Zagazig J. Agric. Res., Vol. 36 No. (6) 2009 1341-1362

THE EFFECT OF SOME OPERATING FACTORS ON THE PERFORMANCE OF HAMMER MILL

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Accepted 8/12/2009

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 operation parameters affecting the performance of hammer mill prototype. The performance of hammer mill was evaluated under the following parameters: four different drum speed, three levels of grain moisture content, three hammer thickness and three concave clearances. The performance of hammer mill was evaluated taking into considering hammer mill capacity and efficiency, particle size distribution (fineness degree), power and energy requirements and operating costs. The experimental results reveal that:

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), to increase percentage of fine milled corn (FMC) and decrease coarse milled corn (CMC). While the proper conditions for operating the hammer mill used to produce mash feed and commercial use were drum speed of 1550 rpm (23.12 m/s), grain moisture content (14%), concave clearance (12 mm) and hammer thickness (1.5 mm), to decrease percentage of fine milled corn (FMC) and increase coarse milled corn (CMC) and medium milled corn (MMC).

Key words: Hammer mill, corn, drum speed, moisture content, concave clearance, hammer thickness, fineness degree.

INTRODUCTION

Nowadays, 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 low up-keep 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. And he mentioned 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 lowers palatability. However, fine grinding may be desirable when pelleting is to follow. Vigneault *et al.* (1992) indicated that as grinding machine variables, for the hammer mill thickness effect, the specific energies increased as the hammer mill thickness increased. The specific energies increased from 5.5 to 9.5kW.h/t for hammer mill thickness increased from 1.59 to 8.00 mm. And they added that the specific energies increased from 4.6 to 12.9 kw.h/t for hammer tip speeds increased from 54 to 86 m/s for a 6.35 mm thick hammer. 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. 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 and he added that higher fineness of grinding % (fine) were 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 fineness degree of grinding (fine). EL- Gayar and Bahnas (2002) studied some factors affecting hammer mill to produce garlic powder such as three hammer tip speeds of (13.82, 18.43 and 23.04m/s), two feed rates (27.00and 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. 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:

1. Evaluate hammer mill prototype during grinding corn grains.
2. Studying some operating and engineering parameters (grain moisture content, drum speed, hammer thickness and concave clearance) which affecting the performance of the hammer mill.
3. Estimating the hammer mill operating cost.

MATERIALS AND METHODS

The experiments 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 operation parameters affecting the performance of hammer mill prototype.

Materials

Corn grain

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

Screens

Two different diameters of screen holes of (3 and 4.2 mm) were used to determine the particle size distribution (fineness degree).

Hammer mill prototype

The hammer mill specification are shown in fig 1 and table (2).

Table 1.The physical properties of corn grain.

Corn variety	Bulk density gm/cm^3	Average grain length mm	Average grain width, mm	Average grain thickens mm
Giza 162	0.680	10.75	8.65	4.9

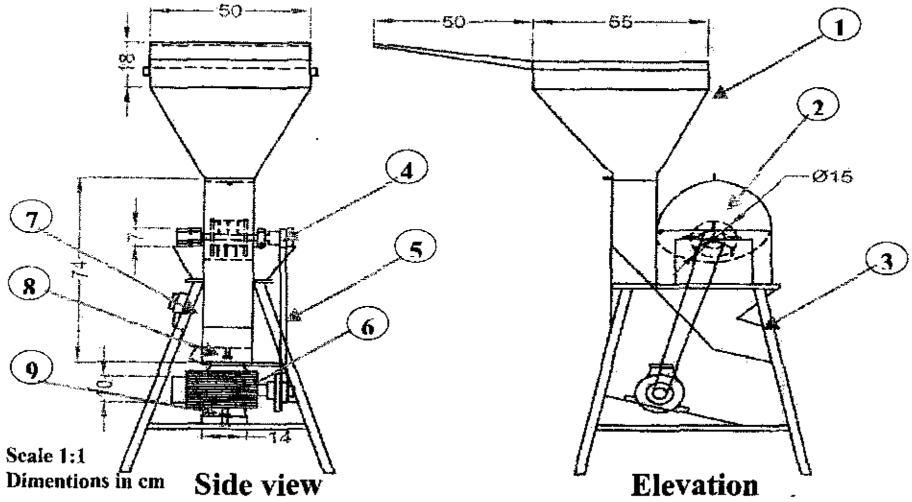

Fig.1. Elevation and side view for hammer mill prototype

(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 used hammer mill prototype, hammers and screen

Hammer mill prototype:	**Hammers and Screen:**
Type : Swinging hammer mill	**I - Hammers**:
Hopper capacity: 100 kg	Type : Swinging hammers
Overall length: 1710 mm	Material: Steel iron.
Overall width: 1380 mm	Length :109.5 mm
Rotor diameter : 145 mm	Width: 39 mm
Rotor width: 110 mm	Thickness : Variable
Total screen area:	Swinging length : 86.5 mm
840 cm^2 (Length (56) * Width (15))	Diameter to fit rode size: 19 mm
Screen opening dia: 6 mm	**II- Screen**
Hammer edge : Smooth	Perforation: 6mm
Number of hammers: 12 hammer	Width :150 mm
Source of power: AC Electrical Motor (3.68 kW)	Roll outside dia: 435 mm
Mass: 110kg	Length over the back:560 mm
	Gauge:25 mm

Other instruments and devices were used in the experiments such as stop watch, grain moisturmeter, electronic balance, varnier caliper, tachometer and clamp meter.

Methods

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

- Four drum rotating 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.
- Three levels of grain moisture contents of 10, 12 and 14%.
- Three hammer thickness of 1.5,3 and 5 mm.
- Three concave clearances of 5,8 and 12 mm.

Measurements

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

Milling capacity and efficiency

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

The actual capacity (AMC) of the milling 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 (η_m) was calculated as follow:

$$\eta_m = \left(\frac{A.M.C}{T.M.C}\right) * 100$$

η_m = The milling efficiency,%.

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

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

Fineness degree (particle size distribution)

The milled grains of corn in commercial markets can be classified into three main categories according to Henderson and Perry (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) It is known that very fine broiler diet is not desirable commercially because the dusty material causes low palatability due to the poultry consumed ingredients that might present in the large form of particle size, in addition to the problems related to the increase of waste thought the mechanical handling and the excessive consumption of power and energy. However, the very fine milling process may be desirable when pelleting process is to follow. On the other hand, the coarse milled corns (CMC) improve palatability, reduce wastage and consumed energy.

