

## STUDY THE EFFECT OF SOME OPERATIONAL FACTORS ON HAMMER MILL

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### ABSTRACT

*The experiments of this study were carried out during the agricultural seasons of 2007/2008 and 2008/2009 at a private mill for milling grains in Abou Kbeer district, Sharkia Governorate to optimize some operating parameters affecting the performance of a prototype hammer mill. The performance of hammer mill was evaluated under different parameters including drum rotational speed, grain moisture content, hammer thickness and concave clearance. The performance of hammer mill was evaluated taking into consideration hammer mill capacity , efficiency, particle size distribution (fineness degree), power , energy requirement and operational cost. The obtained results reveal that it is recommended to use the hammer mill at drum rotational speed about 2250 rpm (33.56m/s), grain moisture content of 10%, concave clearance of 5mm and hammer thickness of 5mm to produce pelleting feed by increasing the percentage of fine milled corn (FMC) and decreasing coarse milled corn (CMC). Producing mash feed for commercial use can be achieved by using the mill at drum rotational speed about 1550 rpm (23.85m/s), grain moisture content of 14%, concave clearance of 12mm and hammer thickness of 1.5mm by decreasing percentage of fine milled corn (FMC) and increasing coarse milled corn (CMC) and medium milled corn (MMC).*

### INTRODUCTION

**N**owadays, the development of animal and poultry production needs to exert more efforts to increase and maintain high levels of feeding crop, in addition to improve the quality and quantity by decreasing grain losses during pre- processing operation, selecting the proper diet in the acceptable phase of livestock and reducing the consumed energy. The hammer mill is used almost exclusively in preparation of broiler rations because of its simplicity, ease to operate and

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low maintenance cost so, it had been widely spread in most of the poultry farms in Egypt, for this reason, such care had to be taken to evaluate this type of mills for better utilization by several investigations to improve its performance. **Martin (1983)** stated that using large particle size for the grain component of the diet is attractive because of the substantial reduction of energy for grinding that would if the grain could be less finely ground without adverse effects. He added that ingredients with widely varying particle sizes are more difficult to mix properly, and large particles tend to segregate from smaller ones during subsequent handling after mixing. **Ensminger et al. (1990)** showed that very fine grinding makes feeds dusty and lower palatability. However, fine grinding may be desirable when pelleting is to follow. **Hassan (1994)** found that increasing of drum speed from 1460 to 2930 and 3910 rpm gave a decrease of 59.1 and 67.9% in grinding energy. The increase of the grain moisture content from 5.4 to 8.1 and 11.4% gave an increase of 20.1 and 49% in grinding energy. He added that the fine grinding percentage was obtained at lower grain moisture content and higher drum speed. In addition, as to fineness degree of grinding (medium and coarse) an opposite trend results comparing with the fine grinding. **EL- Gayar and Bahnas (2002)** studied some factors affecting on hammer mill to produce garlic power such as three hammer tip speeds (13.82, 18.43 and 23.04m/s), two feed rates (27.00 and 43.2 kg/h) two screen hole diameters (1 and 2mm) and two drying methods ( natural and artificial) .They indicated that the highest milling capacity was obtained at 23.04m/s hammer tip speed and the highest milling efficiency was obtained at 13.82m/s hammer tip speed and the milling efficiency takes the opposite trend of the milling capacity. **Hegazy et al. (2002)** indicated that increasing hammer revolving speeds from 1000 to 2500 rpm (16.6 to 41.5 m/s) cause a corresponding increase in the machine productivity. Hence, the objectives of the present study are to (1) evaluate hammer mill prototype during grinding corn grains.(2) study some operating and engineering parameters (grain moisture content, drum rotational speed, hammer thickness and concave clearance) which affecting the performance of the hammer mill (3) Estimate the hammer mill operational cost.

**MATERIALS AND METHODS**

The experiments of this study were conducted during agricultural seasons of 2007/2008 and 2008/2009 at a private mill for milling grains in Abou Kbeer district, Sharkia Governorate to optimize some operating parameters affecting the performance of swinging hammer mill prototype.

**A-Materials:**

**-Corn Grain:**

Experiments were carried out on yellow corn grain (variety of Giza 162) at different moisture contents. Some physical properties of the used corn grains are given in Table (1).

**Table (1): Some physical properties of corn grain.**

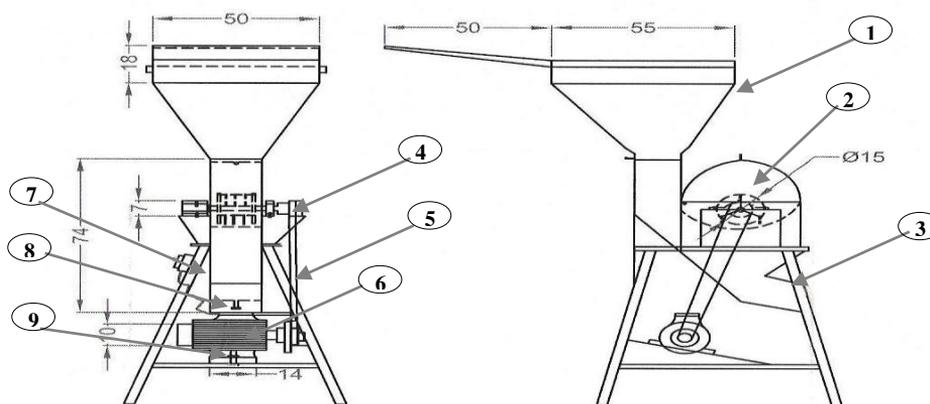
variety	Bulk density ,gm/cm <sup>3</sup>	Average length ,mm	Average width ,mm	Average thickness ,mm
Giza 162	0.680	10.75	8.65	4.9

**-Screens (3mm and 4.2mm diameter):**

Two different diameters of screen holes were used to determine the particle size distribution (fineness degree). Other instruments and devices were used in the experiments such as stop watch, grain moisturmeter, electronic balance, varnier caliper, tachometer and clamp meter.

**-Hammer mill prototype:**

The mill specifications are shown in Fig.(1) and Table(2).



Scale 1:1

Dimensions in cm

Side view

Elevation

**Fig. (1): Elevation and side view of hammer mill prototype**

- (1) Feed hopper, (2) Crushing chamber, (3) Outlet, (4) Pulleys, (5) Belt, (6) Motor, (7) Operating button, (8) Clearance adjustment screw, (9) Belt adjustment screw

**Table (2): The specifications of the hammer mill prototype, hammers and screen.**

<b><u>Hammer mill:</u></b>	<b><u>Hammers and</u></b>
Type : Swinging hammer mill	<b><u>Screen:</u></b>
Hopper capacity: 100 kg	<b><u>I - Hammers:</u></b>
Overall length : 1710 mm	Type : swinging hammers
Overall width : 1380 mm	Material : steel iron.
Rotor Diameter : 145 mm	Length : 109.5 mm
Rotor Width : 110 mm	Width : 39 mm
Total Screen Area: 840cm <sup>2</sup> [Length(56) * Width(15)]	Thickness : variable
Screen Opening Dia: 6 mm	Swinging length : 86.5 mm
Hammer edge : smooth	Diameter to fit rode size: 19mm
No. of hammers : 12 hammer	<b><u>II – Screen</u></b>
Power : Electrical Motor (3.68 kW)	Perforation : 6 mm
Mass : 110 kg	Width : 150 mm
	Roll outside Dia : 435 mm
	Length over the back: 560 mm
	Thickness : 25 mm

**B-Methods:**

The milling experiments were carried out to optimize some operating parameters affecting the performance of hammer mill prototype these parameters are:

- 1-Four drum rotational speeds of 1550, 1800, 2000 and 2250 r.p.m corresponding to drum peripheral speeds of (23.12, 26.85, 29.83 and 33.56 m/s) respectively.
- 2-Three levels of grain moisture content of 10,12 and 14% (w.b).
- 3-Three hammer thickness of 1.5 ,3 and 5 mm.
- 4-Three concave clearances of 5, 8 and 12 mm.

