the seeds. Also feeding tooth steel roller was added(12cm diameter and 100cm length) rotates inside the hopper (350 r.p.m) which causes rows of sunflower seeds to move into the seed hulling zone between hulling rolls. The feeding rate of seeds is able to be adjusted by a shutter concealing a small distributor roller. Adjusting roller speed and clearance between the feeding roll and inclined walls of the hopper regulates the feeding rate. The feed rates used were 300 and 500 kg/hr. The hulling rollers is provided with hard rubber j/s 85° . The clearance between the two surfaces must be smaller than the mean thickness of the sunflower seed. A regulating wheel makes it possible to control the clearance between the rollers. The clearances used were 2, 3 and 4 mm. The hulls covering the kernel are first compressed. The part of the hull which hits against the roll with the higher peripheral speed is subjected also to shearing forces. Hulling is achieved by the action of these two forces.

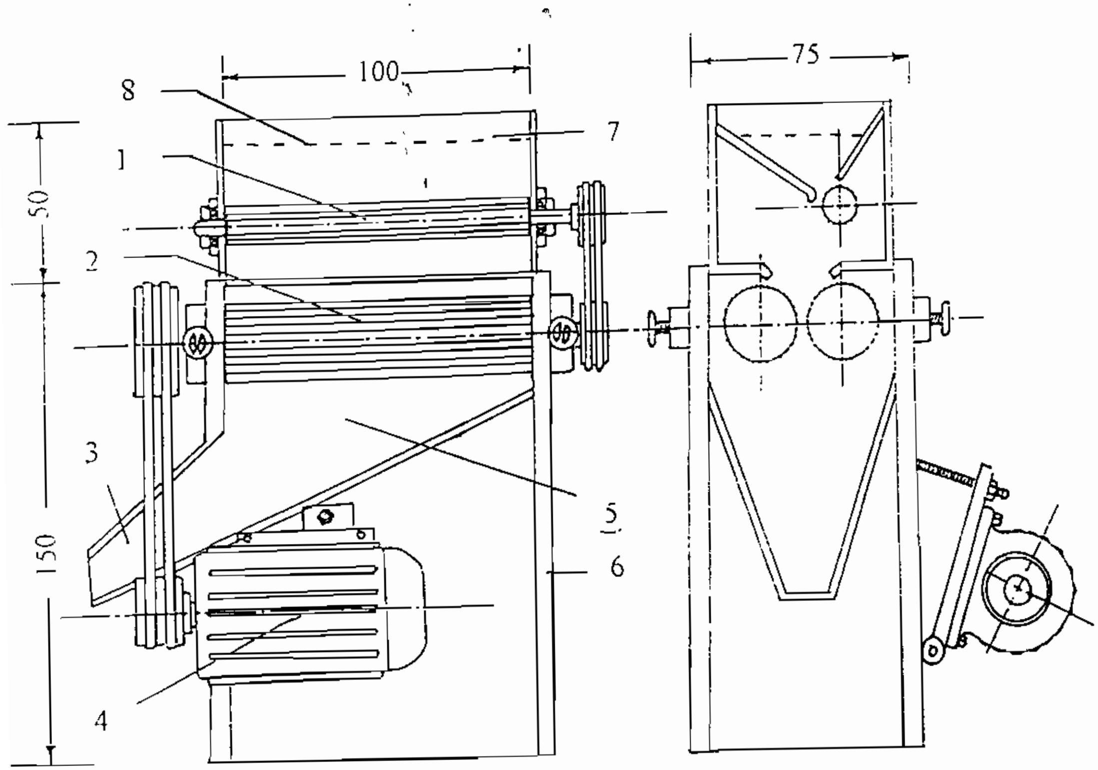

Fig. 1: A sketch of modified hulling machine.

A simple variation speed was used to give the required hulling rollers speed. The difference in hulling rollers speeds causes the hulls to be crushed and removed from kernels. In this study, the lower speed is fixed at 350 r.p.m. and the higher speed can be adjusted to 420, 490, 560 or 630.Therefore, four levels of speed ratio used were 1.2, 1.4, 1.6 and 1.8. The slope of inclined smooth channel for receiving the mixture of out let was increased to be 50° to increase the velocity of out let mixture. Three levels of seed moisture content were used 6, 8, and 10% (d.b.)

Sunflower seeds were fed in the hulling machine and random samples of outlets were taken to indicate the machine performance at different investigated parameters. Each sample was divided into separate parts by visual inspection and the weight of each part

was recorded according to: total mass of sample (M), mass of broken kernels (M_1), mass of unshelled seeds (M_2).