Milling power and energy requirement

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

Total consumed power = load

$$= \frac{\sqrt{3} I.V \eta \cos\Theta}{1000} \quad \text{kW}$$

Where:

I= line current strength in Amperes.

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

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

η = Mechanical efficiency assumed (95%).

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

Specific energy requirement = the consumed power (kW)/milling capacity (Mg/h).

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, 2003):

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

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 in, kW.

e : Hourly cost/kW.h.

m : The monthly average wage, L.E.

144:The monthly average working hours.

RESULTS AND DISCUSSION

The obtained results were discussed as follows:

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 2250rpm (33.56 m/s), grain moisture content 10%, concave clearance 5mm and hammer thickness 5mm. while the highest value of machine efficiency (92.9%) obtained at drum speed 1550rpm (7.87m/s), grain moisture content14%, concave clearance 12mm and hammer thickness 1.5mm.

Fineness Degree

In figs 5 to 7 which showed the relation between drum speed and fineness degree under different grain moisture content, hammer thickness and concave clearance. 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 rotational 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 rotational speed of1550 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 rotational speed of 1550 r.p.m (23.12 m/s). grain moisture content of 10% hammer thickness of 3 mm and concave clearance of 8 mm.

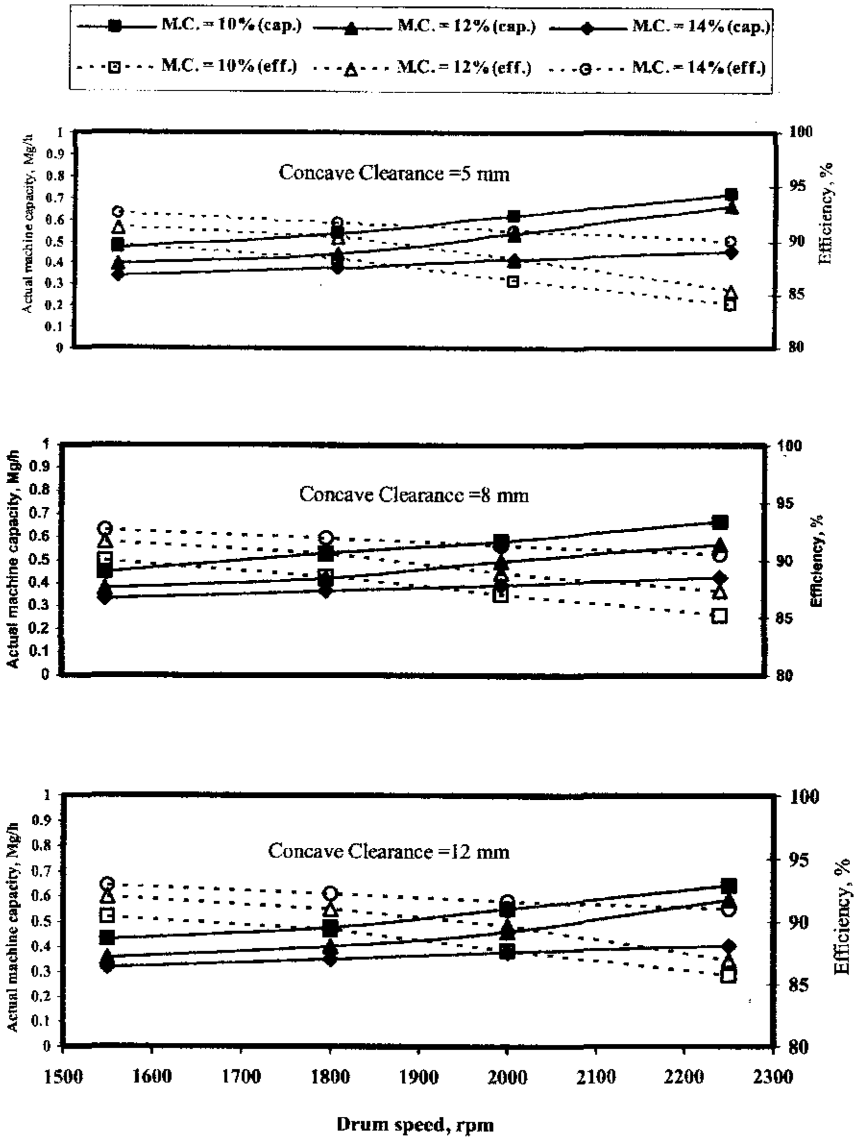

Fig. 2. Effect of drum speed on machine capacity and efficiency under different moisture content and concave clearances at hammer thickness of 1.5mm