**C- MEASUREMENTS:**

Evaluation of the hammer mill was performed taking into consideration the following indicators:

**1.Milling capacity and efficiency:**

The theoretical milling capacity (TMC) of the machine is the rate of productivity if the machine performed 100% of the instant time. The

actual milling capacity (AMC) of the machine is the actual rate of productivity by the amount of actual time consumed in operation (lost + productive time). Lost time is considered as the time spend in refilling the machine hopper, interruptions and simple repairs. The milling efficiency ( $\eta_m$ ) was calculated using the following equation:

$$\eta_m = \frac{A.M.C}{T.M.C} * 100$$

$\eta_m$  = The milling efficiency, %.

T.M.C = The theoretical machine capacity, Mg/h.

A.M.C = The actual machine capacity, Mg/h.

### **2. Fineness Degree (particle size distribution):**

The ground corn samples were classified into three main categories according to **Henderson and Hansen(1968)**. The first one is fine milled corn FMC (< 3 mm), the second is medium milled corn MMC (3-4.2 mm) and the third is coarse milled corn CMC (> 4.2 mm).

### **3. Milling power and energy requirement:**

The require milling power was estimated by using the following equation (**Ibrahime, 1982**):

Total consumed power = load

$$= \frac{\sqrt{3}IV\eta \cos \theta}{1000} \quad (\text{kW})$$

Where:

I= line current strength in Amperes.

V = Potential strength (voltage) being equal to 390V.

$\cos \theta$  = power factor (being equal to 0.84).

$\eta$  = Mechanical efficiency assumed (95%).

The specific energy requirement (kW.h/Mg) was calculated by using the following equation:

$$\text{The specific energy requirement (kW.h/Mg)} = \frac{\text{The consumed power (kW)}}{\text{Actual milling capacity (Mg/h)}}$$

**4. Operating cost:**

$$\text{Operating cost (L.E/Mg)} = \frac{\text{Machine cost (L.E/h)}}{\text{Actual milling capacity (Mg/h)}}$$

The machine cost was determined by using the following formula (Awady *et al.*, 2003) :

$$C = \frac{P}{h} \left( \frac{1}{a} + \frac{i}{2} + t + r \right) + (W.e) + \frac{m}{144}$$

Where:

C : Machine hourly cost, L.E./h.

P : Price of machine, L.E.

h : Yearly working hours.

a : Life expectancy of the machine, year.

i : Interest rate/year .

t : Taxes and over heads ratio, %.

r : Repairs and maintenance ratio, %.

W : Power of motor, kW.

e : Hourly cost/kW.h.

m : The monthly average wage, L.E.

144: The monthly average working hours.

**RESULTS AND DISCUSSION****- Milling Capacity and Efficiency:**

Figs. (2) to (4) showed the relation between drum speed and both of machine capacity and efficiency under different grain moisture content, hammer thickness and concave clearance. It was noticed that the increase of drum speed was accompanied with an increase in machine capacity and a decrease in machine efficiency that can be attributed to the loss in refilling time for refilling the hammer mill hopper increases consequently, the milling efficiency decrease hence, the milling efficiency taken the opposite trend of the milling capacity with drum speed. The highest value of machine capacity of (0.871Mg/h) obtained at drum speed of 2250 rpm (33.56m/s), grain moisture content of 10%, concave clearance of 5mm and hammer thickness of 5mm. while, the highest value of machine efficiency (92.9%) obtained at drum speed of 1550 rpm (23.12m/s), grain moisture content of 14%, concave clearance of 12 mm and hammer thickness of 1.5mm.

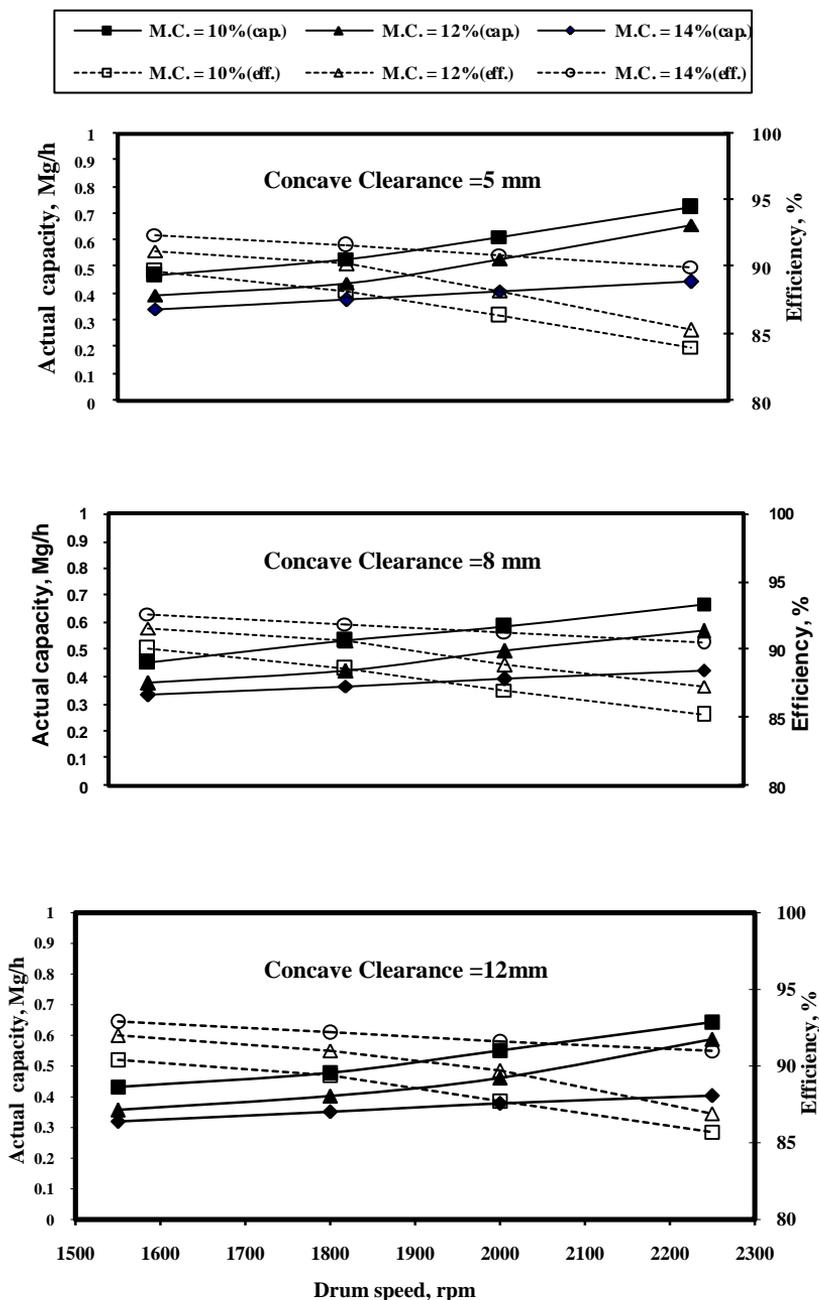
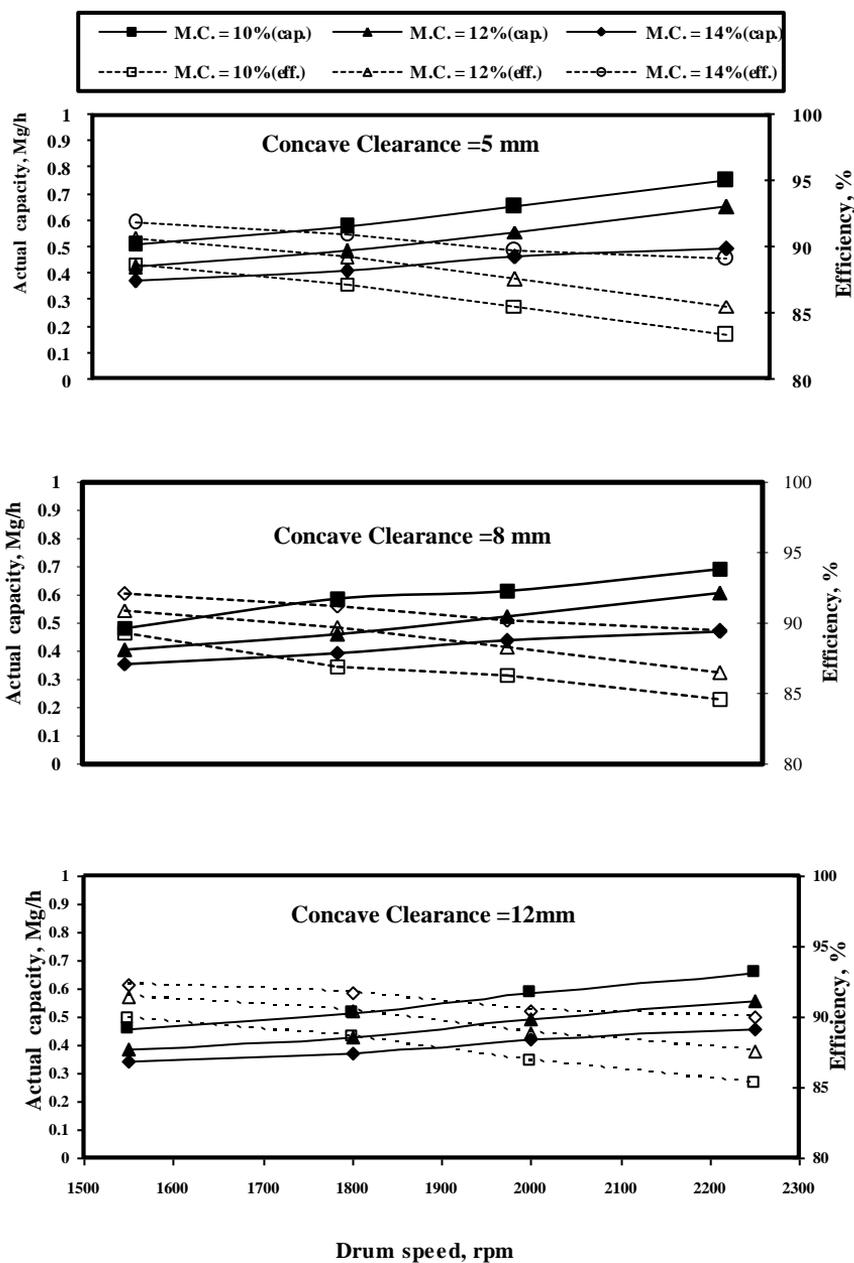


