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ENGINEERING STUDIES ON RECYCLING OF HATCHERY BY-PRODUCT WASTES TO PRODUCE UNTRADITIONAL POULTRY FEEDS

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ABSTRACT: Experiments were carried out to evaluate the performance of hammer milling machine for producing untraditional poultry feeds by recycling hatchery by-product wastes. To fulfill the objective of this research work, some operating parameters affecting the performance of the hammer milling machine were taken into consideration, four hammer revolving speeds (1000, 1500, 2000 and 2500 rpm), two sieve hole diameters (2 and 4 mm) and three feed rates (0.05, 0.07 and 0.09 Mg/hr.). Evaluation of the hammer milling machine was carried out taking into consideration fineness degree, machine productivity, microbiological tests, energy requirements, and operational cost. The obtained results revealed that machine productivity, fineness degree microbiological tests, energy requirements, and operational cost were in the optimum region under conditions of 2500 rpm hammer revolving speed, 4mm sieve hole diameter and 0.09 Mg/hr., feed rate, while the other feed rate from 0.05 Mg/hr., to 0.07 Mg/hr., and 0.09 Mg/hr., and the other speeds (1000, 1500, 2000 and 2500) rpm.

Key words: Hatchery wastes, poultry feeds, hammer mill.

INTRODUCTION

Increasing poultry production is one realistic means of increasing the production of animal protein to meet greater demand due to population pressure. Feeding is one of the most serious problems facing poultry producers, which consumed about 70% from the total cost of production. Feeding problem can be solved by selecting the proper poultry diet in the acceptable phase. In Egypt there are shortage in animal feedstuff by about 3.5 million ton yearly and a great importance is paid to search for new sources of feeds for poultry to save the conventional classical ingredients for human consumption, Converting wastes of hatchery processing plants into non-conventional feedstuffs still a major problem in Egypt. On the other hand, the potential of hatchery by-product wastes reach about 328 million ton/year (**Ministry of Agriculture and Land Reclamation, 2017**).

In recent years, poultry by-product meals have been examined in poultry diets as a non-conventional source and to substitute or supplement for expensive conventional feed. Hatchery by-product meal provides a good potential as calcium, fiber, fat and protien sources for poultry feeding, to minimize environmental pollution. Its of a great importance to give a more attention to increase the efficiency of processing operation through, controlling the processing conditions and transferring the appropriate technology to the hatchery-house, by taking into consideration the technological and economical aspects.

Hatchery by-products usually include unhatched eggs, unsalable chicks and eggshells that could be used as poultry diets for hens and growing chicks. **Shahriar *et al.* (2008)** reported that protein from hatchery waste flour have high biological value, a good balance of amino acids, as well as more competitive prices compared to soybean and fish meal. They added that the utilization of hatchery wastes after proper processing has two advantages. First, it is a

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useful and economical source of nutrients for poultry. Second, it reduces the pollution. **Mehdipour *et al.* (2009)** reported that hatchery waste has a good nutrient content, *i.e.* crude protein (33.1%), fat (29%), crude fiber (12.1%), calcium (25.62%) and phosphorus (1.47%). **Serrano *et al.* (2013)** reported that the nutritional content of the hatchery waste that consisting of eggs shell, infertile eggs and un-hatched eggs have a water content of ± 60%, crude protein of ± 20% and crude lipid of ±9%. Those are supporting factors for the growth of microorganisms.

Both hammering and rolling can achieve the desired result of achieving adequately ground ingredients, but other factors also need to be looked at before choosing the suitable method to grind. **Mavromichalis *et al.* (2000)** reported that hammer milling is commonly used in commercial feed mills to reduce the particle size of the grain. The hammer mill utilises metal arms that grind the grain by pushing it through a metal screen, with particle size altered through the use of different screen sizes. Current commercial screen sizes can vary depending on the range of animal feed being produced. **Austin (2002)** reported that hammer mills utilize impact loading to break down larger-sized particles into smaller-sized particles, while hammer mill performance is dependent on the initial particle size, moisture content, material properties, feed rate, and machine variables, the most important property is the moisture content of the feed material. **Yancey *et al.* (2013)** reported that the most common mechanical preprocessing technologies focus on size reduction and include hammer and knife milling/grinding, chipping, shredding and ball roller milling. Hammer mills use large rotating drums with protruding metal bars (*i.e.*, hammers) that impact the material at high velocity to shatter and tear material particles. Typically, the metal bars swings freely from the drum, but fixed hammers are also common in hammer mill designs. Hammer mills have a wide application in size reduction because of their simple design, ruggedness and versatility.

Few investigators studied the effect of using hatchery by-products (unhatched eggs, egg shells and unsalable chicks) instead of animal calcium and protein sources in poultry diets. They concluded that, hatchery by-products could replace meat and bone meal in chick diet up to 8% of total dietary protein.

The samples of hatchery wastes was put inside the autoclave. After closing in autoclave, the air was vented and the pressure raised as quickly as possible to the required level of steam pressure (cooking pressure) 225 K Pa. for 15 min after reaching the pressure. Then the pressure was released and the autoclave allowed to reach the atmospheric level. Samples of cooked were dried in the sun for three days, and the dried material was ground in a local hammer mill.