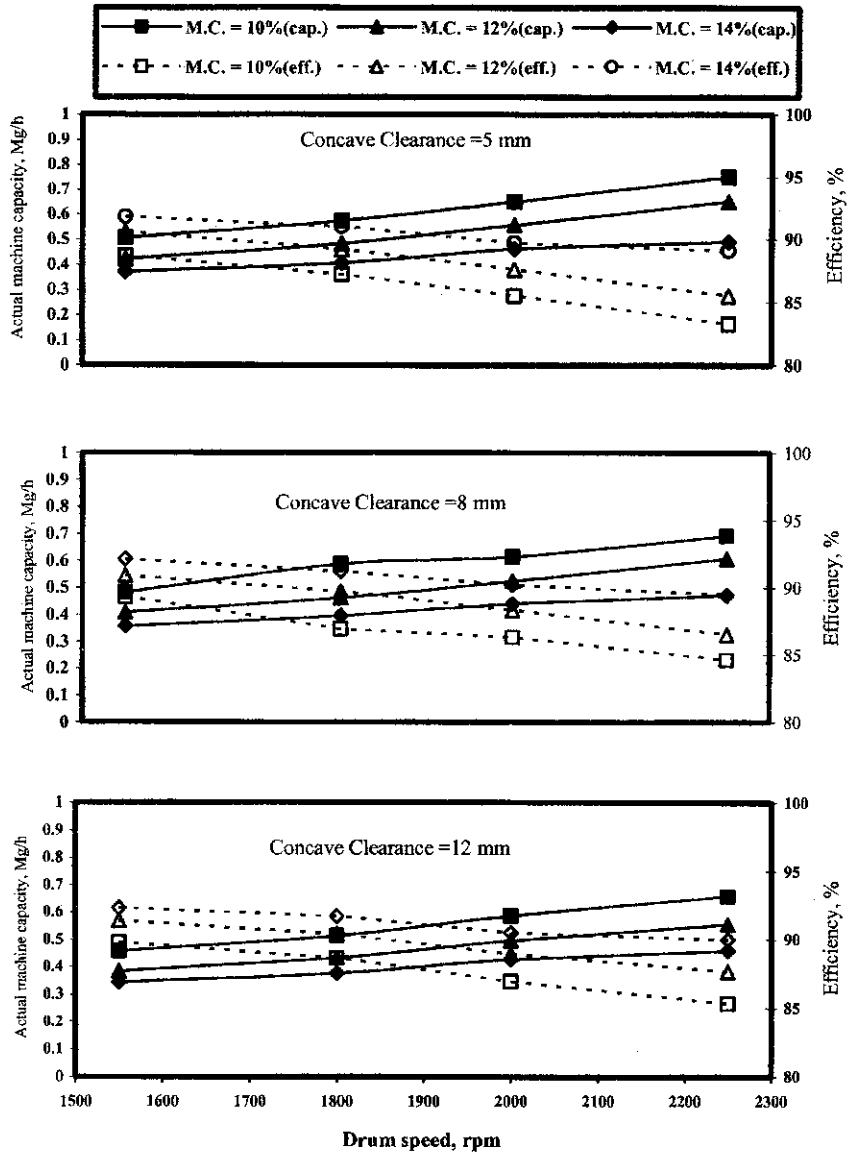

Fig. 3. Effect of drum speed on machine capacity and efficiency under different moisture content and concave clearances at hammer thickness of 3mm

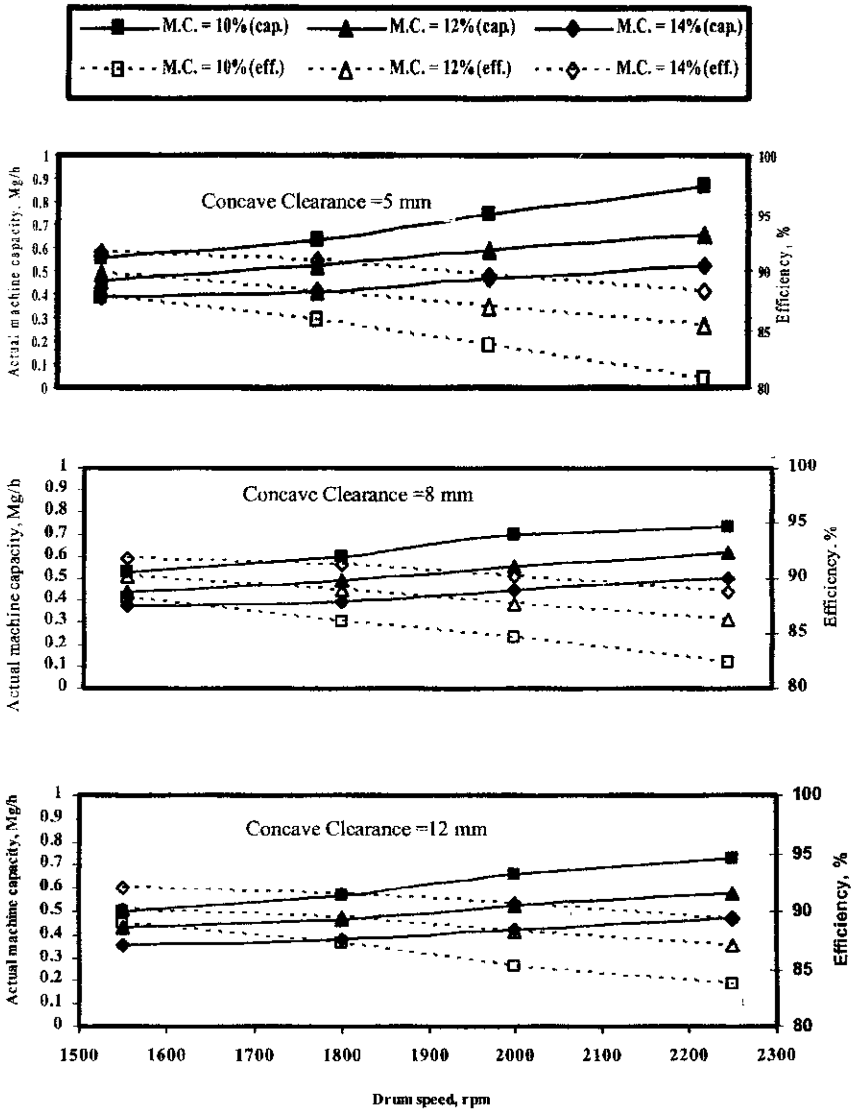

Fig. 4. Effect of drum speed on machine capacity and efficiency under different moisture content and concave clearances at hammer thickness of 5mm