Fig. (2): Effect of drum speed on machine capacity and efficiency under different moisture contents and concave clearances at hammer thickness of 1.5mm



**Fig.(3):Effect of drum speed on machine capacity and efficiency under different moisture contents and concave clearances at hammer thickness of 3mm.**

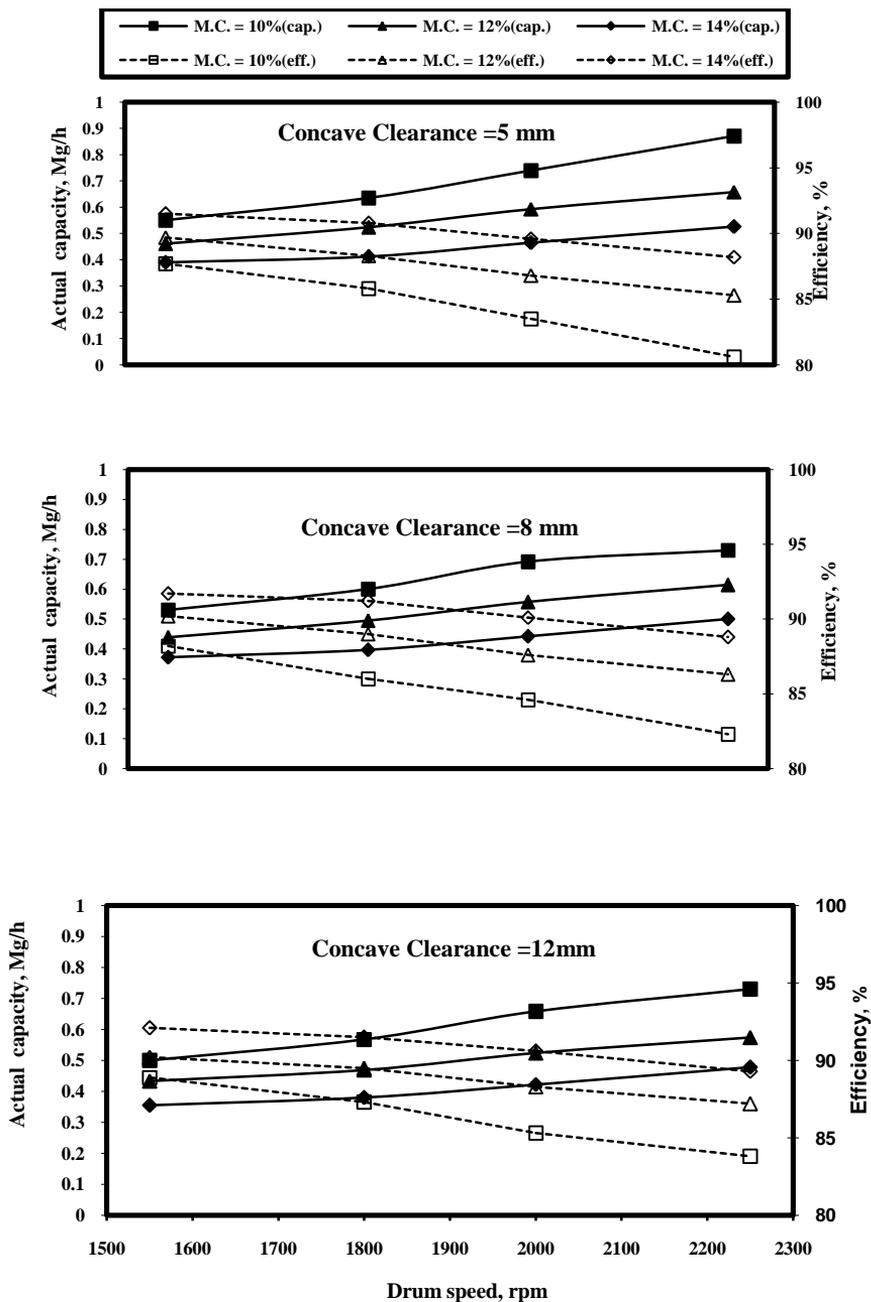
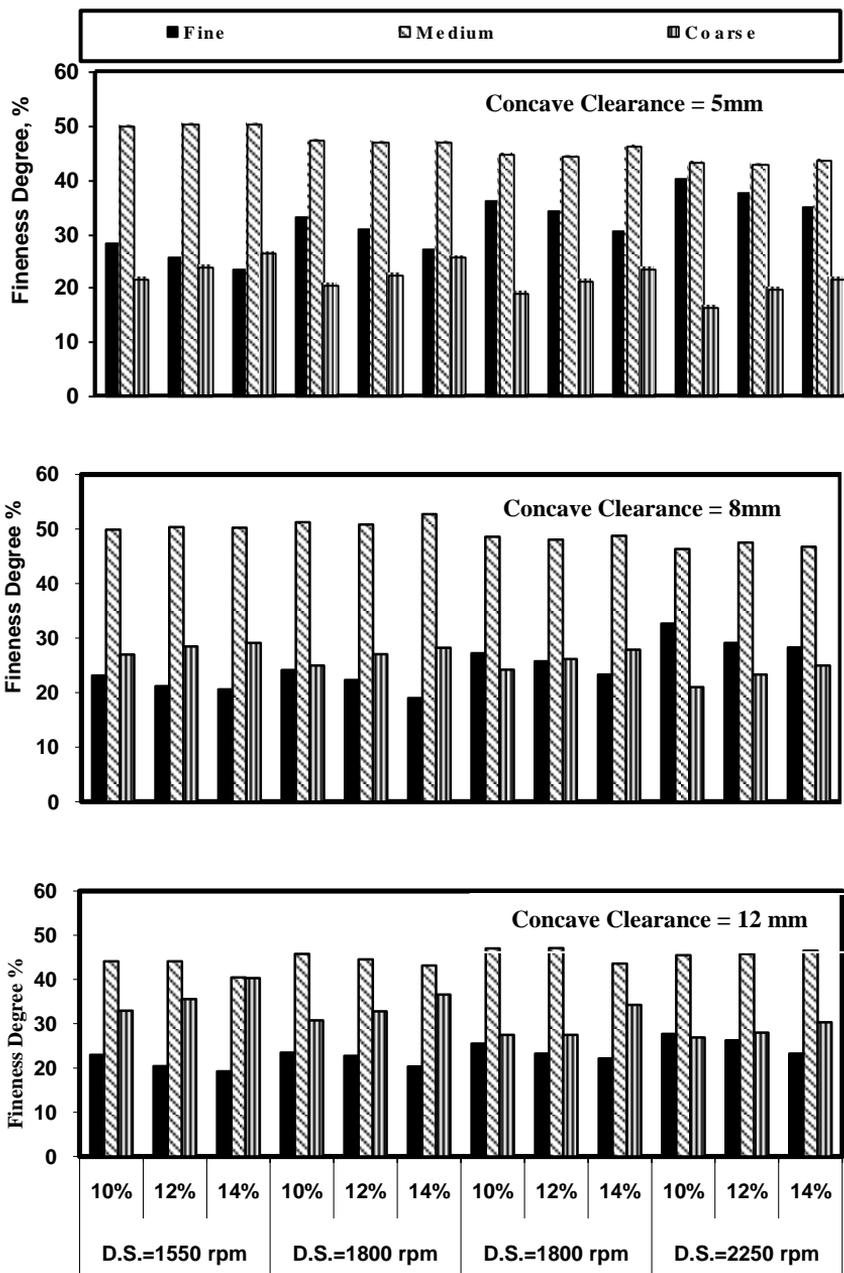
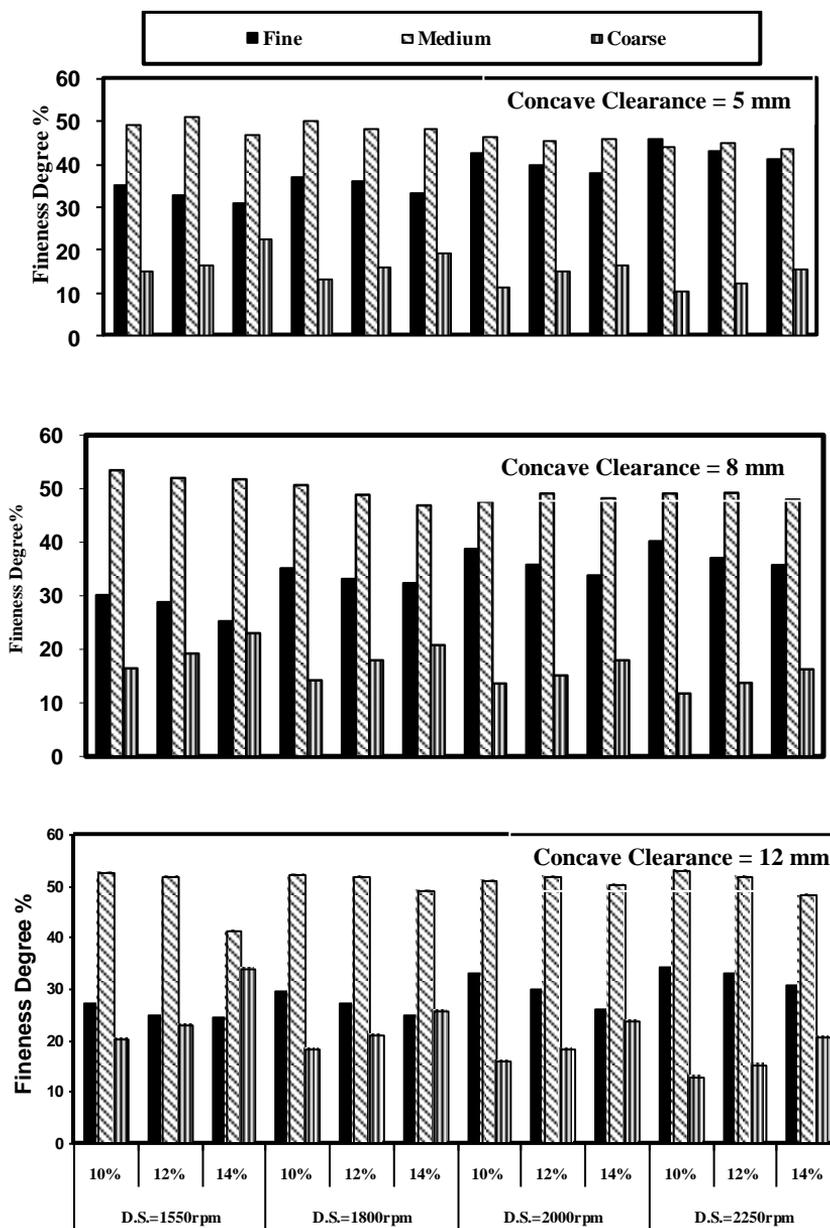