So, the following study was conducted to evaluate the performance of hammer milling machine for producing untraditional poultry feeds.

The specific objectives of the present investigation are:

- Recycling hatchery by-product wastes for producing untraditional poultry feeds.
- Utilizing the hammer milling machine for preparing poultry diets.
- Optimizing some different operating parameters affecting the performance of the hammer milling machine.

MATERIALS AND METHODS

Laboratory and field experiments were carried out during the seasons of 2017 and 2018 at Gemmiza Animal Production Research Station, Gharbia Governorate, Egypt to evaluate the performance of hammer milling machine for producing untraditional poultry feeds by recycling hatchery by-product wastes.

Materials

The used hatchery wastes

The hatchery wastes (unhatched eggs, egg shells and unsalable chicks) were used to be milled using the milling machine and then mixed with feed additives. These wastes were obtained from a local hatchery plant, approximately one day after processing operation.

The milling machine

A local hammer mill (fixed beaters-type) was used for grinding hatchery by-product wastes

(Fig. 1). While specifications of the used milling machine were tabulated in Table 1.

The milling machine consists mainly of power source, grinding unit and chassis.

Power source

Electrical motor of 1.5 hp (1.2 kW) was used as a power source. The motor speed was changed manually by changing the The motor pulley. The motor pulley was 9.1 cm diameter.

The milling unit

The milling unit consists of the following parts:

- The feeding hopper: it has dimensions of (30× 34) cm hole and 42 cm height.
- The milling drum: The milling drum pulley 8.7 cm diameter was used for grinding hatchery wastes. The milling drum was powered by the electric motor through pulley and belt. While specifications of the used milling drum were tabulated in Table 2.
- The sieves: Two sieves were used. The first one was with 2mm sieve hole diameter while the second was with 4mm sieve hole diameter.
- The outlet feeder: it had dimensions of (21× 21 cm) and its height from the ground 40 cm was suitable for packing the milled hatchery wastes.

The chassis

The chassis was formed from 5 cm beams and had 45 cm width and 65 cm length.

Methods

Experiments were carried out to study and evaluate the performance of the hammer milling machine under different operational parameters.

Experimental conditions

To fulfill the objective of this research work, some operating parameters were taken into consideration.

- Four different hammer revolving speeds (1000, 1500, 2000, and 2500 rpm) corresponding to (16.6, 25, 33.3, and 41.5 m/sec.)
- Two different grinding sieve hole diameters (2 and 4 mm)
- Three different hatchery wastes feed rates (0.05, 0.07, 0.09 Mg/hr.)

The samples of hatchery wastes was put inside the autoclave. After closing in autoclave, the air was vented and the pressure raised as quickly as possible to the required level of steam pressure (cooking pressure) 225 KPa. for 15 min after reaching the pressure. Then the pressure was released and the autoclave allowed to reach the atmospheric level. Samples of cooked were dried in the sun for three days, and the dried material was ground in a local hammer mill (**Hegazy *et al.*, 2002**).

Measurements

The hammer milling machine was evaluated taking into consideration the following indicators:

Particle size distribution

The eggshells granulation and sieve analysis were determined using a laboratory automatic sieve shaker (PaSakha Teraoka – type SNF-7 Japan made) as follows: After milling all sample, a 250 grams of milled sample was placed on the top of sieves and the shaker was run for 5 minutes, using a sieve series of 0.7, 1.4, and 2 mm round holes, respectively. After each test period the percentage of through and over tails were recorded.

Finally the mean weight diameter (MWD) was determined according to the following equation:

$$MWD=\frac{\sum_{i}^{n} .X_i.W_i}{W_{i-n}} ....(1)$$

Where:

MWD: the mean eggshell diameter, mm.

X_i: the mean diameter of each division, mm.

W_{i-n}: the sample mass of each division, g.

Machine productivity

Machine productivity was calculated using the following formula:

$$\text{Machine productivity (Mg/hr.)} = \frac{M_P}{T} \quad ......(2)$$

Where:

M_P=milled mass (Mg)

T = the time consumed in operation (hr.)

Table 1. Specifications of the milling machine

Type	Hammer mill
Made	Egypt
Hammers No.	12
Screen size	(2 and 4)
Power source	Single phase (electric motor)
Power req, Hp (kw)	1.5 (1.2 kW)
Operating speed, rpm	1000,1500,2000,2500
Overall length, cm	65
Overall width, cm	45
Overall height, cm	102

Table 2. Specifications of the milling drum

Type of beaters	beaters
Diameter, cm	28
Width, cm	21
No. of rows	4
No. of beaters/row	3
beater dimensions	12 cm long x 5 cm wide x 1 cm thickness

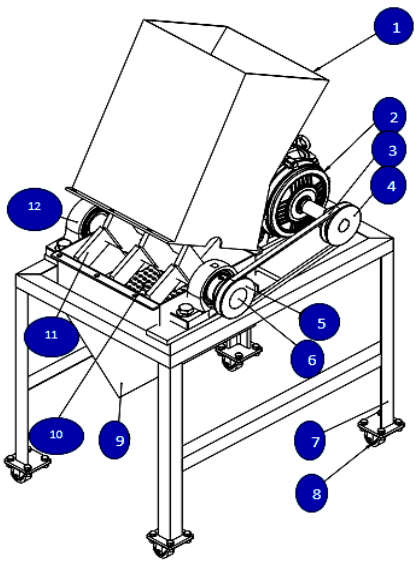

Fig. 1. A sechmatic diagram of the hammer mill machine

1- hopper, 2- electric motor, 3-belt, 4- motor pulley, 5- drum pulley, 6-bearing, 7- chassis, 8- wheels, 9- outlet hole, 10- concave, 11- drum, 12- grinding room.