To estimate the effect of previous parameters on sunflower hulling quality three calibration terms were used namely the percentage of broken kernel(B%), hulling efficiency (H%), and net consumptive energy (E, W.h/kg)

the broken sunflower percent was determined according to (Ismail,1994) and (Abd-Elmagid, 1989) as follows:

$$B(\%)=\left(\frac{M_1}{M}\right)\times 100$$

M_1 = mass of broken kernels, g.,

M = total mass of the sample, g.

the hulling efficiency (H%) was calculated according to :(Tayel and Khairy,1998)as follows:

$$H(\%)=\left(1-\frac{M_2}{M}\right)\times 100$$

M_2= mass of unshelled seeds g.,

M= total mass of sample g.

Net power requirement was calculated by the following formula:

Net power (p) = Electric power (load) - Electric power (no load)

Net consumption energy was calculated by the following formula:

$$E = P/R$$

where:

E = Net power consumptive, (w.h./kg),

P = Net power, (W),

R = Feeding rate, (kg/h).

The experiments were arranged in a randomized complete block design using factorial analysis of variance with three replicates. The analysis of variance was executed by SPSS program.

RESULTS AND DISCUSSION

The results for the modified hulling machine are shown graphically in Figures (2, 3, and 4). Significant differences of hulling efficiency, broken kernels percentage and power consumption were found to exist for the different feed rates within each levels of clearance, rollers speed ratio and moisture content of seeds. An analysis of variance was made on the hulling efficiency, broken percentage and power consumption . The results showed that there was a significant effect of each factor, however , the clearance has the highest significant of all. Also, there were significant interactions between each two factors.

Fig. (2) shows that, the hulling efficiency of sunflower seeds decreased as the clearance between rollers increased under the other variables. It was observed that, increasing clearance from 3 mm to 4mm, the decreasing rate of hulling efficiency is more than the decreasing rate of clearance from 2mm to 3mm. This may be due to that, any increment in the clearance more than 3 mm, led to be the clearance more than the thickness of most the seeds. The highest value of hulling efficiency was remarked (97.5) at 2 mm clearance, 1.8 speed ratio, 300 kg/h feed rate and 6% moisture content of seeds.

However, data and Figures showed that the hulling efficiency, broken kernels percentage and power consumption were the highest at the smallest clearance. The effect of the speed ratio was more pronounced at low levels of clearance but had very little effect on broken percentage at high levels of clearance. This is an agreement with Soliman (1987), Maher (1987) and Abd El-magid (1989) who used an rollers machines in husking rice and stated that "increasing the clearance means increasing the percentage of unshelled paddy".

The effect of feeding rate was more pronounced at the low levels of clearance. As feeding rate increased at low levels of clearance the broken percentage and power consumption increased but the hulling efficiency decreased especially at low levels of seed moisture content. This decrease of hulling efficiency and the increase of broken percentage may be due to possible grain to grain contact instead of grain to rubber contact as more sunflower seed could pass through the same clearance than that is normally expected at smaller feed rate. In this case the resilience of the rubber and therefore it is hulling action is not fully utilized resulting in lower hulling efficiency and more breakage. This is in agreement with Soliman (1987).