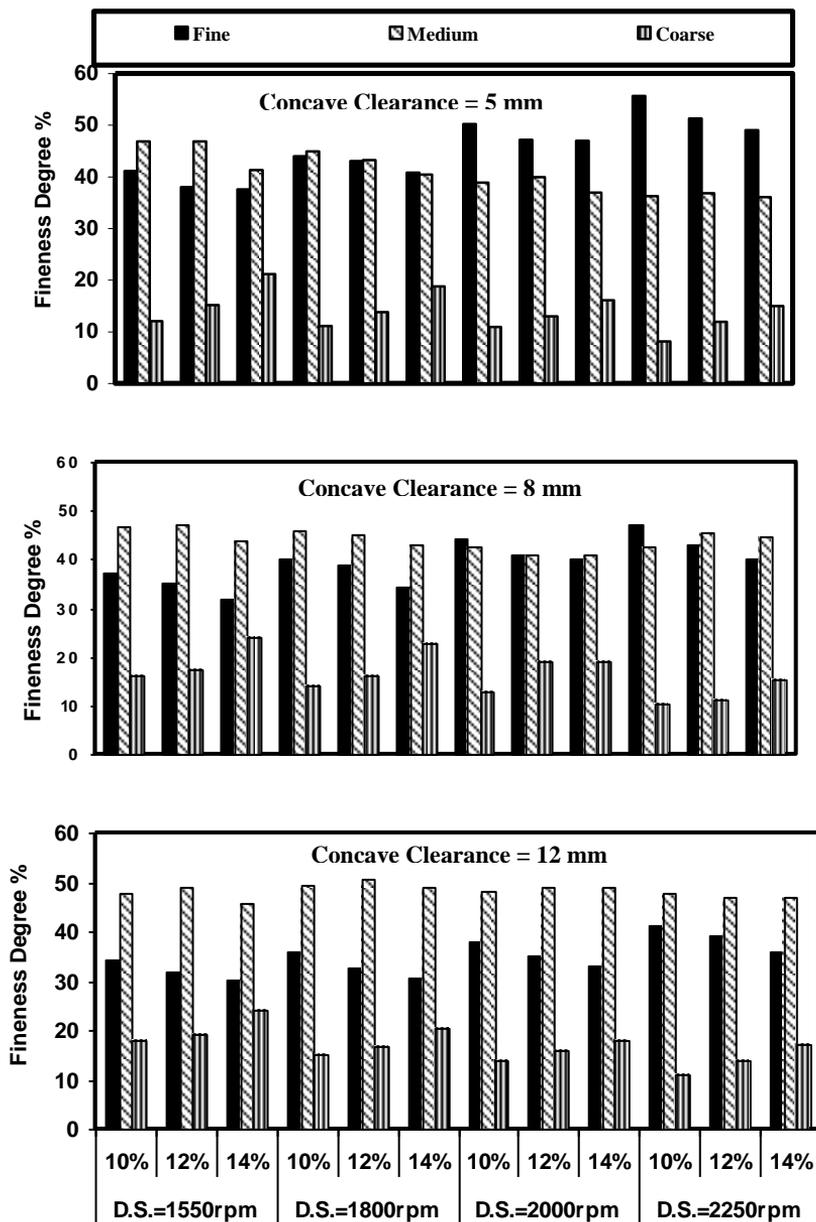
Fig.(4):Effect of drum speed on machine capacity and efficiency under different moisture contents and concave clearances at hammer thickness of 5mm



**Fig.(5):Effect of drum speed on fineness degree under different moisture contents and concave clearances at hammer thickness of 1.5mm.**



**Fig.(6):Effect of drum speed on fineness degree under different moisture contents and concave clearances at hammer thickness of 3mm.**



**Fig.(7):Effect of drum speed on fineness degree under different moisture contents and concave clearances at hammer thickness of 5mm.**

**Fineness Degree:**

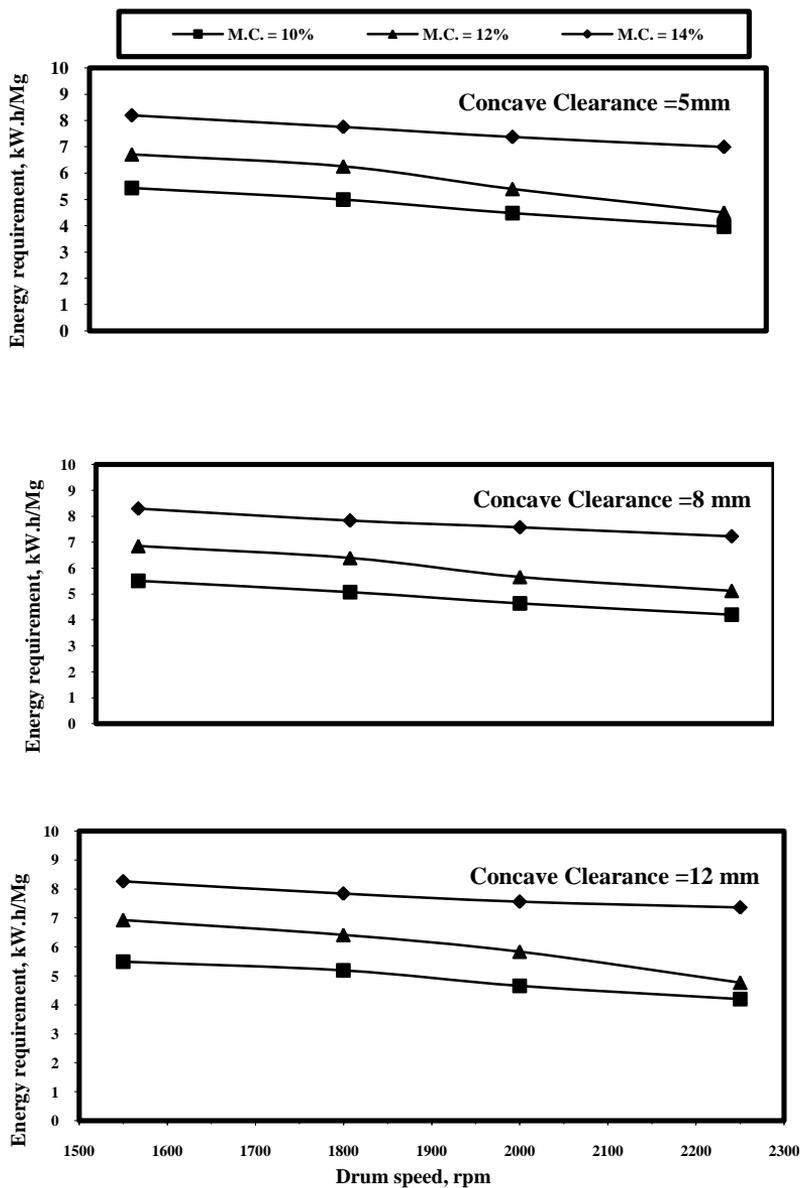
In Figs. (5) to (7) which showed the relation between drum speed and fineness degree under different grain moisture contents, hammer thickness and concave clearances. It was cleared that the increase of drum speed was followed with an increase in fine milled corn (FMC%) while coarse milled corn (CMC%) decrease. The highest value of (FMC%) of (55.33%) obtained at drum speed of 2250 r.p.m (33.56 m/s), grain moisture content of 10%, hammer thickness of 5 mm and concave clearance of 5 mm while, the highest value of (CMC%) of (40.33%) obtained at drum speed of 1550 r.p.m (23.12 m/s), grain moisture content of 14%, hammer thickness of 1.5 mm and concave clearance of 12 mm. Finally, the highest value of medium milled corn (MMC%) of (53.41%) obtained at drum speed of 1550 r.p.m (23.12m/s). grain moisture content of 10% hammer thickness of 3 mm and concave clearance of 8 mm.

**-Energy requirement:**

The relation between drum speed and specific energy requirement under different grain moisture contents, hammer thickness and concave clearances was represented in Figs.(8) to (10). It was observed that the increase of drum speed was occurred a decrease in specific energy requirement that is can be attributed to increasing of machine capacity rate is higher than increasing in power required rate. The lowest value of specific energy requirement (3.53 kW.h/Mg) obtained at drum rotational speed of 2250 rpm (33.56 m/s), grain moisture content of 10%, concave clearance of 5 mm and hammer thickness of 5 mm.