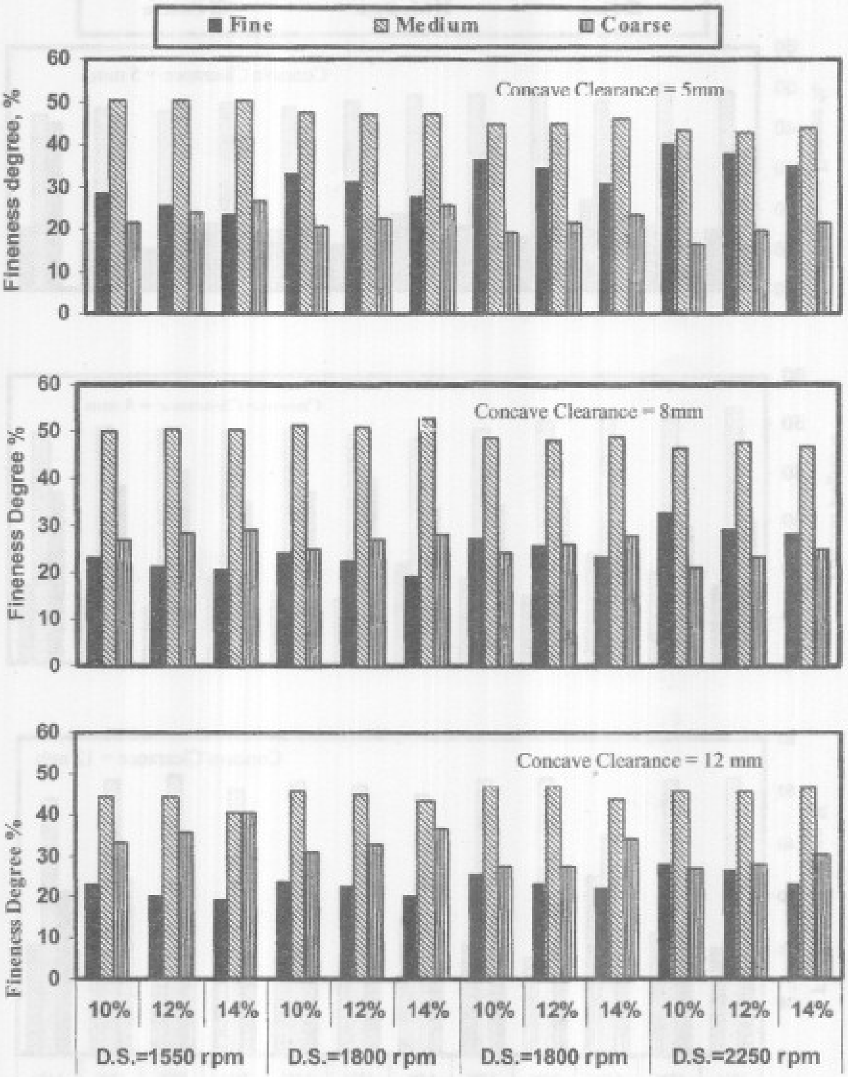

Fig. 5. Effect of drum speed on fineness degree under different moisture content and concave clearances at hammer thickness of 1.5mm

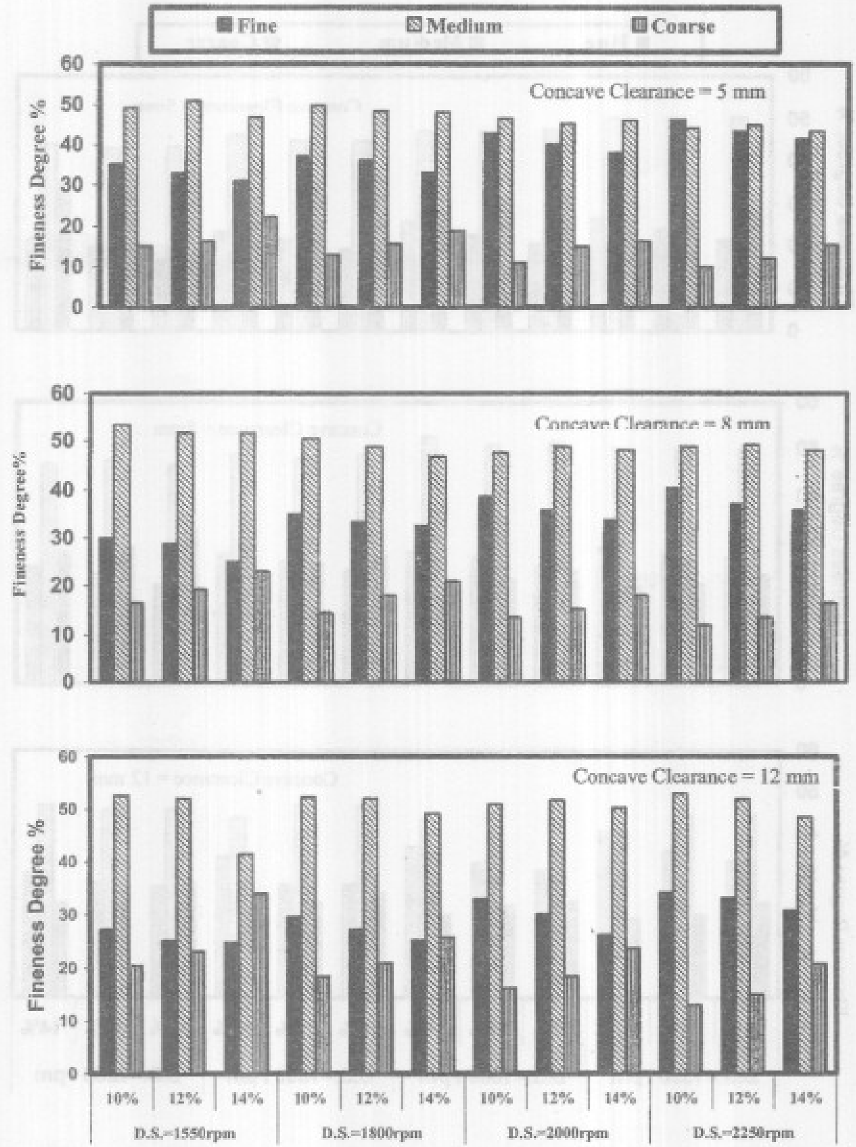

Fig. 6. Effect of drum speed on fineness degree under different moisture content and concave clearances at hammer thickness of 3mm