Specific energy requirements

The consumed power for cocking and milling operations was estimated using super clamp meter (700-k type). The consumed power was estimated according to **(Kurt, 1979)** as follow:

$$P=\sqrt{3}\times\eta\times\cos\varphi\times I\times V/1000 \text{ ....(3)}$$

Where:

P = total consumed power under machine working load, kW

I = line current strength in Amperes

V = potential difference (voltage) being equal to 380 V

η = mechanical efficiency assumed (80 %)

cos φ = power factor (was taken as 0.7).

Specific energy requirements in (kW.hr./Mg) were calculated using the following equation:

Specific energy requirements (kW.hr./Mg) = Consumed power (kW)/ Machine productivity (Mg/hr.).

Operating cost

Machine cost was determined according to the conventional method of estimating both fixed and variable costs according to price level of 2018.

The operating cost was determined using the following formula.

Operating cost (LE/Mg) = Machine cost (LE/hr.)/Machine productivity (Mg/hr.).

Final milled hatchery wastes quality

The final milled hatchery wastes quality was determined based on microbiological tests. Microbiological tests were performed in the laboratories of Animal health Research Institute, Ministry of Agriculture, the samples were infected by *E. coli*, Proteus, and yeasts.

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following heads:

Particle Size Distribution

Figs. 2 and 3 illustrate the granulation data and fineness degree of the milled hatchery wastes as affected by the interactions between the studied factors.

Results in Fig. 2 show that increasing hammer revolving speed, and decreasing sieve hole diameter tended to increase the percentage of fineness degree of the milled product.

The results also showed that at similar operational conditions the values of fineness degree were higher using 2 mm sieve hole diameter compared with fineness degree produced from 4 mm sieve hole diameter.

The results also showed that, at any hammer revolving speed from 1000 to 2500 rpm, the highest degree of fineness (< 0.7 – 1.4) was obtained using 2 mm sieve hole diameter comparing with fineness degree produced from 4 mm sieve hole diameter. Meanwhile, the medium degree of fineness (1.4 – 2.0), was always achieved with 4 mm sieve hole diameter at any hammer revolving speeds.

Results in Fig. 3 indicate that the mean weight diameter (MWD) was affected by hammer speed and sieve hole diameter. The results also showed that during milling process, increasing hammer revolving speeds decreased the MWD of milled hatchery wastes. The MWD under feed rate 0.05 Mg/hr., where 1.35, 1.295, 1.24 and 1.2 for speeds 1000, 1500, 2000, and 2500 rpm, respectively for 2 mm sieve hole diameter, while the corresponding values were 2.520, 2.440, 2.373 and 2.3, respectively for the same speeds with 4 mm sieve hole diameter. Also The MWD under feed rate 0.07 Mg/hr., where 1.265, 1.21, 1.185 and 1.16 for speeds 1000, 1500, 2000 and 2500 rpm, respectively for 2 mm sieve hole diameter, while the corresponding values were 2.400, 2.353, 2.290 and 2.199 respectively for the same speeds with 4 mm sieve hole diameter. Also the MWD under feed rate 0.04 Mg/min where 1.195, 1.142, 1.102 and 1.045 for speeds 1000, 1500, 2000 and 2500 rpm, respectively for 2 mm sieve hole diameter, while the corresponding values were 2.325, 2.250, 2.187 and 2.080, respectively for the same speeds with 4 mm sieve hole diameter.