**-Operational cost:**

Figs.(11) to (13) showed the relation between drum rotational speed and operational cost under different grain moisture contents, hammer thickness and concave clearances. It was noticed that the increase of drum rotational speed was occurred a decrease in operational cost that is can be attributed to increasing in machine capacity. The lowest value of operational cost (14.06 L.E./Mg) obtained at drum rotational speed of 2250 rpm (33.56m/s), grain moisture content of 10%, concave clearance of 5mm and hammer thickness of 5mm.



**Fig.(8):Effect of drum speed on specific energy requirement under different moisture contents and concave clearances at hammer thickness of 1.5mm.**

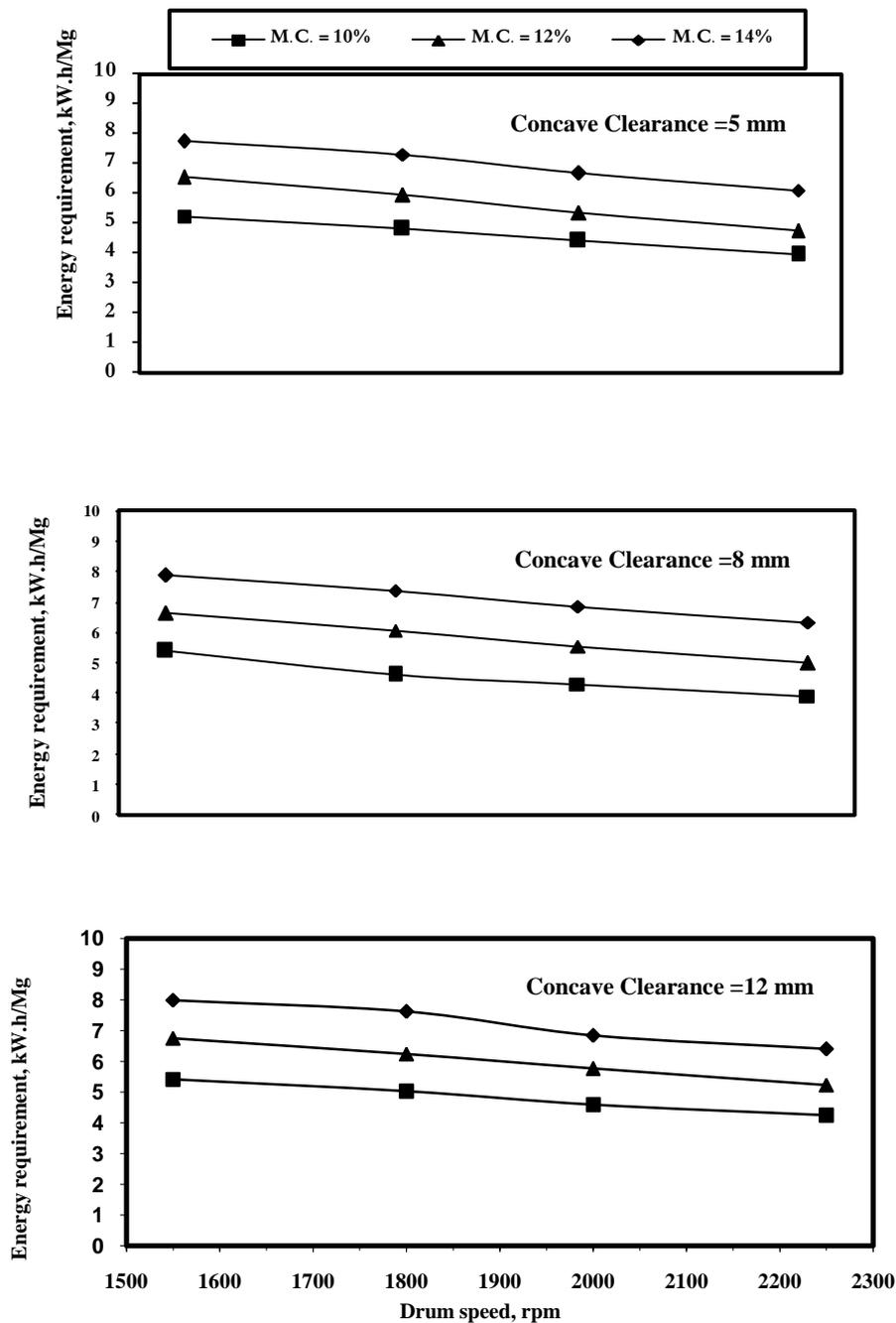
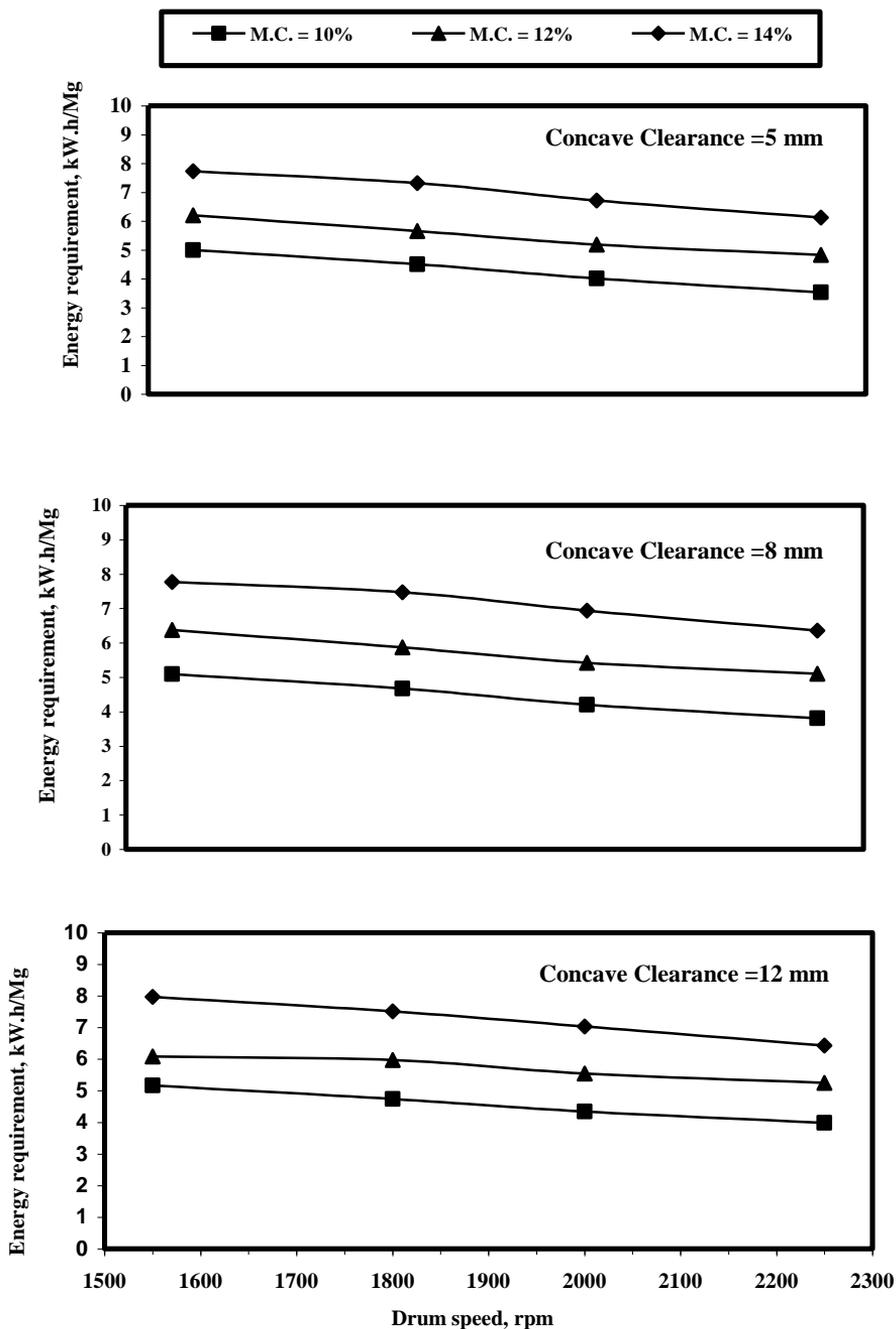
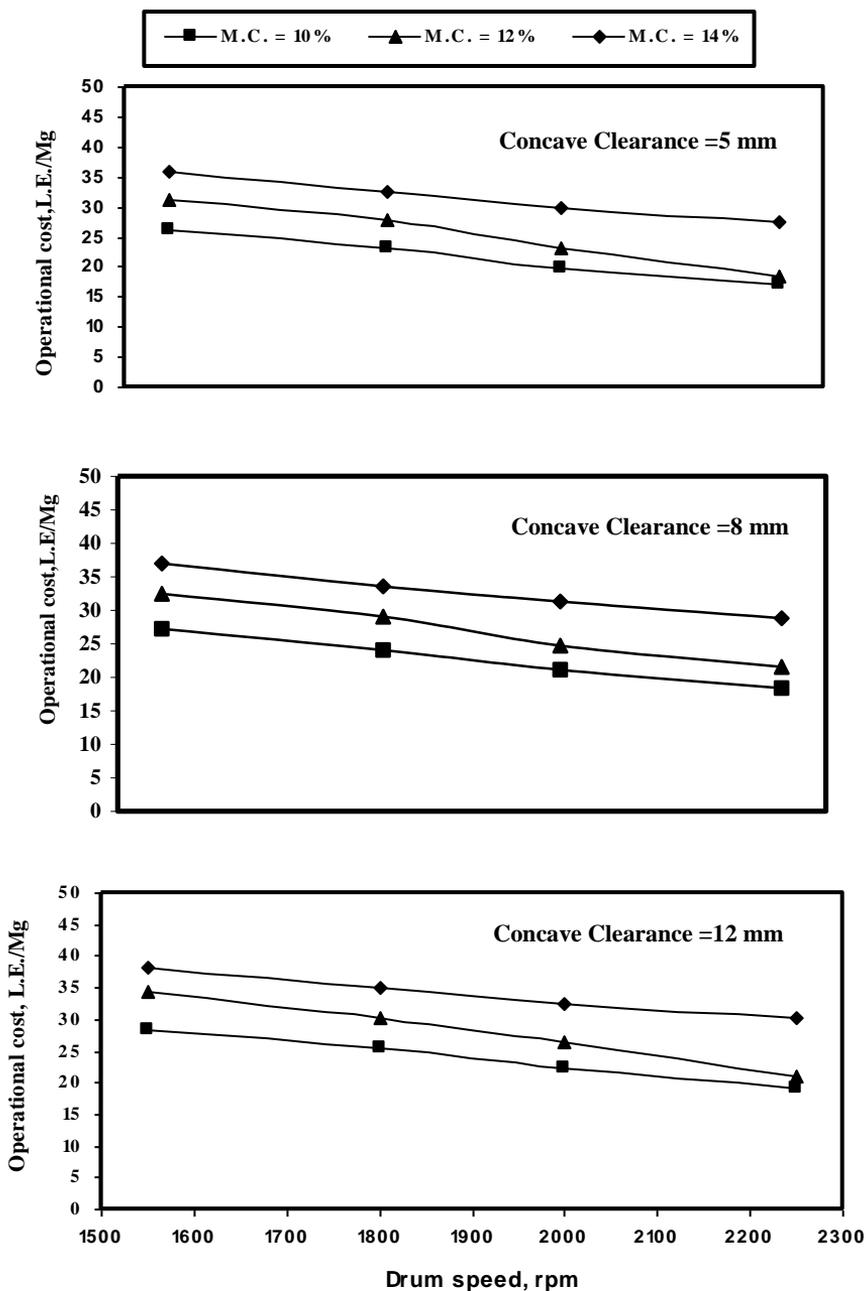