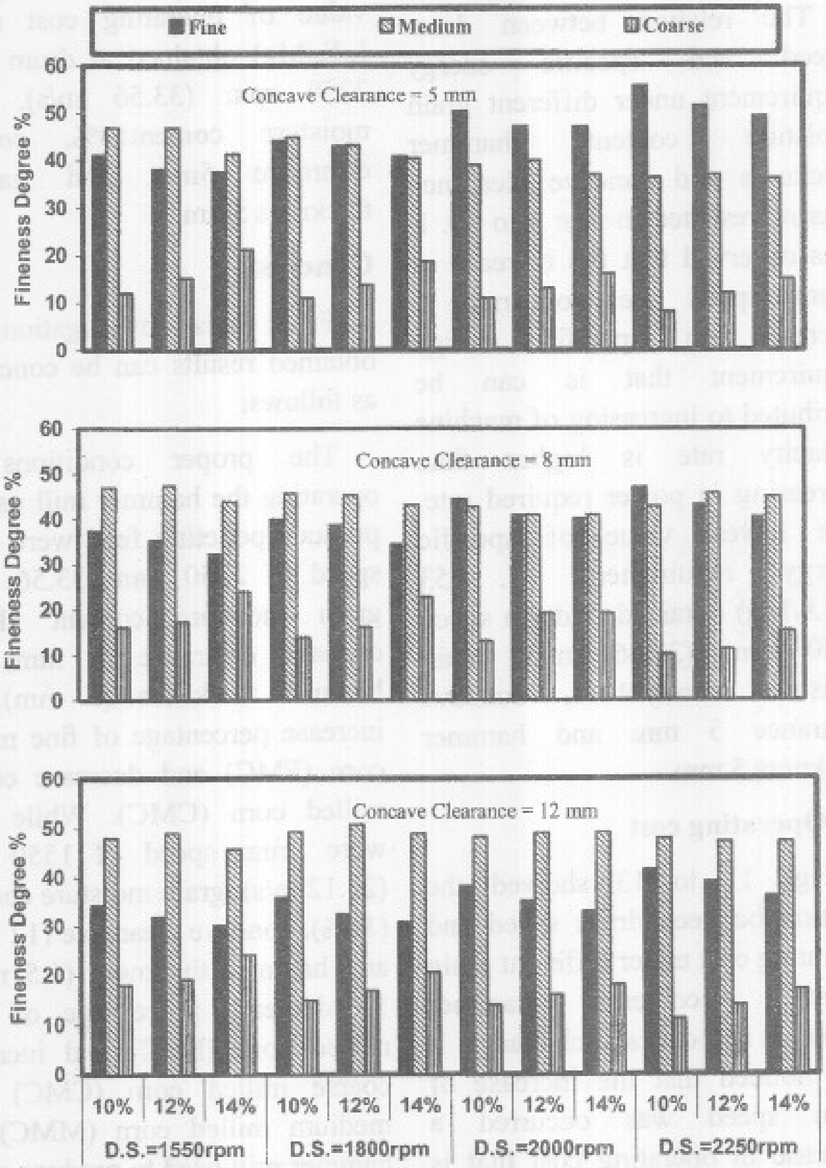

Fig. 7. Effect of drum speed on fineness degree under different moisture content and concave clearances at hammer thickness of 5mm

Energy requirement

The relation between drum speed and specific energy requirement under different grain moisture content, hammer thickness and concave clearance 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 speed 2250 rpm (33.56 m/s), grain moisture content10%, concave clearance 5 mm and hammer thickness 5 mm.

Operating cost

Figs 11 to 13 showed the relation between drum speed and operating cost under different grain moisture content, hammer thickness and concave clearance. It was noticed that the increase of drum speed was occurred a decrease in operating cost that is can be attributed to increasing in machine capacity. The lowest value of operating cost (14.06 L.E./Mg) obtained at drum speed 2250 rpm (33.56 m/s), grain moisture content10%, concave clearance 5mm and hammer thickness 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). To increase percentage of fine milled corn (FMC) and decrease coarse milled corn (CMC). While they were drum speed of 1550 rpm (23.12 m/s), grain moisture content (14%), concave clearance (12 mm) and hammer thickness (1.5 mm). To decrease percentage of fine milled corn (FMC) and increase coarse milled corn (CMC) and medium milled corn (MMC) for hammer mill used to produce mash feed and commercial use.

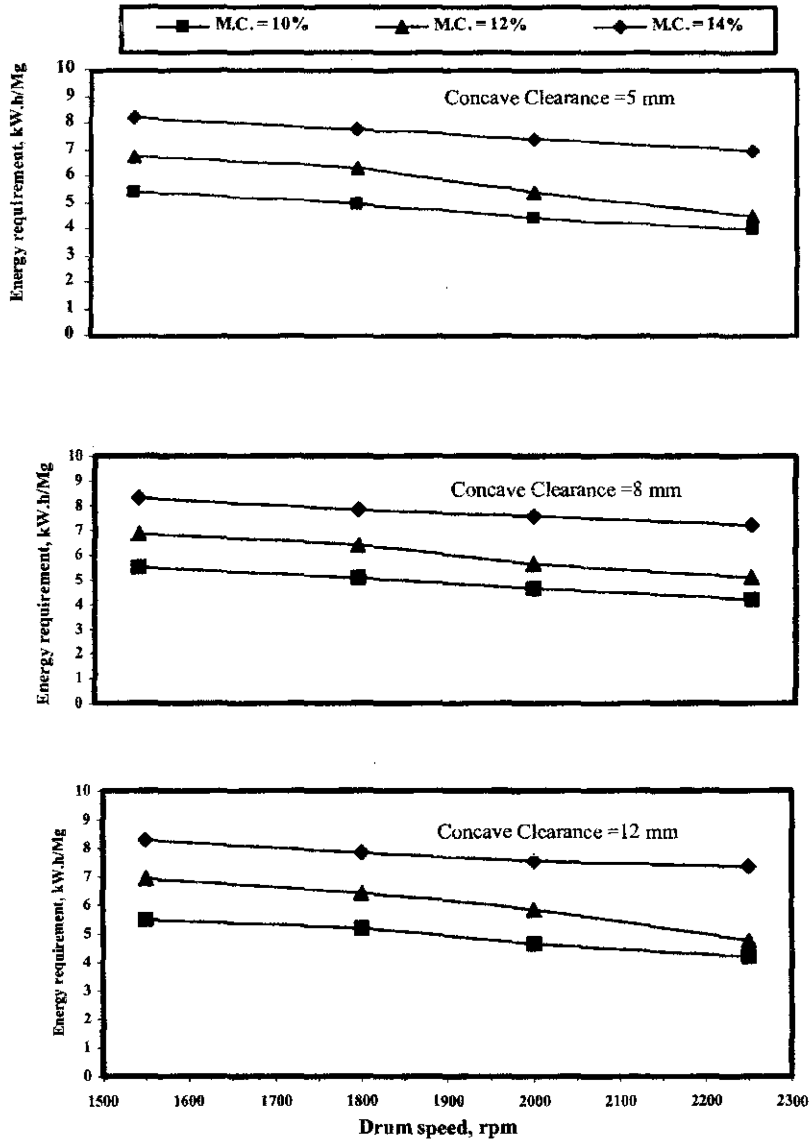

Fig.8. Effect of drum speed on specific energy requirement under different moisture content and concave clearances at hammer thickness of 1.5mm

