

A STUDY ON PERFORMANCE IMPROVEMENT OF THE LOCAL MANUFACTURED HAMMER MILL USED IN POULTRY FARMS

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ABSTRACT

The study aims to modify and evaluate the performance of the local crushing machine used in the Egyptian poultry farms for crushing and grinding soybean and maize grains.

The effect of some parameters such as screen opening sizes (6, 9 and 14 mm.), feeding rates (250, 400, 500 and 700 kg/h), the number of hummers (45, 60 and 90) and flywheel diameters, (200, 350, 450 and 600 mm) on the fineness degree, (%), power, (kW), and energy requirements (kW.h/Mg) were investigated. The optimum operating conditions of the modified hammer mill were obtained at the screen opening sizes of 6 and 9 mm for soybean and maize grains respectively, feeding rate of 550 kg/h, number of hummers of 90, and the flywheel diameter of 450 mm.

The results also showed that changing the size of the hammer mill electric motor from 7.5 to 11 kW gave high performance and safe operation with different number of hammers and flywheel diameter for all treatments.

INTRODUCTION

Increasing poultry and animal production is one realistic means of increasing the production of animal protein to meet greater demand due to population pressure. The recent development of the poultry and animal production requires special progress in the techniques and equipments. Feeding is one of the most serious problems facing poultry and animal producers. Whereas it represents a major cost in any intensive system of poultry or animal production. Pond *et al.*; (1985) stated that the grain processing is done primarily to improve digestibility and efficient of utilization. For a method to be effective, it must (a) reduce wastage and (b) increase consumption rate of grain. Behnke (1983) showed that the most important reasons for grinding feedstuffs are to improve digestibility, mixing and to aid in further processing such as pelleting. Reece *et al.* (1986) indicated that traditionally feed prepared for poultry has all of the ingredients ground to the same approximate fineness. When the diet is fed, in mash form is not all of the same approximate fineness; the bird may selectively consume ingredients that might present in the large particle sizes. Maynard and Hied (1964) and Kozmin (1988) classified the types of milling equipment as cutting machines, pressing (crushing) machines, and machines acting by free impact. Milling equipment may depend upon one or a combination of two or more of these types. Earle (1985) stated that the grinders can be divided into two classes (crushers and grinders). In the first class (crusher) the major action is compressive, whereas grinders combine shear and impact with compressive forces. El-Hadidi *et al.* (1997) evaluated the performance of four different types of crushing machines generally used in Egyptian poultry farms. They indicated that the highest efficiencies were (85.8 and 84.9 %), and

productivities (0.6 and 0.76 ton/h) using burr mill and swinging beaters hammer mill respectively. Also, they concluded that no significant differences were found between mills with respect to fineness degree.

Kilborn *et al.* (1982) concluded that kernel hardness is only one factor that would be expected to affect energy requirements during milling. Other factors such as feed rate, roll gap, roll speed and tempering procedure also play a significant role. Ali and Dimian (1988) reported that the type of materials, moisture content, fineness of grinding, rate of feed, type and condition of mill, affect the power requirement and milling capacity. They added that hammer mill reduced the size by impact, while burr (plate) mill reduces the size by crushing and shear forces. El- Hddi *et al.* (1996) indicated that disc speed in the range of (300 to 350 r.p.m), discs clearance of (1.5-2.0mm) and feeding rate of 250 kg/h may be considered as optimum factors in milling process of wheat and maize grains. Also, they mentioned that the power requirements were higher in maize as compared with that needed for wheat grains at all speeds, clearance and feeding rates. Reece *et al.* (1986) reported that the grinding with hammer mill could be reduced by 35 % if mill screen size could be increased from 4.76 to 7.94 mm. Hassan (1994) showed that grinding capacity increased, and grinding energy decreased as fineness of grinding increased by increasing screen size from 3.20 mm to 6.35 mm which in turn gave an increase of 68.1 % in grinding capacity and a decreased of 55% in grinding energy. Culpin (1986) showed that the power required for very fine grinding is much greater than for medium grade. The objects of grinding grain for stock are to increase palatability and to facilitate mixing other constituents of the ration. Degree of grinding required for young chick is 1.6 mm for adult poultry is 3.2 mm. Hegazy (1995) concluded that at any feeding rate, increasing milling speed, and decreasing the clearance between working surfaces, were found to be important factors in increasing flour color degree, while the required horsepower for milling operation increased.

Selecting and applications of proper technique and equipments for feeding poultry are serious problems that facing poultry producers. According to the investigations through the operating of hammer mill it was found that widely varying in ground grain particle sizes, and also there are high fluctuations in power consumption during crushing which will damage the electric motor.

The main objective of the present study was to modify and evaluate the performance of the local crushing machine used in Egyptian poultry farms. The modifications were mainly made to select the proper dimensions for each of flywheel diameter, number of hammers, and main source of power.