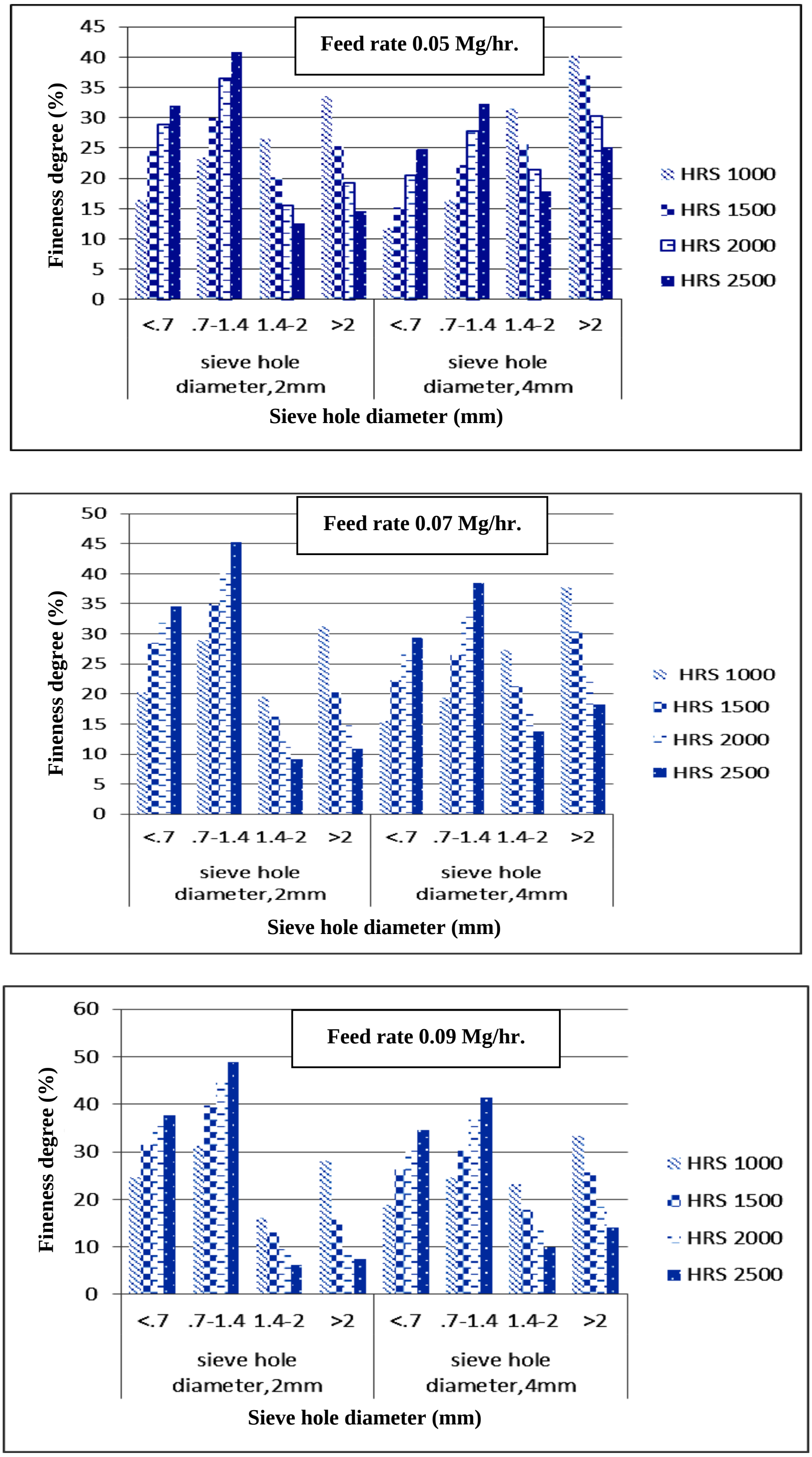

Fig. 2. Effect of different hammer revolving speeds and sieve hole diameters on the fineness degree under different feed rates