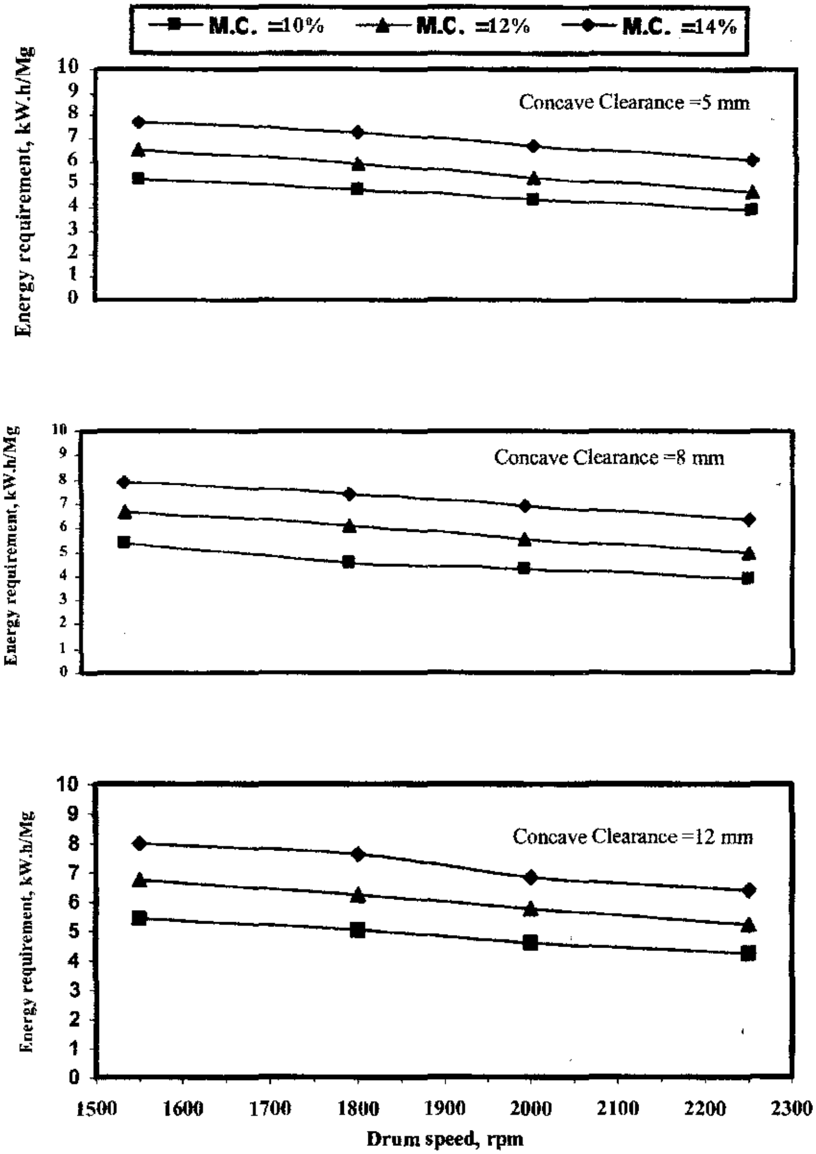

Fig. 9. Effect of drum speed on specific energy requirement under different moisture content and concave clearances at hammer thickness of 3mm

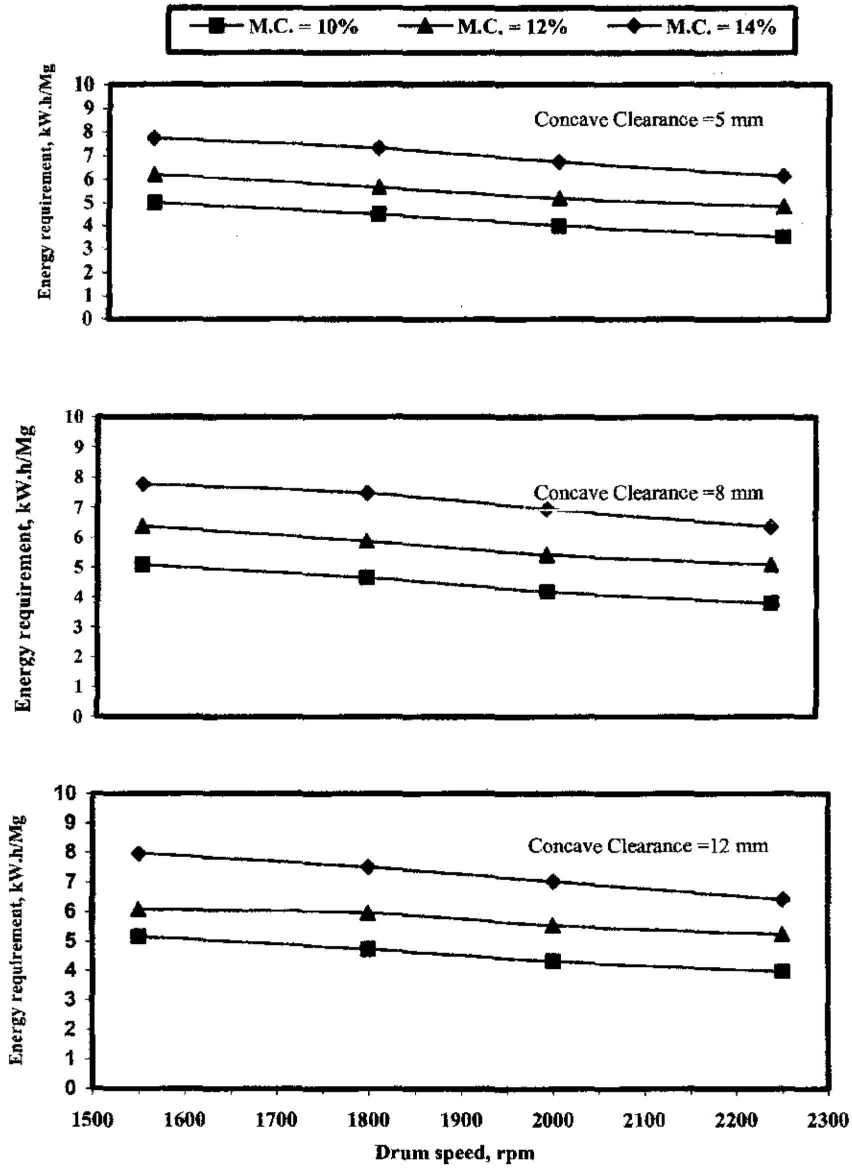

Fig. 10. Effect of drum speed on specific energy requirement under different moisture content and concave clearances at hammer thickness of 5mm