MATERIALS AND METHODS

The main experiment was carried out at the Agriculture Experiment Research Station, Sakha- Kafr El-Sheikh Governorate. To fulfill the objective of this study, a local Egyptian hammer mill has been modified and evaluated. The specifications of the hammer mill before modifications are shown in table (1) and Fig. (1).

The selected milling machine is function according to the theory of impact for grinding grains by means of swimming hammers. It was selector for the modification depends on the physical and mechanical properties of the grains.

Table (1): Specifications of hammer mill before modifications.

| Item | Specifications |
|-----------------------------|----------------|
| Number of hammers | 45 |
| Hammer clearance, mm | 12.5 |
| Flywheel diameter, mm | 350 |
| Hammer edge | Smooth |
| Hammer size (L. W.T), mm | 100, 50, 25 |
| Screen opening diameter, mm | 14 |
| Rotor shaft speed, rpm. | 2200 |
| AC motor power, kW | 7.5 |
| Number of concave bars | 3 |

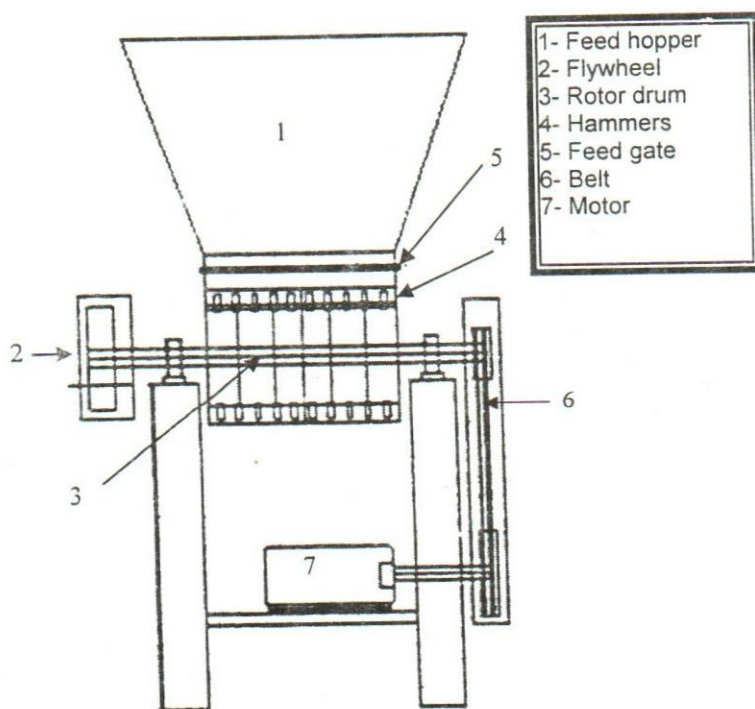


Fig. 1: Schematic diagram of the developed hammer mill.

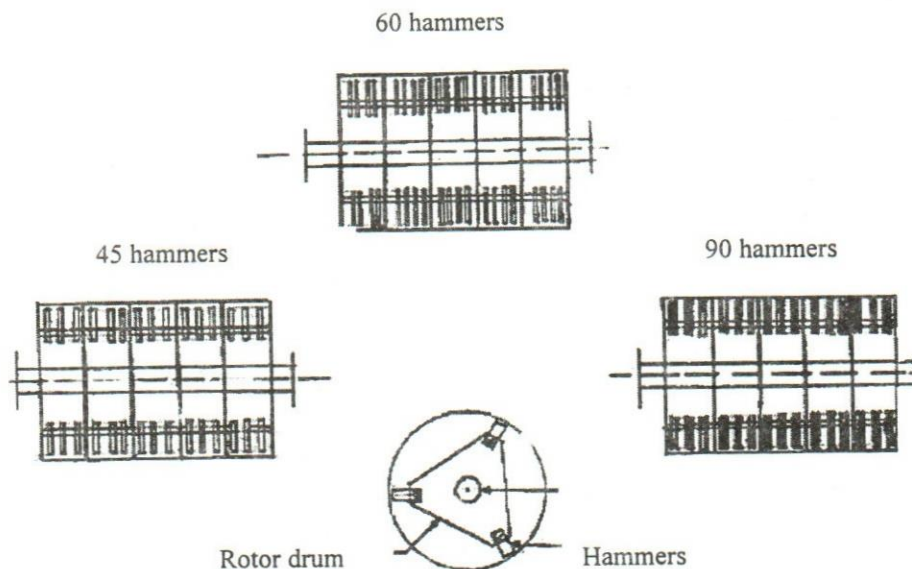
The operation theory of this milling machine depends upon impact force by forcing the product against the screen and crushing it until particles pass through. The grain is held against the screen by centrifugal force and

forced around over the perimeter of the screen at high velocity. Particles are discharged from the milling zone through the screen holes.

Preliminary experiments were carried out to explore the proper power source, where was change the hummer mill electric motor from 7.5 to 11 kW because the small electric motor did not have enough power to drive the developed machine under full load. The drum of hammer mill revolving speed 1800 rpm during the grinding operation.