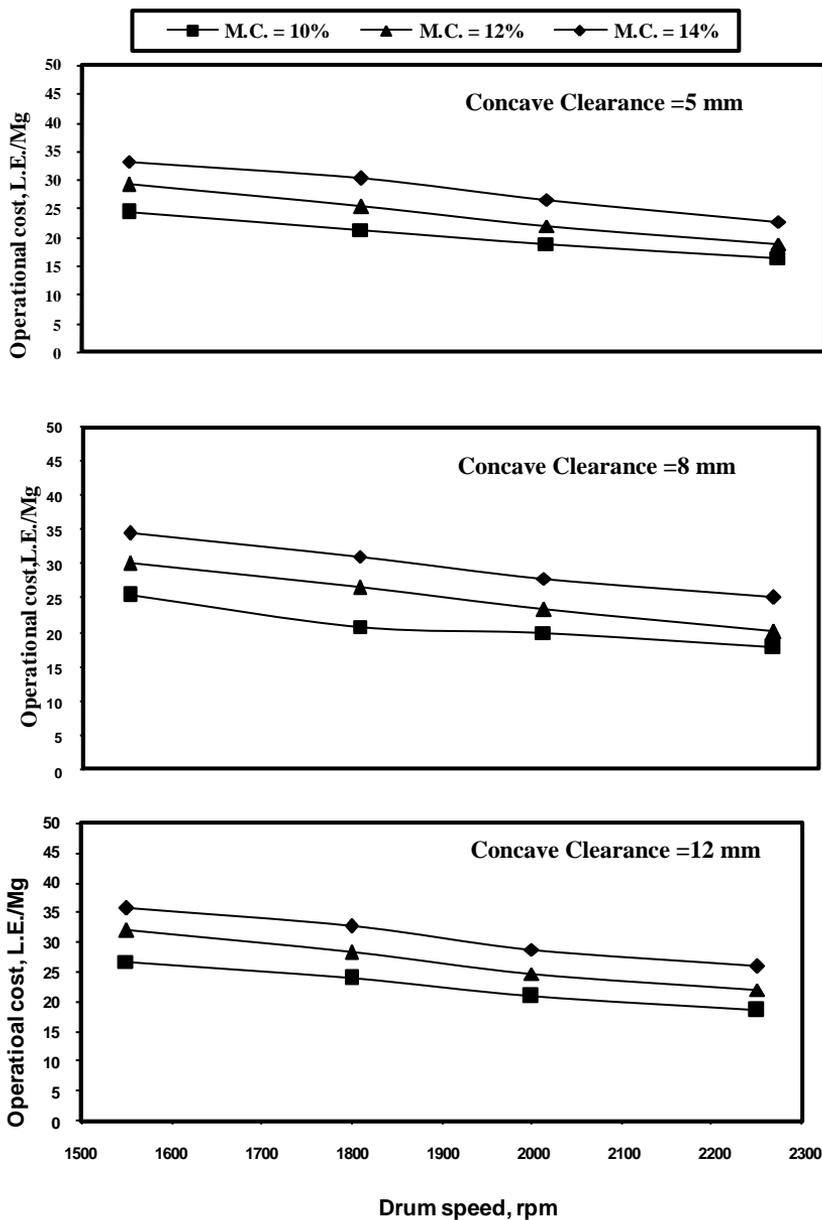
Fig.(9):Effect of drum speed on specific energy requirement under different moisture contents and concave clearances at hammer thickness of 3mm.