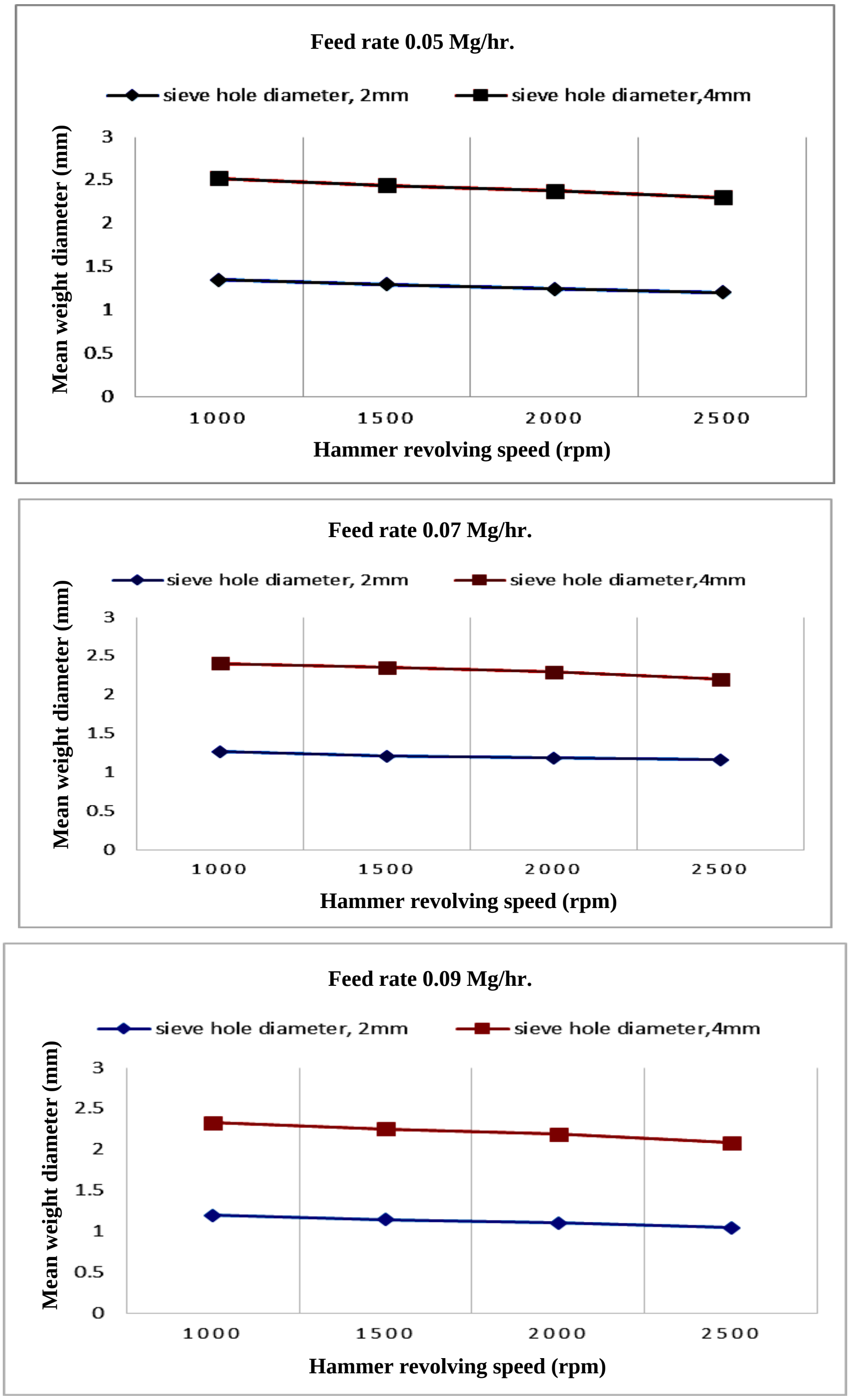

Fig. 3. Effect of hammer revolving speeds and sieve hole diameters on the mean weight diameter under different feed rates

Machine Productivity

Fig. 4 illustrate the machine productivity of the milled eggshells as affected by the interactions between the studied factors.

The results indicated that increasing hammer revolving speeds from 1000 to 2500 rpm (16.6 to 41.5 m/sec.) caused a corresponding increase in the machine productivity, meanwhile, the machine productivity decreased as sieve screen size decreased from 4 to 2 mm. On other wards, the results showed that at 2500 rpm hammer revolving speed, the machine productivity under feed rate 0.05 Mg/hr., increased from 0.081 to 0.147 Mg/hr. also the machine productivity under feed rate 0.07 Mg/hr., increased from 0.096 to 0.172 ton/hr. Also the machine productivity under feed rate 0.09 Mg/min were increased from 0.130 to 0.198 Mg/hr., as the sieve size increased from 2 to 4 mm. This increase in machine productivity with increasing hammer revolving speeds and sieve hole diameter may be attributed to the increase in the fineness degree of milled eggshell and increase the particle kinetic energy acquired by the hammers impact which giving it more ability to throughput from the sieve and this in turn increased the machine productivity.

Specific Energy Requirements

Fig. 5 illustrate the milling specific energy requirements under different operational parameters.

It can be seen that increasing hammer revolving speeds caused a corresponding increase in the power requirements at all sieve hole diameters in the range of 2 to 4 mm. The same trend of increase in power requirements as a function of decreasing sieve hole diameter was also noticed at all hammer speeds in the range of 1000 to 2500 rpm.

It can be seen that increasing hammer revolving speed and decreasing sieves hole diameter cause a corresponding increase in the specific energy requirements for both sieves under study.

While the specific energy requirements decrease slightly as hammer revolving speed increase from 1000 to 2500 rpm for both sieves under study. This decrease in energy by increasing the speed of hammer may be due to the increase in machine productivity.

Operating Cost

A detailed cost analysis of different elements included in hatchery wastes processing operation was carried out in order to evaluate the economical feasibility of eggshell processing. In this study two parameters were calculated as the absolute total cost including both fixed and variable costs per hour according to price level of 2019.

On other words, the difference between the cost of processing hatchery wastes and the commercial price of animal feed was found large. Thus, using the modified method for preparation and conversion hatchery wastes (as calcium, fat and protein source) may be saved of the total ration cost, moreover, minimizing the environmental pollution.

Fig. 6 illustrate the milling cost (LE/Mg) under different operational parameters. The results showed that different hammer revolving speeds, sieve hole diameter and feed rate. It can be seen that increasing hammer revolving speeds and increasing sive hole diameter caused a decrease in the operation cost (LE/Mg).

On other wards, the results showed that at 2500 rpm hammer revolving speed, the cost under feed rate 0.05 Mg/hr., decreased from 283.95 to 165.46 LE/Mg., also the cost under feed rate 0.07 Mg/hr., decreased from 239.58 to 133.72 LE/ton. Also the cost under feed rate 0.09 Mg/hr., decreased from 176.92 to 116.16 LE/Mg., as the sieve size increased from 2 to 4 mm.

Microbiological Evaluation

Microbiological tests were performed in the laboratories of Animal health Research Institute, Ministry of Agriculture, and were carried out to assess the intensity of microbiological infect before and after processing. The results of the microbiological tests indicated that before processing, the samples were infected by *E. coli*, Proteus, and yeasts. Meanwhile, the samples taken from hatchery by-product after cooking in autoclaving operation were save and completely free from bacteria, diseases sources, and all salmonella kinds. This result is in line with that of **Hegazy *et al*. (2002)**.