Two kinds of cereal grains were used in this investigation namely soybean (Giza-2), and yellow maize (Three Ways Cross-352). The mean moisture content of soybean and maize grains at the time of experiments was 12.68 % and 13.84 %, respectively. The soybean and maize samples were fed from the feed hopper into the hammer mill by gravity. The grain feed rate was controlled by changing manually a sliding feed gate at the bottom of feed hopper.

The modified hammers were made from mild steel flat plates of 100 mm length, 50 mm width and 2.5 mm, thickness with sharpened edges as shown in Fig. (2).



Side view of rotor drum with hammers.

Fig. 2: Three different sets of hammers.

The modified hammer mill was tested at four different feeding rates of about 250, 400, 500 and 700 kg/h, and three screen opening sizes of 6, 9 and 14 mm during the grinding process. The second step was to evaluate the performance of different sets of hammer (45, 60 and 90) and four flywheel diameters (200, 350, 450 and 600 mm) for the best of feeding rate and screen opening size during the grinding process.

In each test, the consumed time was measured from the instant of full grain dropping until the instant of end time using a stop watch. Samples of ground soybean and maize were taken directly from the milling machine outlet. The samples were packed in polyethylene socks and analyzed for particle size, by using an automatic sieve shaker (TERAOKA model SAF-7) according to ASAE Standard S 319 (ASAE, 2000). After each test, the mass of ground materials on each sieve was determined and calculated as percentage of the total products. An oven drying method was used to determine grain moisture content. For each test, a super clamp meter was used for measuring the electrical energy consumption of the milling machine, and the electrical power was calculated.

RESULTS AND DISCUSSION

The experiments were carried out to evaluate the modified grinding machine, as well as grinding efficiencies during milling soybean and maize grains. The different criteria of grinding of grains such as physical properties (particle size distribution and sieve analysis) and other factors related to the power and energy requirements during grinding operation were taken into consideration.

1- Effects of screen opening size and feeding rate on the fineness degree.

The results manifested in Table (2) show the effect of hammer mill screen opening sizes and feeding rates on the particle size distribution (fineness degree, %) during grinding soybean and maize grains. Increasing the screen opening sizes from 6 to 9 mm at feeding rate 550 kg/h decreased the fineness degree by 10.08 % and 9.22 % in the sieves less than 2.36 mm for soybean and maize crops respectively. At the same time, increasing the screen opening sizes from 9 to 14 mm at feeding rate 550 kg/h decreased the fineness degree by 28.65 % and 27.44 % in the sieves less than 2.36 mm for soybean and maize crops respectively.

The results indicated that using the screen opening sizes 6 to 9 mm for soybean and maize crops respectively always gave the best results of the fineness degree.

On the other side, increasing feeding rate from 250 to 700 kg/h for the sieves less than 2.36 mm decreased the fineness degree for soybean and maize crops.

Also, increasing feeding rate from 250 to 550 kg/h at screen opening size 6 mm decreased the fineness degree by about 18.94 % and 5.84 % in the sieves less than 2.36 mm for soybean and maize crops respectively. While increasing feeding rate from 550 to 700 kg/h at the screen opening size 9 mm decreased the fineness degree by about 23.07 % and 25.3 % in the sieves less than 2.36 mm for soybean and maize crops respectively. The results indicated that the feeding rate 550 kg/h always gave the best results of the fineness degree in the sieves less than 2.36 mm for all treatments during grinding soybean and maize grains.

Table (2) Effects of screen opening size, and feeding rate on the fineness degree for soybean and maize crops.

| Type of crop | Sieves opening Size, mm | 6 | | | 9 | | | 14 | | | | | |
|--------------|-------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | | 250 | 400 | 550 | 700 | 250 | 400 | 550 | 700 | 250 | 400 | 550 | 700 |
| Soybean | <1.7 | 57.95 | 51.08 | 49.89 | 39.11 | 47.25 | 44.97 | 43.02 | 34.91 | 38.14 | 33.23 | 30.94 | 24.73 |
| | 1.7 - 2.36 | 24.13 | 20.86 | 19.08 | 13.95 | 22.07 | 24.53 | 19.0 | 12.61 | 16.87 | 14.98 | 15.05 | 13.22 |
| | 2.36 - 3.35 | 10.78 | 16.96 | 17.93 | 24.00 | 20.68 | 14.75 | 18.8 | 26.49 | 18.01 | 21.84 | 23.51 | 22.08 |
| | 3.35 - 4.75 | 4.14 | 9.98 | 10.14 | 16.04 | 7.11 | 10.21 | 11.93 | 17.00 | 20.0 | 17.76 | 16.8 | 24.14 |
| | >4.75 | 0 | 1.12 | 2.96 | 6.9 | 2.89 | 5.54 | 7.25 | 8.99 | 6.98 | 12.19 | 13.7 | 15.83 |
| Maize | <1.7 | 53.27 | 50.77 | 49.39 | 36.85 | 49.59 | 45.4 | 44.28 | 33.39 | 39.0 | 36.62 | 33.9 | 24.0 |
| | 1.7 - 2.36 | 22.69 | 28.23 | 22.08 | 18.18 | 21.3 | 22.0 | 22.6 | 18.0 | 20.3 | 20.0 | 18.63 | 11.11 |
| | 2.36 - 3.35 | 12.20 | 9.8 | 15.89 | 24.76 | 17.22 | 18.74 | 18.09 | 25.49 | 22.08 | 18.5 | 20.3 | 24.7 |
| | 3.35 - 4.75 | 8.84 | 7.3 | 8.17 | 12.43 | 6.8 | 8.63 | 9.5 | 13.27 | 11.41 | 14.17 | 16.0 | 21.64 |
| | >4.75 | 3.00 | 3.9 | 4.47 | 7.78 | 5.09 | 5.23 | 5.53 | 9.85 | 6.41 | 10.71 | 11.17 | 18.55 |