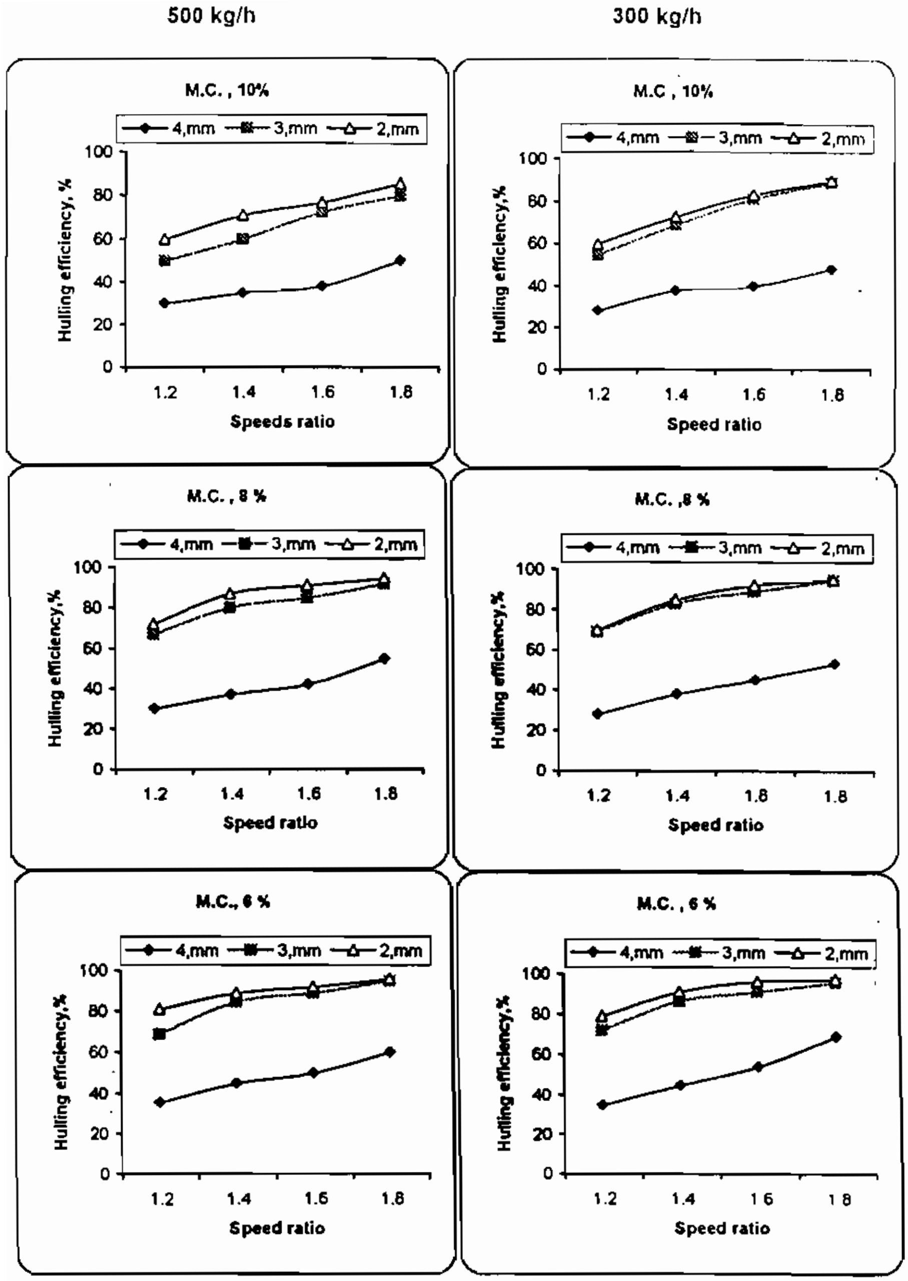

Fig.2: Effect of rollers speed ratio on hulling efficiency, % at three levels of clearance, moisture content and two feeding rates

It seems to be more economical to use the machine at 3 mm with 1,6 speed ratio rather than 2 mm clearance and 1.8 speed ratio because hulling efficiency are very close at summits and at the mean time its broken percentage is quite low. And will not make a serious problem because the low percentage of broken kernels not affect the production of oil and technical on other products, but the problem will appears in the separating operations depending on terminal velocity.

A computer program for multiple regression analysis was used to describe the hulling efficiency(H%),broken percentage(B%) and net energy consumption(E, W.h/kg) as functions of clearance (C, mm), speed ratio(S), moisture content(M%) and feeding rate (F, kg/h), the following linear equations were obtained.

$$H\% = 100.297 - 20.223\,C + 41.039\,S - 0.012\,F - 3.457\,M \qquad (R^2 = 0.86)$$
$$B\% = 10.835 - 5.256\,C + 18.722\,S + 0.004\,F - 1.743\,M \qquad (R^2 = 0.87)$$
$$E = 6.507 - 1.596\,C + 5.219\,S - 0.011\,F + 0.156\,M \qquad (R^2 = 0.92).$$

The hulling efficiency which reflects the amount of shelled sunflower seed after a single pass hulling is considerably high in the clearance range from 2mm to 3mm. At a clearance in the range higher than 3mm, the hulling efficiency drops significantly but the power consumption is getting low. As clearance decreased below 3mm the power consumption rose significantly as shown in Fig. (4).The broken percentage is inversely related to roll clearance. As clearance decreased the broken percentage increased linearly as shown in Fig. (3). Also, was observed that, the mean values of hulling efficiency decreased when the moisture content increase from 6 to 10% but the decreasing rate from 8 to 10% was more than the decreasing rate when moisture content increase from 8 to 6%.The effect of moisture content on hulling efficiency and broken kernels is neglictable at high levels of clearance(4 mm) and speed ratio (1.2).