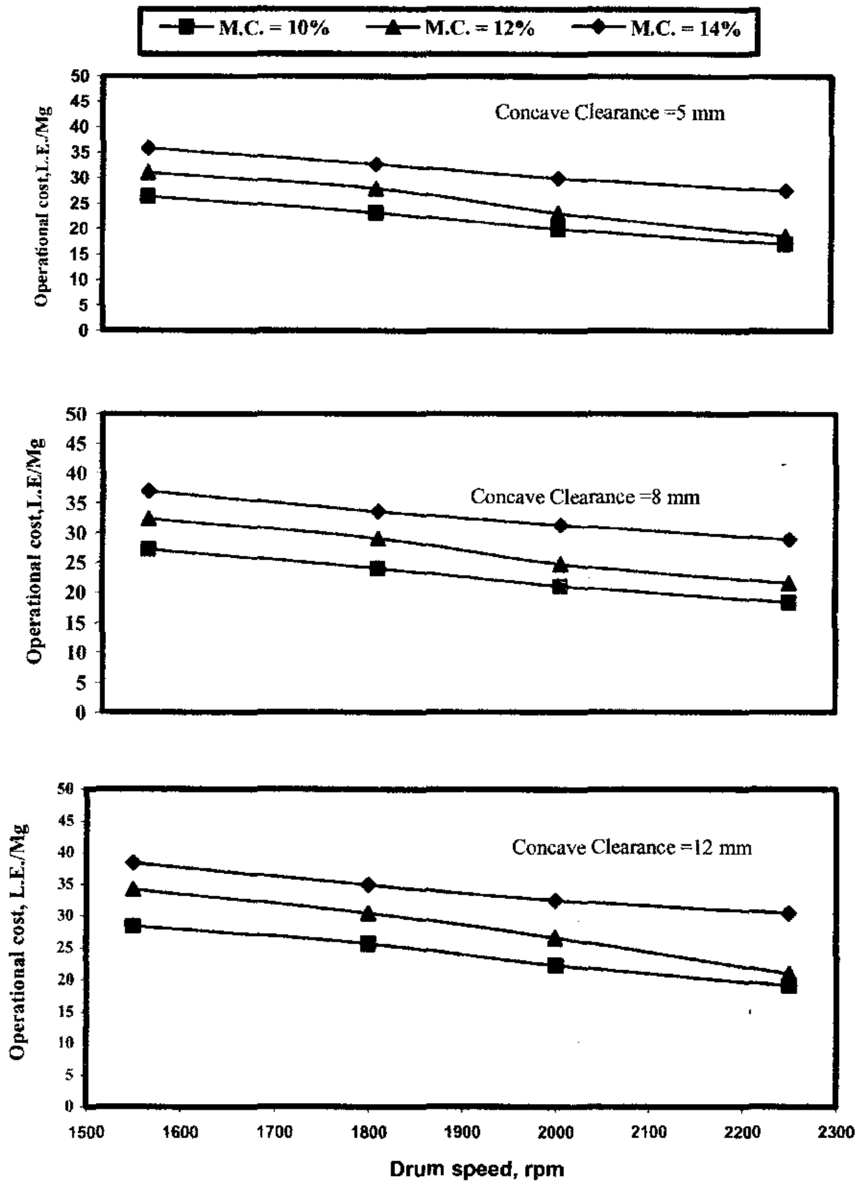

Fig. 11. Effect of drum speed on operating cost under different moisture content and concave clearances at hammer thickness of 1.5mm

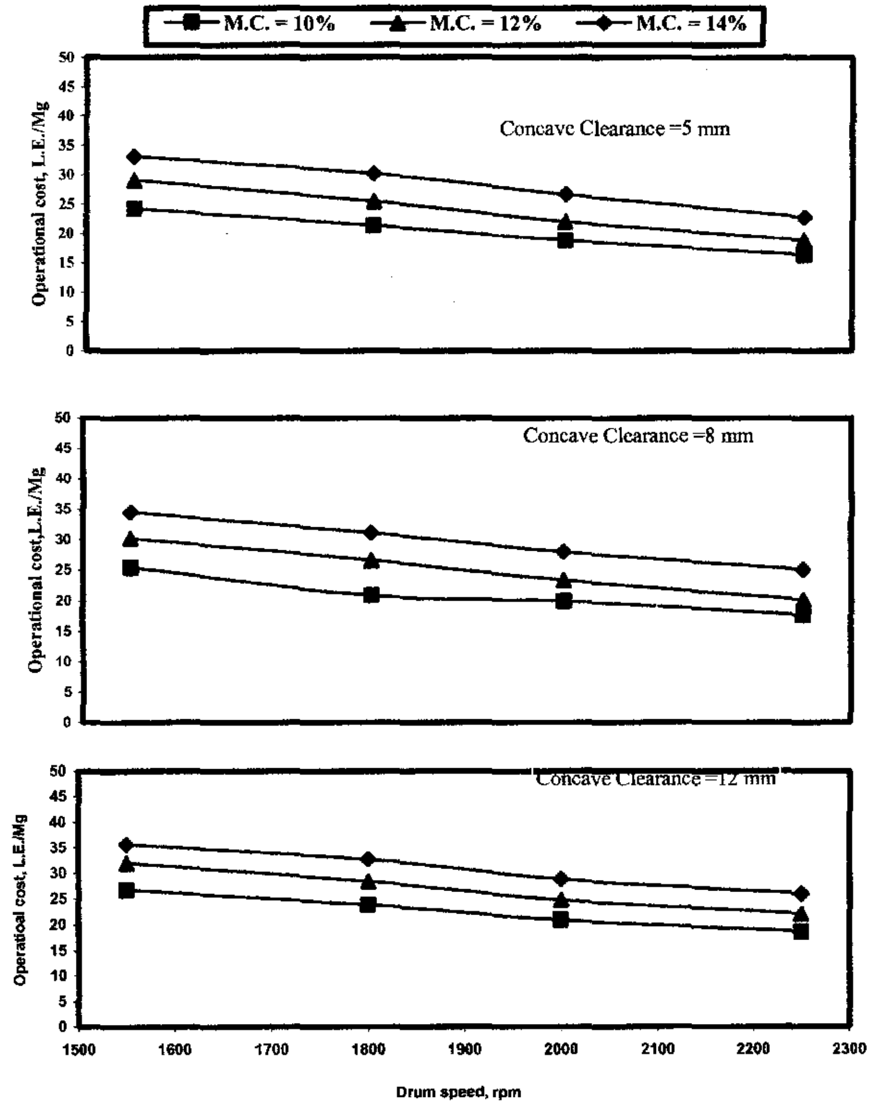

Fig. 12. Effect of drum speed on operating cost under different moisture content and concave clearances at hammer thickness of 3mm