2- Effects of mill screen opening size and feeding rate on the power requirements.

From Fig. (3) it can be found that, the power requirement for grinding operation increased as the feeding rates increased, while it decreased with increasing the screen opening size. On the other wards, the results indicated that increasing feeding rate from 250 to 700 kg/h increase in the grinding power consumption from 3.9 to 7.6, from 3.4 to 7.0 and from 3.1 to 6.0 kW at the screen opening size of 6, 9 and 14 mm respectively for soybean and from 4.7 to 8.6, from 4.2 to 7.5 and from 3.6 to 7.1 kW at the three above mentioned screen opening sizes respectively for maize crop. The proper results of the grinding power consumption occurred at the optimum feeding rate of 550 kg/h and the screen opening sizes of 6 and 9 mm for soybean and maize crops respectively.

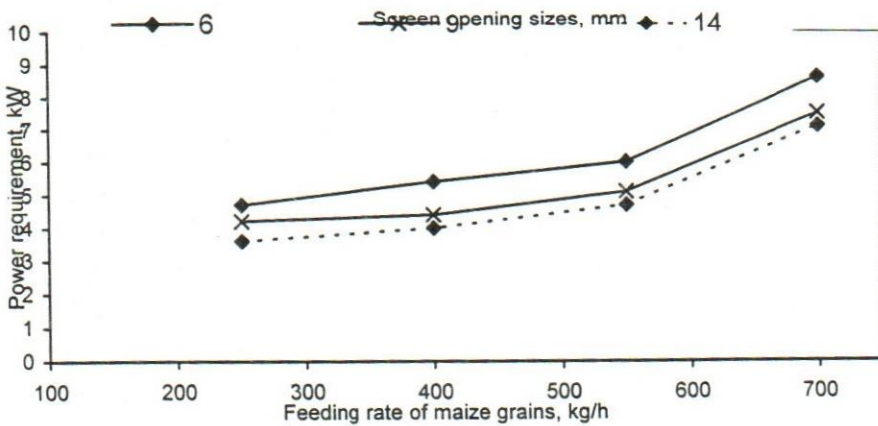
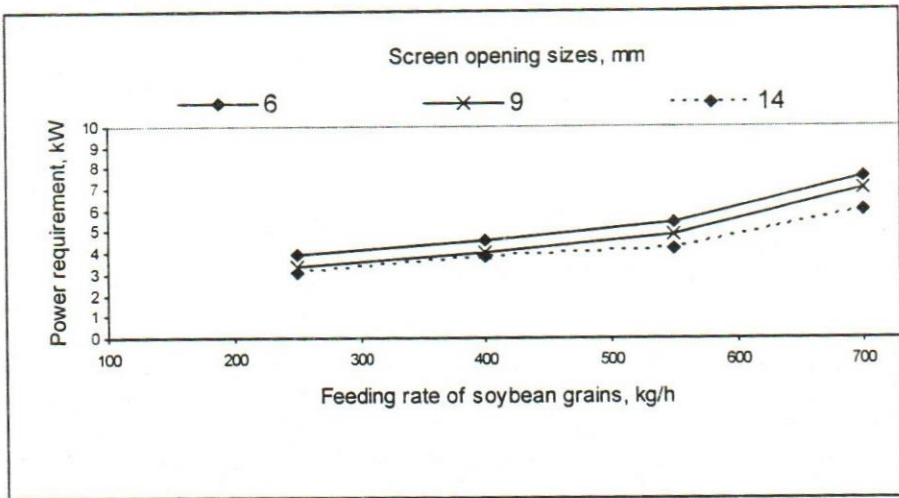


Fig. 3: Effects of different screen opening sizes and feeding rates on the power requirements for soybean and maize crops

3- Effects of the number of hammers and flywheel diameter on the fineness degree.

From the data shown in Figs. 4 and 5, it can be seen that the fineness degree increased as the number of hammers and the flywheel diameter increased during grinding soybean and maize grains. That result trend is attributed to the fact that by increasing the number of hammers and flywheel diameter for the same operating conditions will increase the number of hitting on the flowed material. At the same time, the material is held against the screen by centrifugal force and forced around over the perimeter of the screen at high velocity, and hence the material was finer and passed through the screen faster.