The operational efficiency was maximum(91.5%) at roll clearance 3mm, speed rates 1.6, seed moisture content 6% and feeding rate 500 kg/h. these operational parameters are considered the optimum.

Fig. (4) illustrated the power consumed as affected by the interaction between clearance and speed ratio of rollers at different moisture content and two levels of feeding rate. We can observed that the power consumed seemed to be affected by clearance with the increase of speed ratio from 1.2 to 1.8 at all levels of moisture content and feeding rates.

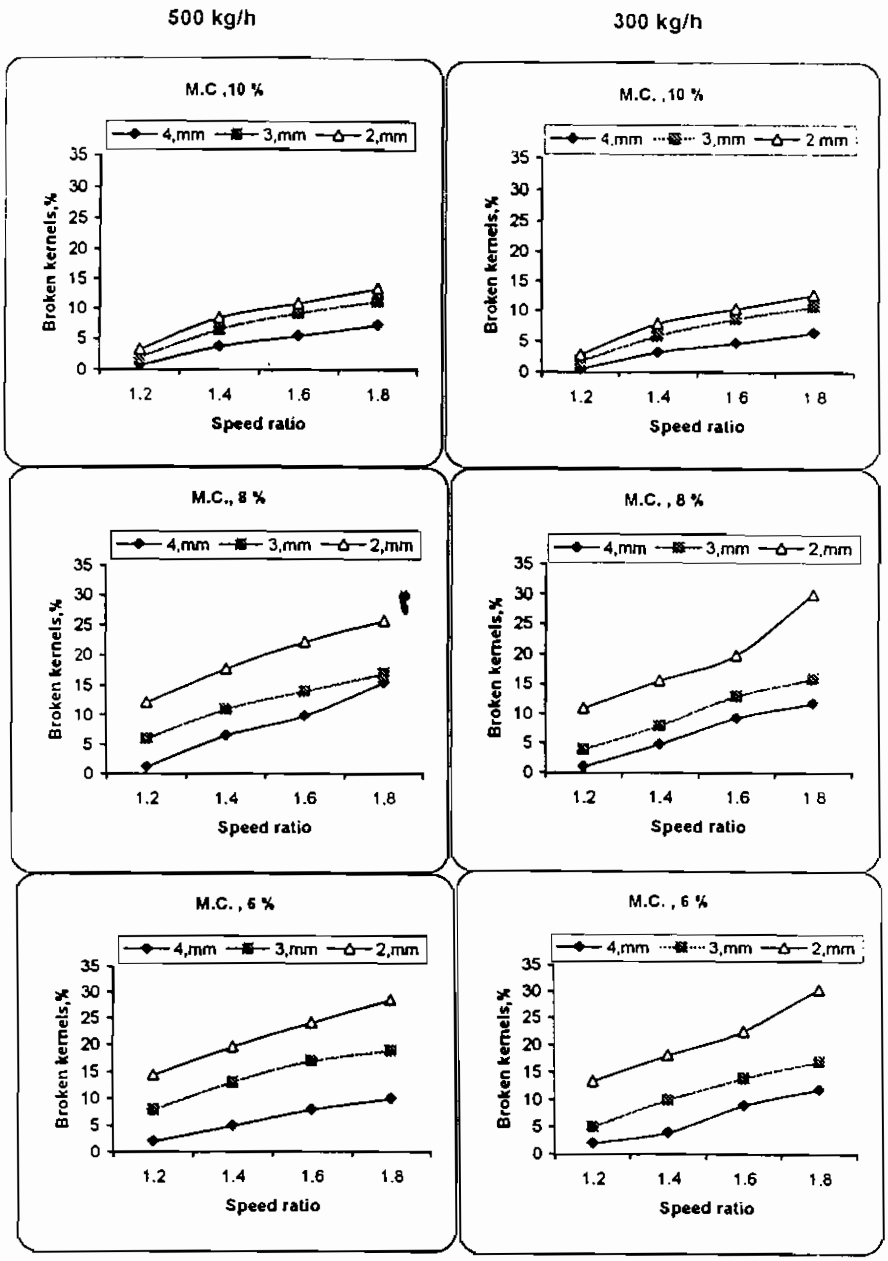

Fig.3: Effect of rollers speed ratio on broken kernels percentage, % at three levels of clearance, moisture content and two feeding rates