Conclusion

Experiments were carried out to evaluate the performance of hammer milling machine for producing untraditional poultry feeds by recycling hatchery by-product wastes.

The obtained results revealed that machine productivity, fineness degree microbiological tests, energy requirements, and operational cost were in the optimum region under the following conditions:

- 2500 rpm hammer revolving speed.
- 4 mm sieve hole diameter.
- 0.09 Mg/hr., feed rate.

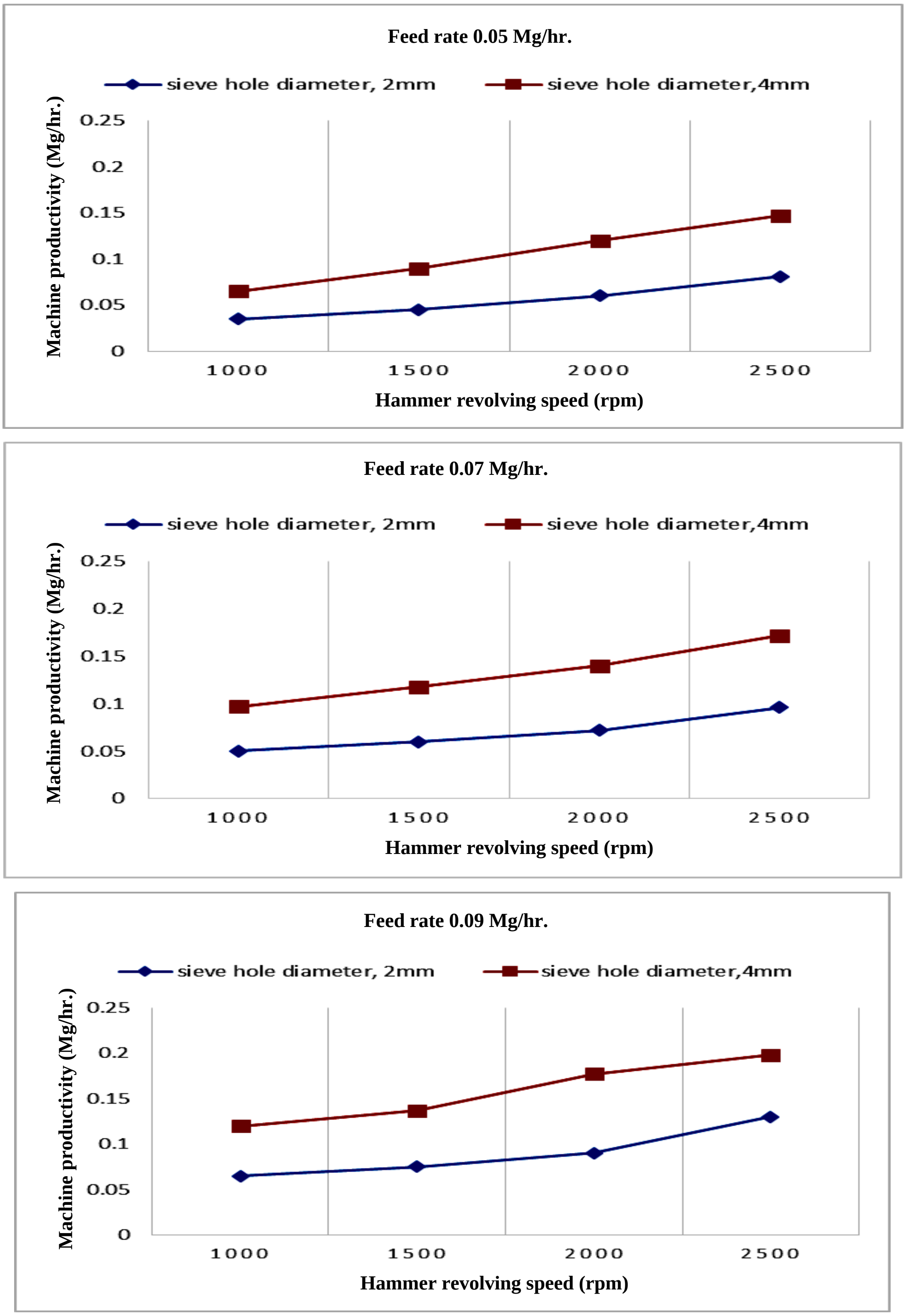

Fig. 4. Effect of hammer revolving speed and sieve hole diameter on the machine productivity under different feed rate