On the other words, the results indicated that increasing the flywheel diameter from 200 to 600 mm increase in the fineness degree by 31.51, 24.32 and 22.89 % in the sieves less than 2.36 mm at the number of hammers of 45, 60 and 90 respectively for soybean crop and by 29.85, 24.29 and 27.5 % in the sieves less than 2.36 mm at the three above mentioned the number of hammers respectively for maize crop.

In addition the obtained results showed that increasing the number of hammers from 45 to 60 cause a corresponding increase in the fineness degree by 2.82 and 6.15 % in the sieves less than 2.36 mm for soybean and maize crops respectively at the flywheel diameter 450 mm. at the same time, increasing the number of hammers from 60 to 90 increase the fineness degree by 10.13 and 12.16 % in the sieves less than 2.36 mm for soybean and maize crops respectively at the flywheel diameter 450 mm. The results also showed that the values of fineness degree in the sieves less than 2.36 mm are higher for soybean grains in comparing with fineness degrees produced from maize grains for all treatments. This may be due to the increase of fiber content of maize grains.

On the other hand, the difference in results obtained between the flywheel diameters of 450 and 600mm was not significant. The results also indicated that the flywheel diameter 450 mm and the number of hammers 90 always gave the best results of the fineness in the sieves less than 2.36 mm for all treatments during grinding soybeans and maize grains.

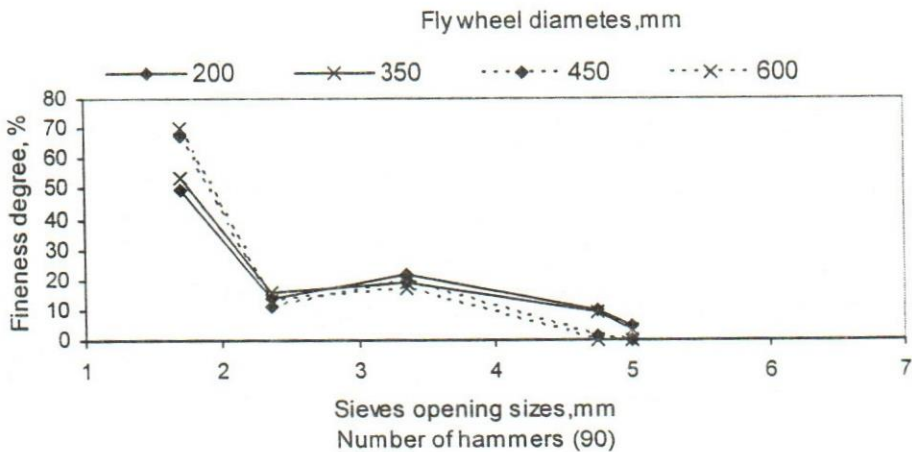
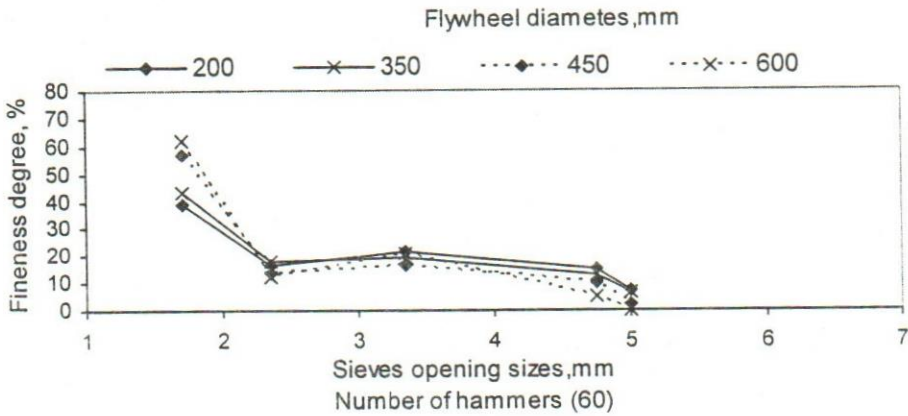
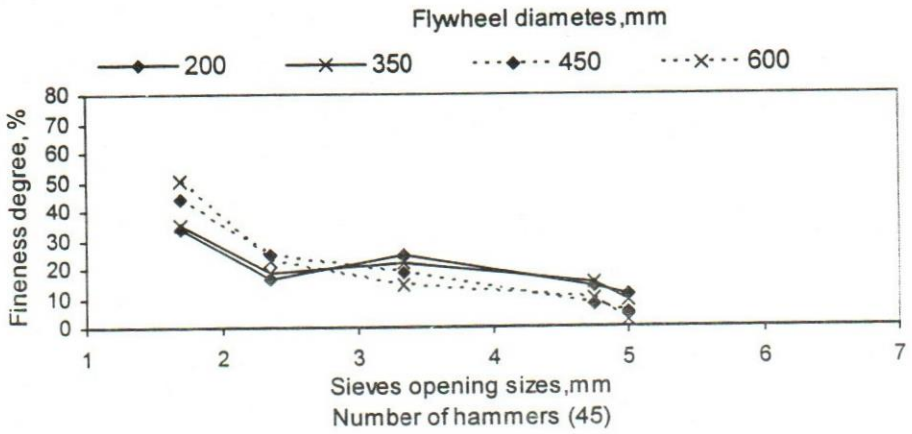


Fig. 4: Effect of number of hammers and flywheel diameter on the fineness degree for maize crop.