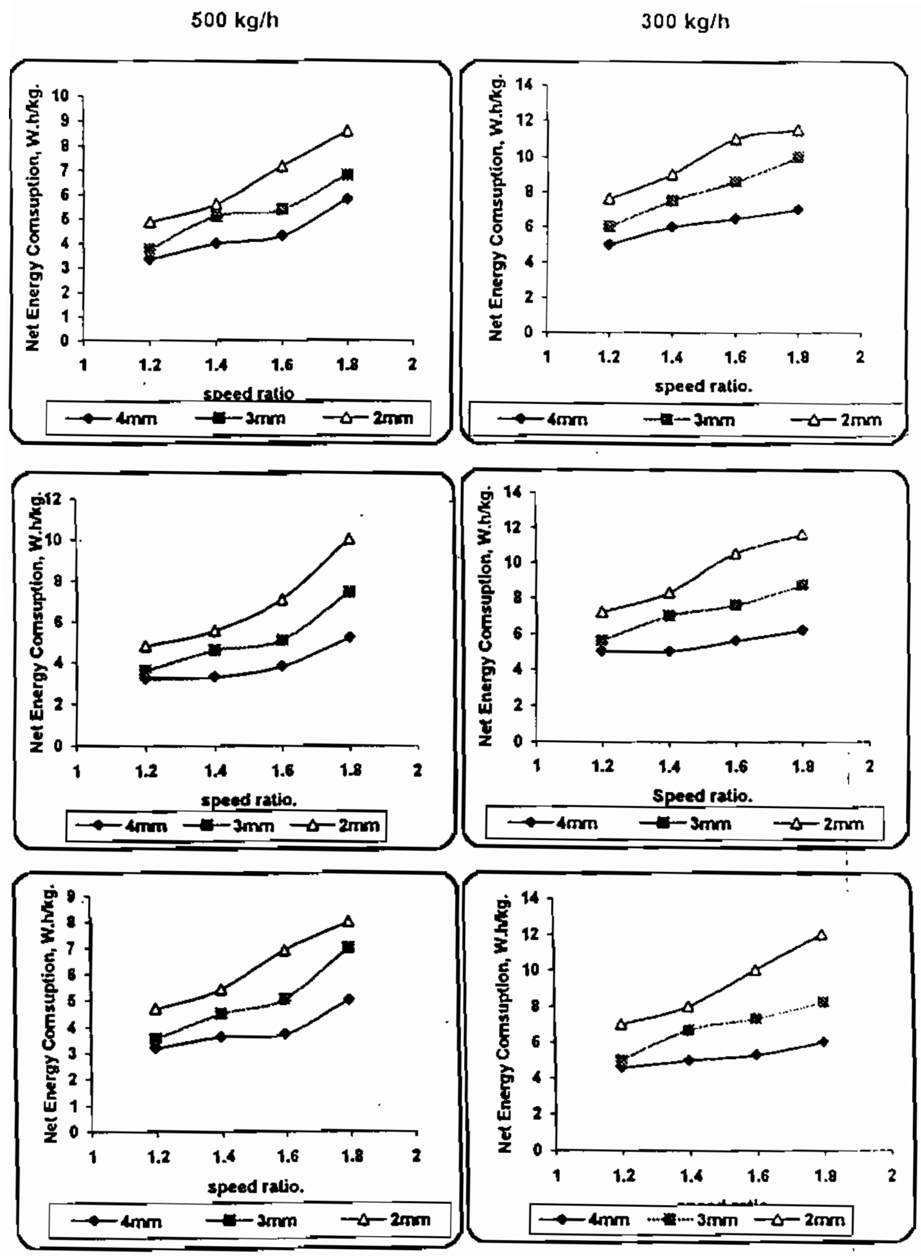

Fig.4: Effect of rollers speed ratio on net energy consumption (W.h/kg) at three levels of clearance, moisture content and two feeding rates

The power consumed decreased when the clearance increase from 2 to 4 mm at all M.C. and speed ratio, it was observed that, increasing of speed ratio from 1.2 to 1.8 , led to increase the rate of power consumed at 2mm clearance more than the increasing rate at 4mm clearance. Also noticed that, increasing of the feeding rate led to increase the power requirement (W) but the net energy (W.h/kg) decreased. In general results of developed rollers machine for sunflower hulling gave more much acceptable results than the old machine

CONCLUSION

From the results presented, the following conclusions may be drawn:

1-using the developed local machine for sunflower hulling is satisfactory and succeeded for purpose as a step forward to the complete design.