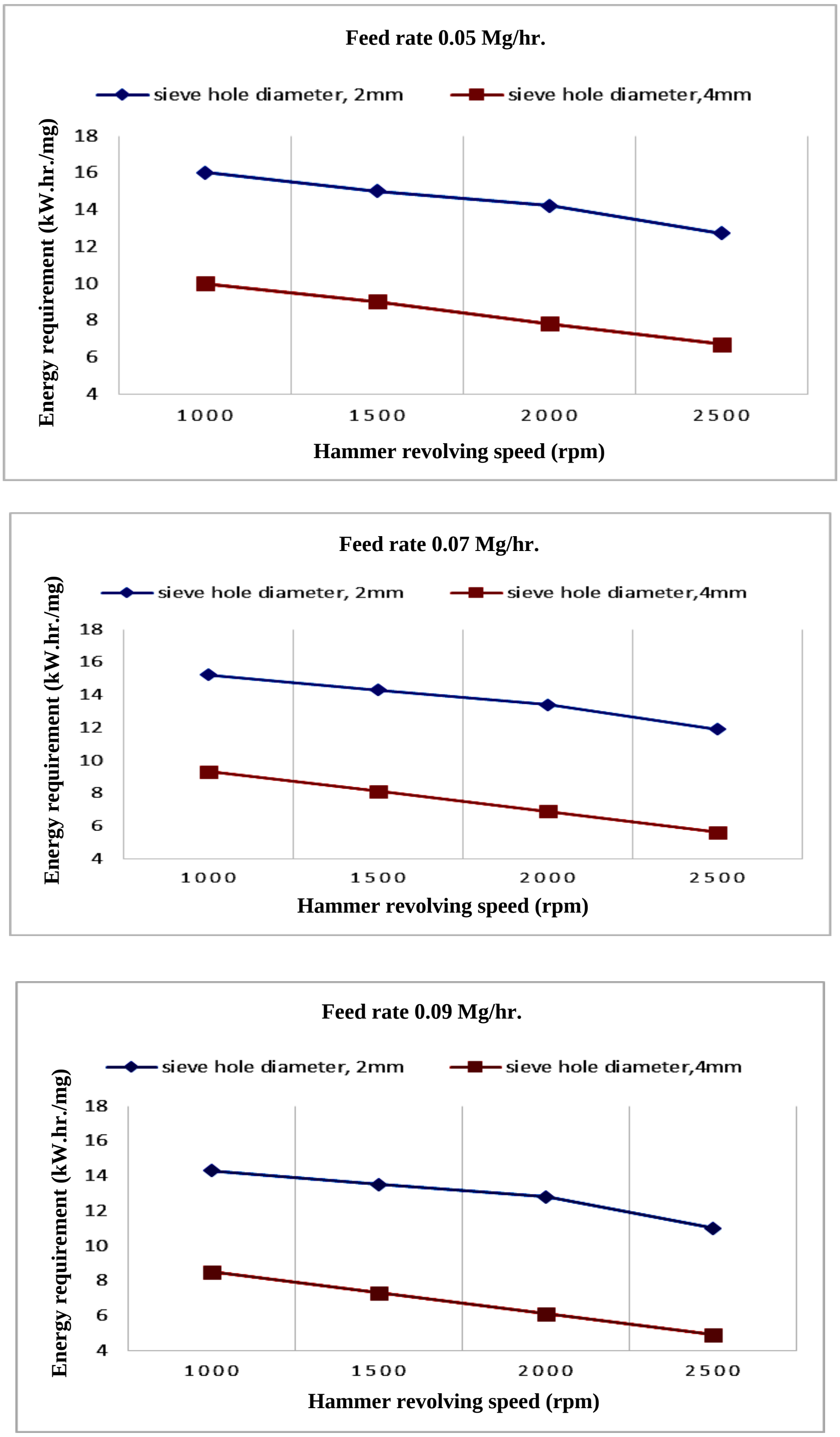

Fig. 5. Effect of hammer revolving speeds and sieve hole diameters on the energy requirements under different feed rate