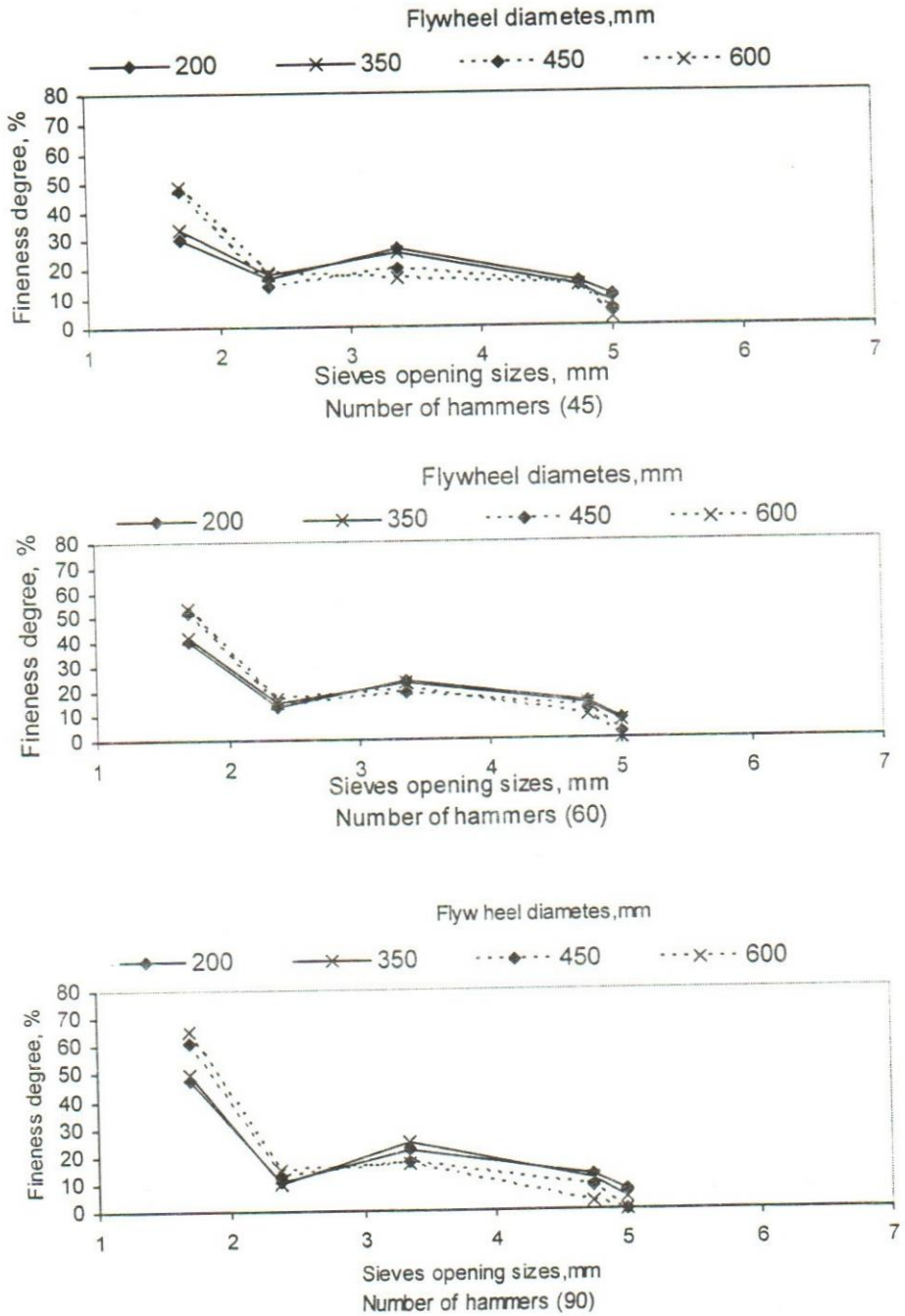


Fig. 5: Effect of number of hammers and flywheel diameter on the fineness degree for maize crop.

4- Effect of the number of hammers and flywheel diameter of hammer mill on the power (kW) and energy requirements (kWh/Mg)

Table (3) and Fig.(6) show the effect of the number of hammers and flywheel diameter on the power (kW) and energy requirements (kWh/Mg) for grinding soybean and maize grains. It can be noticed that the power and energy requirements increased as the number of hammers and flywheel diameters increased.