2-Hulling efficiency, broken kernels percentage and net energy consumption for a hulling machine are affected significantly by roll clearance, speed ratio, seeds moisture content and feeding rate adjustments.

3- Proper selection of clearance adjustments speed ratio and feeding rate plays a major role in the effectiveness of the hulling process.

4-Using moisture content in the range of 6-8% (d.b.) for hulling recommended to increase the efficiency, decreasing moisture content under this range caused increasing of broken kernels and will affect oil seed press at oil production.

5- The optimum operational conditions of the developed machine can be obtained by adjusting the machine to 3mm clearance, 1.6 speed ratio and 500 kg/h feed rate at 6 to 8% moisture content.

Under the specified optimum operational conditions the huller yields a hulling efficiency of (89-91.5%), a broken percentage of (14-16.5) and net energy of (5.04 -7.3) at feeding rates of (300 -500kg/h) respectively.

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الملخص العربي

تطوير وتقييم أداء آلة تقشير بذور عباد الشمس محلية الصنع

د/ جمال رشاد جامع

تبرز اهمية محصول عباد الشمس كاحد المحاصيل الزيتية الذي يقع عليه عبأ الحد من مشكلة الزيوت في مصر حيث تتسع الفجوة بين إنتاج واستهلاك المحاصيل الزيتية في مصر لما تتسم به بذور عباد الشمس من ارتفاع نسبة الزيت فضلا عن جودته ونقاءه وسهولة استخلاصه وتوافر الظروف البيئية والمناخية لزراعته في مصر. بالإضافة إلى استخدام قلب بذور عباد الشمس حديثا في تصنيع الطحينة والحلاوة الطحينية وكذلك كمادة محسنة في تصنيع الخبز والحلويات.

ولقد وجد أن تقشير بذور عباد الشمس تساعد في عملية استخلاص الزيوت وتقلل من تكاليفها وتقلل من نسبة الشموع والألوان في الزيت المستخلص، ومن ثم ظهرت الحاجة لآلة تقشير بذور عباد الشمس للحصول على قلب بذور عباد الشمس بأقل نسبة ممكنة من القشر.

ويهدف هذا البحث إلى تطوير ماكينة لتقشير البذور ذات أسطوانات صنعت بورشة خاصة بمدينة بنها لاستخدامها في مشروع تعظيم إنتاج الزيوت من عباد الشمس بكلية الزراعة جامعة المنوفية ولكن عند تشغيلها وجد أنها منخفضة الكفاءة ونسبة البذور التالفة عالية وقليلة الإنتاجية وتم عمل التعديلات اللازمة بورشة كلية الزراعة – جامعة المنوفية، ورعي أثناء التعديل تزويد الماكينة بأدوات للتحكم في عوامل التشغيل الرئيسية تحت الدراسة وهى الخلوص بين الدرفيلين ونسبة السرعة بين درفيلي التقشير وكذلك التحكم في معدل التلقيم ونسبة الرطوبة للبذور المستخدمة.

تم دراسة تأثير العوامل السابقة على كفاءة التقشير ونسبة القلب المكسور والطاقة المستهلكة في عملية التقشير.

وقد أسفرت الدراسة عن النتائج الآتية:-

استخدام الماكينة بعد التعديل أعطى معدلات مرضية من كفاءة التقشير ونسبة القلب المكسور والطاقة المستهلكة.

يفضل استخدام نسبة الرطوبة في حدود من 6-8% عند تقشير البذور حيث أن ارتفاع نسبة الرطوبة يؤدى إلى تقليل الكفاءة وزيادة الطاقة المستهلكة وانخفاضها يرفع نسبة القلب المكسور وقد يؤثر بالسلب على عملية استخراج الزيت عند الضغط.

تأثرت كفاءة التقشير ونسب القلب المكسور من عملية التقشير بدرجة كبيرة بكل من الخلوص بين الأسطوانات والسرعة النسبية للأسطوانات وكذلك معدل التغذية .

وكانت ضوابط التشغيل التي تعطى كفاءة التشغيل المثلى لماكينة التقشير هي 3مم خلوص، 1.6 نسبة سرعة، نسبة رطوبة للبذور من 6-8%، معدل تغذية 500 كجم/ساعة.

وقد تم استنتاج المعادلات الرياضية على أساس الارتداد الخطى لوصف كفاءة التقشير ونسبة الكسر والطاقة المستهلكة في التقشير كدالة للخلوص بين الأسطوانتين والسرعة النسبية وكذلك معدل التغذية ونسبة الرطوبة للبذور.

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