**Fig.(10):Effect of drum speed on specific energy requirement under different moisture contents and concave clearances at hammer thickness of 5mm.**



**Fig.(11):Effect of drum speed on operational cost under different moisture contents and concave clearances at hammer thickness of 1.5mm.**



**Fig.(12):Effect of drum speed on operational cost under different moisture contents and concave clearances at hammer thickness of 3mm.**

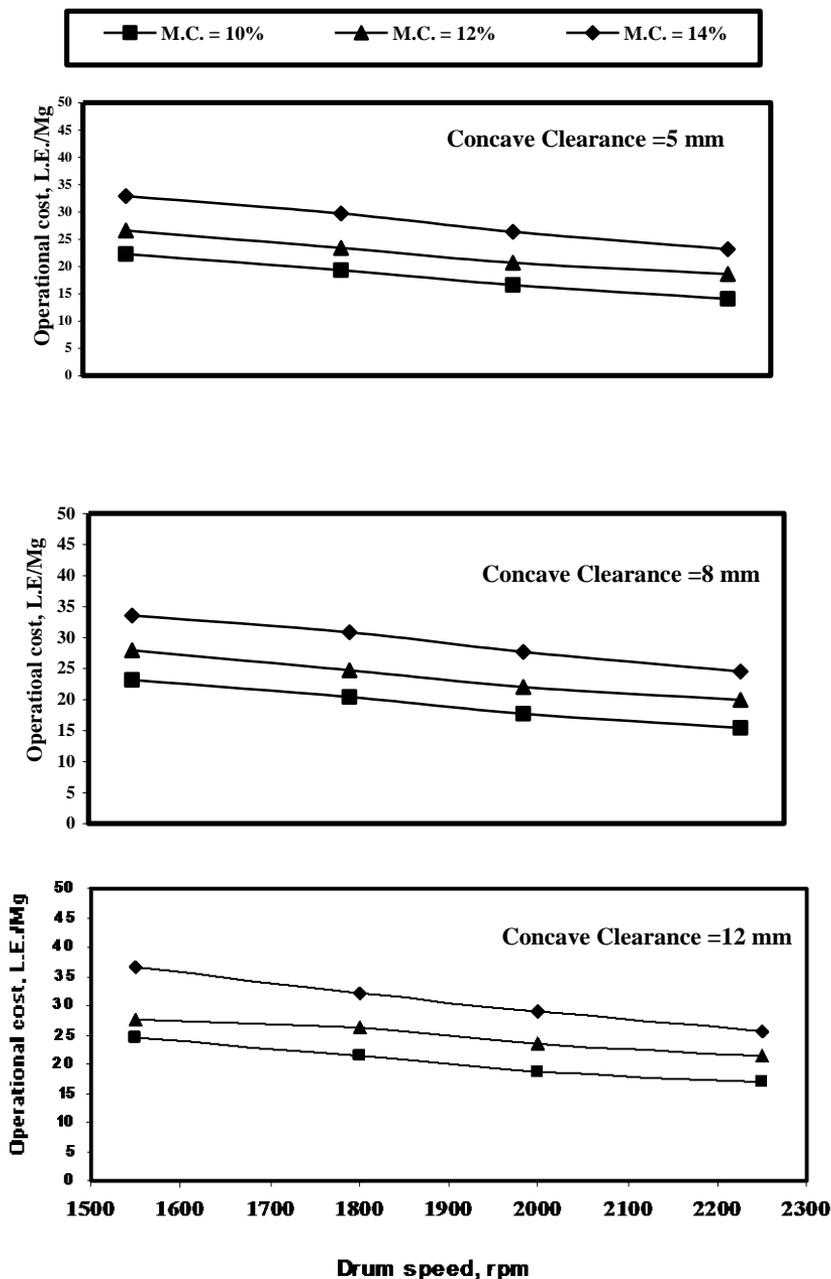


Fig.(13):Effect of drum speed on operational cost under different moisture contents and concave clearances at hammer thickness of 5mm.

## CONCLUSION

From this investigation, the obtained results can be concluded as follows: The proper conditions for operating the hammer mill used to produce pelleting feed were drum speed of 2250 rpm (33.56 m/s), grain moisture content (10%), concave clearance (5 mm) and hammer thickness (5 mm) by increasing percentage of fine milled corn and decreasing coarse milled corn while, to produce mash feed for commercial use can be achieved by using the mill at drum speed about 1550 rpm (23.12m/s), grain moisture content (14%), concave clearance (12mm) and hammer thickness (1.5mm) by decreasing percentage of fine milled corn and increasing coarse milled corn and medium milled corn.

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### الملخص العربي

#### دراسة تأثير بعض عوامل التشغيل على آلة جرش الحبوب المطرقية

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أجريت التجارب على الذرة الصفراء المنتجة محليا في خلال صيف الموسم الزراعي ٢٠٠٧-٢٠٠٨ و ٢٠٠٨-٢٠٠٩ بمجرشة مطرقية لجرش الحبوب بمركز أبو كبير- محافظة الشرقية وذلك لدراسة تأثير بعض عوامل التشغيل على أداء آلة جرش الحبوب المطرقية و كانت أهداف الدراسة تشمل تقييم المجرشة أثناء عملية جرش حبوب الذرة الصفراء، دراسة بعض عوامل التشغيل والعوامل الهندسية (رطوبة الحبوب - سرعة الدرفيل - الخلوصل بين المطارق والصدر - سمك المطارق) المؤثرة على أداء هذه المجرشة، حساب تكاليف التشغيل للمجرشة وقد أجريت التجربة باستخدام أربع سرعات دورانية للدرفيل (١٥٥٠-١٨٠٠-٢٠٠٠ و ٢٢٥٠ لفة/الدقيقة) تناظر سرعة محيطية (٢٣.١٢-٢٦.٨٥-٢٩.٨٣-٣٣.٥٦ م/ث) على الترتيب، ثلاث مستويات للرطوبة في حبوب الذرة الصفراء (١٠-١٢-١٤%) علي أساس رطب، ثلاث قيم لسمك المطارق (١.٥-٣-٥ مم) و ثلاث قيم للخلوصل بين المطارق والصدر (٥-٨-١٢مم). وتم تقييم أداء المجرشة المطرقية من حيث إنتاجية الآلة وكفاءتها، درجة النعومة (توزيع الحبيبات)، القدرة والطاقة المستهلكة، تكاليف التشغيل. و توصي الدراسة باستخدام المجرشة في مصانع العلف المصعب على سرعة دورانية للدرفيل ٢٢٥٠ لفة/الدقيقة (٣٣.٥٦ م/ث) ورطوبة للحبوب (١٠%) وخلوصل بين حافة المطرقة والصدر (٥مم) وسمك المطارق (٥ مم). وذلك لزيادة النسبة المئوية للجرش الناعم وتقليل النسبة المئوية للجرش الخشن، بينما في مصانع العلف الغير مصعب والاستخدام التجاري توصي الدراسة باستخدام المجرشة على سرعة دورانية للدرفيل ١٥٥٠ لفة/الدقيقة (٢٣.١٢ م/ث) ورطوبة للحبوب (١٤%) وخلوصل بين حافة المطرقة والصدر (١٢مم) وسمك المطارق (١.٥مم). وذلك لتقليل النسبة المئوية للجرش الناعم وزيادة النسبة المئوية للجرش الوسط والخشن.

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