Table (3) Effect of number of hammers and flywheel diameter of hammer mill on the power consumption (kW) for grinding soybean and maize grains.

| Type of crop | Soybean | | | Maize | | |
|-----------------------------------|---------|-----|-----|-------|-----|------|
| No. of hammers Flywheel dia.mm | 45 | 60 | 90 | 45 | 60 | 90 |
| 200 | 5.2 | 5.5 | 6.5 | 5.4 | 5.9 | 6.8 |
| 350 | 5.6 | 6.8 | 7.4 | 6.5 | 7.7 | 8.4 |
| 450 | 6.9 | 7.4 | 7.6 | 6.9 | 8.2 | 8.7 |
| 600 | 8.1 | 8.8 | 9.6 | 8.4 | 9.4 | 10.1 |

However, the results indicated that increasing the number of hammers from 45 to 90 caused a corresponding increase in the grinding power consumption from 5.2 to 6.5, from 5.6 to 7.4, from 6.9 to 7.6, and from 8.1 to 9.6 kW at flywheel diameters of 200, 350, 450 and 600 mm respectively for soybean crop, and from 5.4 to 6.8, from 6.5 to 8.4, from 6.9 to 8.7 and from 8.4 to 10.1 kW at the four above mentioned flywheel diameters levels respectively for maize crop.

On the other hand, the obtained data showed that increasing the number of hammers from 45 to 90 caused a corresponding increase in the grinding energy consumption from 9.45 to 11.82, from 10.18 to 13.45, from 12.55 to 13.82 and from 14.73 to 17.45 kWh/Mg at flywheel diameters of 200, 350, 450 and 600mm respectively for soybean crop and from 9.82 to 12.36, from 11.82 to 15.27, from 12.55 to 15.82 and from 15.27 to 18.36 kWh/Mg at the four above mentioned flywheel diameters respectively for maize crop.

The results of power and energy consumptions are higher in maize grains as compared with that needed for soybean grains at all tested treatments for grinding operation. That results trend may be due to the hardness of maize grains and have a higher content than that of soybean.

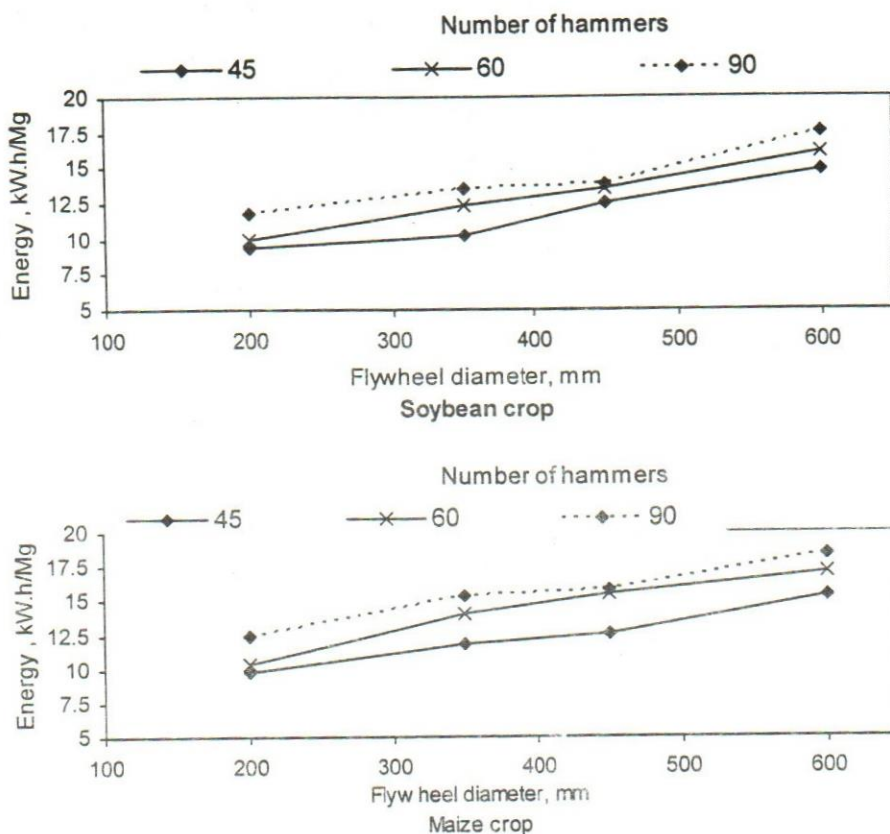


Fig. 6: Effect of number of hammers and flywheel diameters on the energy consumption for grinding soybean and maize grain.

CONCULATION

The main results can be summarized as follows:-

- 1- Using screen opening sizes of 6 and 9 mm for grinding soybean and maize grains respectively gave the best results of power requirements and the fineness degrees in the sieves less than 2.36 mm for all tested treatments.
- 2- Soybean grains exhibited the highest values of the fineness degree in the sieves less than 2.36 mm than that exhibited by maize grains for all investigated treatments.
- 3- The fineness degrees were increased in the sieves less than 2.36 mm for all treatments by decreasing the screen opening size and the feeding rate of soybean and maize grains during the grinding operation,
- 4- The values of power and energy requirements are higher in maize grains as compared with that needed for soybean grains at all treatments for grinding operation.