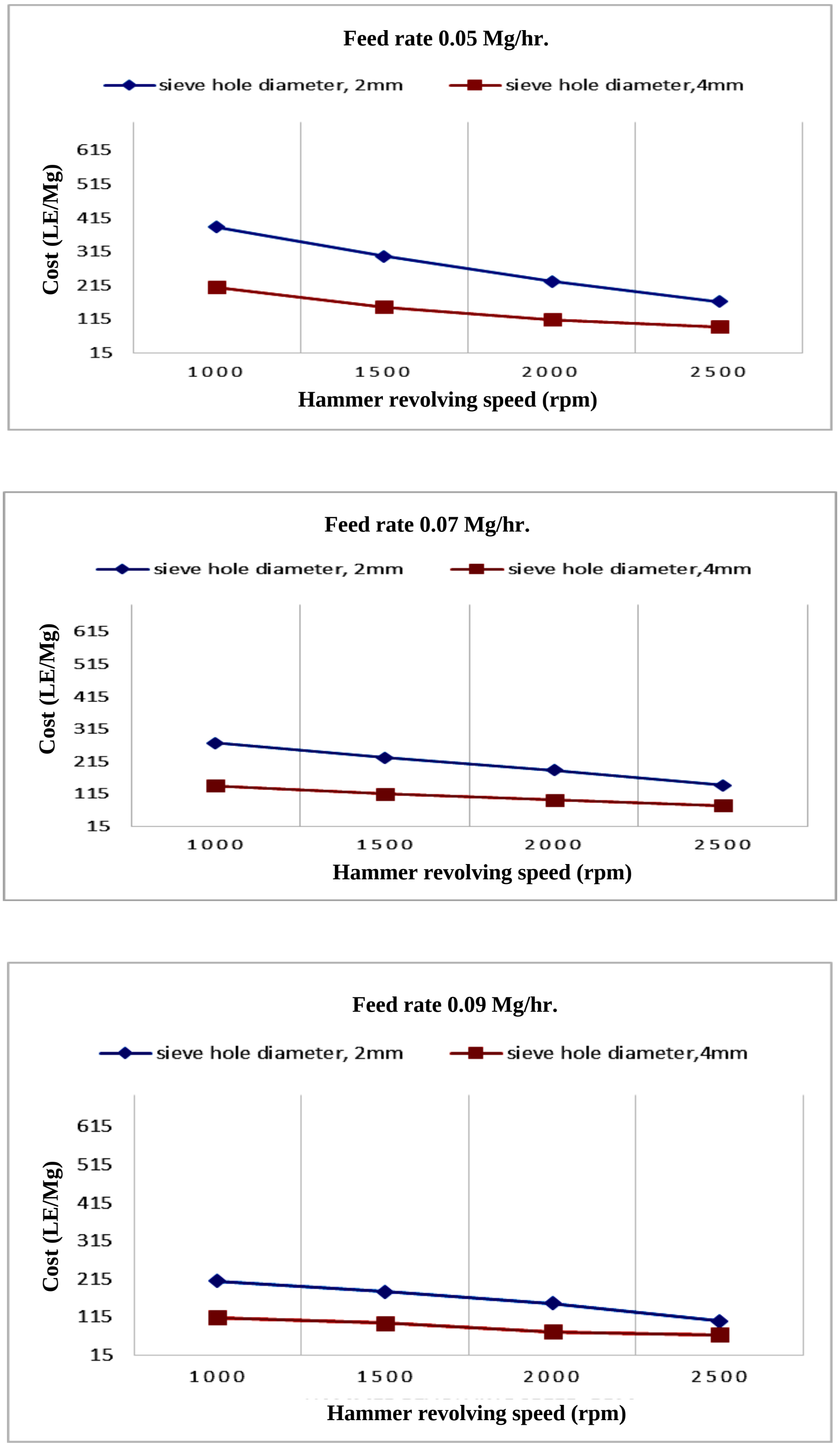

Fig. 6. Effect of hammer revolving speeds and sieves hole diameters on the operating cost under different feed rates

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دراسات هندسية على إعادة تدوير مخلفات معامل التفريخ لإنتاج أعلاف غير تقليدية للدواجن

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تعتبر عملية التفريخ الصناعي للبيض أحد العوامل الاقتصادية والرئيسية في مجال تربية الدواجن حيث تجري بهدف زيادة الإنتاج الداجني وتلبية احتياجات السوق، هذا وينتج عن معامل التفريخ مخلفات، هذه المخلفات يتم التخلص منها إما بالحرق المباشر أو بالدفن مما يمثل عبء على أصحاب المعامل بالإضافة إلى حدوث تلوث كبير للبيئة، كما أكدت الدراسات السابقة إمكانية الاستفادة من قشور البيض كبديل لمصدر الكالسيوم في العليقة ليصبح علف غير تقليدي يتميز بجودته ورخص ثمنه، ولما كانت درجة الجرش لقشر البيض تختلف تبعاً لنوع المجرشة ونظرية تشغيلها فإن هذه الدراسة تهدف لتقييم أداء آلة جرش من النوع المطرقي شائع الاستخدام في مزارع الدواجن وذلك لدراسة بعض العوامل التشغيلية المؤثرة على كفاءة طحن القشر، أجريت التجربة لدراسة بعض العوامل المؤثرة علي أداء آلة جرش من النوع المطرقي لمعرفة انسب العوامل ألمستخدمه التي تؤثر علي أداء المجرشة وذلك للحصول علي أعلي إنتاجية بأقل التكاليف، تم استخدام المجرشة تحت أربع مستويات لسرعة دوران المطارق (١٠٠٠ – ١٥٠٠ – ٢٠٠٠ – ٢٥٠٠ لفة/دقيقة) (١٦.٦- ٢٥- ٣٣.٣- ٤١.٥ م/ث ومقاسين لقطر فتحات غربال الطحـن (٢ – ٤ مم) وثلاث معدلات تغذية (٠.٠٥، ٠.٠٧ و٠.٠٩ ميجاجرام/ساعة) كما تم قياس أداء المطحنة أخذا فى الاعتبار كل من درجة النعومة للمنتج المطحون والإنتاجية واحتياجات الطاقة ودراسة خواص الجودة لمسحوق القشر الناتج، كما تم تقييم اقتصاديات التشغيل للآلات المستخدمة في تنفيذ الدراسة، وقد أظهرت النتائج أن أفضل درجة نعومة وأفضل إنتاجية وأقل تكاليف تشغيل تتحقق تحت ظروف التشغيل الآتية: ضبط سرعة دوران المطارق عند ٢٥٠٠ لفة/دقيقة، ضبط معدل تغذية القشر عند ٠.٠٩ ميجاجرام/ساعة واستخدام قطر فتحات الغربال بمقاس ٤ مم.

المحكمـــــون:

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