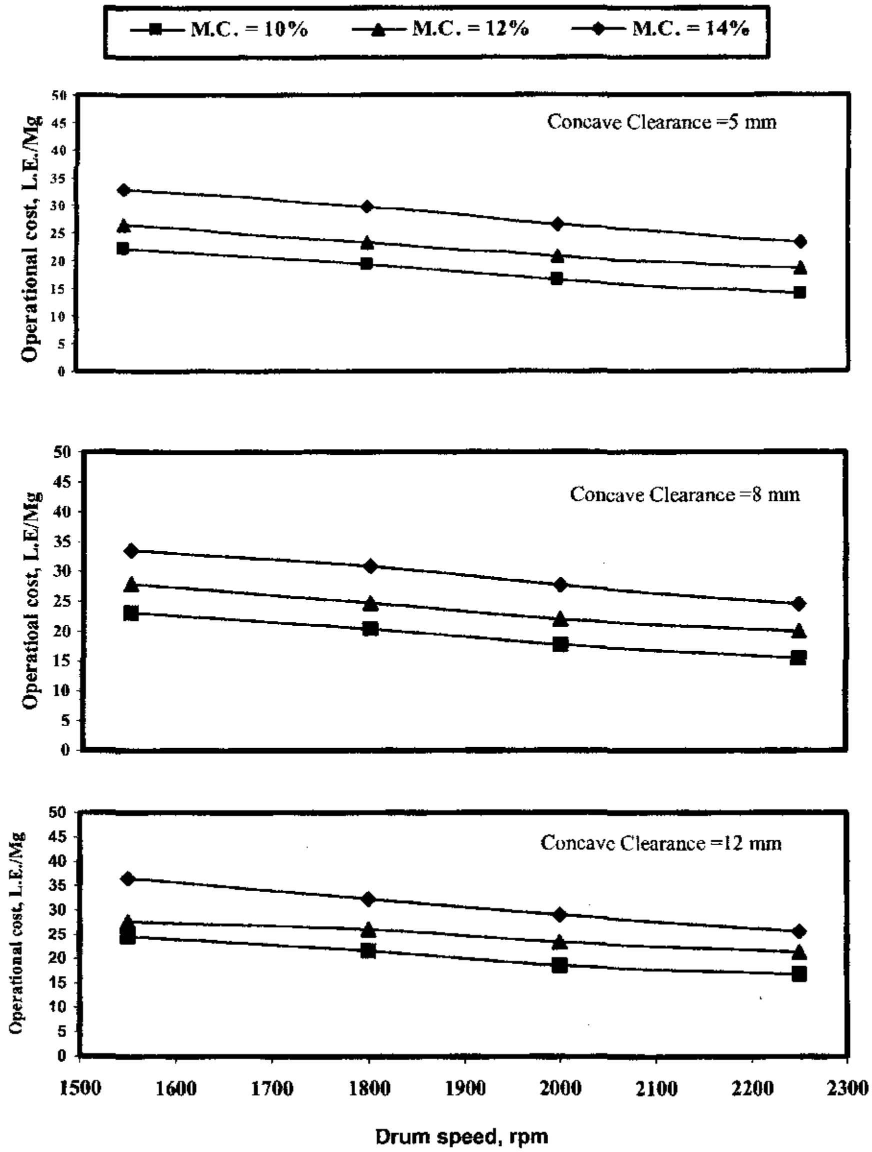

Fig. 13. Effect of drum speed on operating cost under different moisture content and concave clearances at hammer thickness of 5mm

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تأثير بعض عوامل التشغيل على اداء آلة جرش الحبوب المطرقية

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أجريت التجارب على الذرة الصفراء المنتجة محليا فى خلال صيف الموسم الزراعى ٢٠٠٧–٢٠٠٨و٢٠٠٨–٢٠٠٩بمجرشة مطرقية لجرش الحبوب بمركز أبو كبير– محافظة الشرقية وذلك لدراسة تأثير بعض عوامل التشغيل على اداء آله جرش الحبوب المطرقية.

وكانت أهداف الدراسة:

١- تقيم المجرشة أثناء عملية جرش حبوب الذرة الصفراء.
٢- دراسة بعض عوامل التشغيل والعوامل الهندسية (رطوبة الحبوب – سرعة الدرفيل – الخلوص بين المطارق والصدر – سمك المطارق) المؤثرة على أداء هذه المجرشة.
٣- حساب تكاليف التشغيل للمجرشة.

وقد أجريت التجربة باستخدام المعاملات الآتية:

١- أربع سرعات دورانية للدرفيل(١٥٥٠–١٨٠٠–٢٠٠٠–٢٢٥٠لفة/الدقيقة) سرعة خطية (٢٣,١٢–٢٦,٨٥–٢٩,٨٣– ٣٣,٥٦ م/ث) على الترتيب.
٢- ثلاث مستويات للرطوبة فى حبوب الذرة الصفراء (١٠–١٢–١٤%).
٣- ثلاث قيم لسمك المطارق (١,٥–٣– ٥ مم).
٤- ثلاث قيم للخلوص بين المطارق والصدر(٥–٨–١٢مم).

وقد تم تقييم أداء المجرشة المطرقية من حيث:

١- إنتاجية الآلة وكفاءتها. ٢- درجة النعومة (توزيع الحبيبات).
٣- القدرة والطاقة المستهلكة. ٤- تكاليف التشغيل.

ومن أهم النتائج المتحصل عليها:

للحصول على أفضل الظروف لتشغيل المجرشة المطرقية فيوصى باستخدامها تحت الظروف الآتية:

أ – فى مصانع العلف المصبع يوصى باستخدام المجرشة على النحو التالى:
السرعة الدورانية للدرفيل٢٢٥٠ لفة/الدقيقة (٣٣,٥٦م/ث) ورطوبة الحبوب (١٠%) والخلوص بين حافة المطرقة والصدر(٥مم) وسمك المطارق (٥ مم). وذلك لزيادة النسبة المئوية للجرش الناعم وتقليل النسبة المئوية للجرش الخشن بقدر الإمكان.

ب– فى مصانع العلف الغير مصبع والاستخدام التجارى يوصى باستخدام المجرشة على النحو التالى:
السرعة الدورانية للدرفيل١٥٥٠ لفة/الدقيقة (٢٣,١٢م/ث) ورطوبة الحبوب (١٤%) والخلوص بين حافة المطرقة والصدر(١٢مم)وسمك المطارق(١,٥مم). وذلك لتقليل النسبة المئوية للجرش الناعم وزيادة النسبة المئوية للجرش الوسط والخشن بقدر الامكان.