- 5- The optimum operating conditions of the modified hammer mill were achieved at screen opening sizes of 6 and 9 mm for soybean and maize grains respectively, feeding rate of 550 kg/h, the number of hammers 90 and flywheel diameter of 450 mm. Also, the above mentioned parameter levels gave the best results of the fineness degree and power consumption.
- 6- Changing the size of the hammer mill electric motor from 7.5 to 11 kW is recommended to give higher performance, and safe operation with different number of hammers and flywheel diameter for all treatments.

Applied recommendations:-

Grinding using 450 mm as flywheel diameter and 90 as the number of hammers had the superior effect in the power and energy requirements than the other tested grinding flywheel diameters and the number of hammers for grinding soybean and maize grains

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دراسة علي تطوير أداء مجرشة محلية الصنع مستخدمة في مزارع الدواجن إبراهيم صلاح الدين محمد يوسف* * باحث أول بمعهد بحوث الهندسة الزراعية- الدقي-الجيزة- مصر.

نظرا لأهمية الدواجن في مصر كمصدر للبروتين الحيواني ونظرا لاعتماد الدواجن علي العلف المنتج من حبوب فول الصويا والذرة الصفراء ونظرا للخبرة الكبيرة لمربي الدواجن في هذا المجال وسعيهم الجاد لخفض تكاليف الإنتاج بدأ عدد كبير من المربين بتجهيز الأعلاف ذاتيا بمزارعهم مما دفعهم للإقبال علي شراء المجارش المختلفة المصنعة محليا.

وتعتبر عملية جرش الحبوب من العمليات الهامة والشائعة والبسيطة حيث تتم باستخدام مجارش مختلفة تقوم بتقليل حجم الحبيبات مع إعطائها درجة من التجانس مما يساعد علي تحسين هضم الطيور لها وكذلك سهولة خلطة مع باقي عناصر العليقة وبالتالي تقليل نسبة الفاقد.

الغرض من هذه الدراسة هو إجراء بعض التعديلات الهندسية الهامة لمجرشة محلية الصنع والشائعة الاستخدام في مزارع الدواجن وذلك لتحسين أدائها والحصول علي اعلي درجة من التجانس لنتائج الجرش والاستفادة من الطاقة المتاحة بأقصى قدر ممكن مع ضمان التشغيل الآمن لها. حيث تضمنت هذه التعديلات كل من قطر الحدافة- عدد السكاكين- مصدر القدرة

وقد تمت الدراسة علي النحو التالي:-

١- تم تعديل قدرة الموتور الكهربائي للمجرشة من ٧,٥ إلي ١١ كيلووات حيث كان الموتور الصغير غير مناسب وغير امن لتشغيل المجرشة عند السرعات العالية والأحمال الكبيرة.

٢- تم تقييم أداء المجرشة باستخدام أربعة معدلات لتغذية الحبوب (٢٥٠، ١٠٠، ٥٥٠، ٧٠٠ كج/س) مع استخدام ثلاثة أقطار مختلفة لفتحات الغرابيل (٦، ٩، ١٤ مم) عند جرش حبوب فول الصويا والذرة الصفراء.

٣- تم التقييم النهائي للمجرشة المعدلة باستخدام ثلاثة أعداد مختلفة من السكاكين المثبتة علي درفيل الجرش (٤٥، ٦٠، ٩٠) مع استخدام أربعة أقطار مختلفة للحدافة (٢٠٠، ٣٥٠، ٤٥٠، ٦٠٠ مم) وذلك مع أفضل معدل تغذية للحبوب وانسب قطر لفتحات الغرابيل عند جرش حبوب فول الصويا والذرة الصفراء. هذا وقد تم دراسة جميع العوامل الهندسية السابقة الذكر علي درجة النعومة للحبوب المجروشة والقدرة المستهلكة.

٤- وقد أوضحت النتائج أن استخدام الغرابيل ذات أقطار فتحات ٦، ٩ مم لكل من حبوب فول الصويا والذرة الصفراء علي التوالي أعطت أفضل النتائج لنعومة الحبوب المجروشة والقدرة المستهلكة.

٥- أظهرت النتائج أن معدل تغذية الحبوب ٥٥٠ كج/س وعدد السكاكين المثبتة علي درفيل الجرش ٩٠ وقطر الحدافة ٤٥٠ مم أعطت أفضل النتائج لنعومة الحبوب المجروشة وتجانسها والطاقة المستهلكة.

٦- كانت درجة النعومة لحبوب فول الصويا المجروشة دائما اعلي منها في حبوب الذرة المجروشة، بينما كان مقدار الطاقة المستهلكة لجرش حبوب الذرة الصفراء دائما اعلي منه في جرش حبوب فول الصويا.