Misr J. Ag. Eng., 26(2): 608- 623 FARM MACHINERY AND POWER

FABRICATION AND MANUFACTURE OF A LITTER REMOVAL MACHINE FOR POULTRY FARMS

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ABSTRACT

A litter removal machine was fabricated and constructed for exciting, removing and scraping the litter (bed) of the poultry breeding farms. The evaluation of machine is carried out through the terms of five litter moisture content(25.43, 28.15, 31.30, 35.58, and 38.82 %), five machine forward speeds (0.57, 0.87, 1.13, 1.42, and 1.73 km/h) ,number of knives groups (3 and 4 groups), and number of knives per each group (3 and 4 knives) .The machine productivity, removal efficiency, power, energy, and criterion cost were investigated to evaluate the machine performance. The proper kinematics parameter (ratio of knife peripheral velocity to machine forward speed) is experimentally estimated to maximize removal efficiency and minimized both energy and cost. The results concluded the following;

1. The maximum of removal efficiency, the minimum of energy requirement and criterion cost were achieved at litter moisture content of 31.30 %, four groups of knives, four knives per each group on the unit

2. The kinematic parameter of 1.6 (0.5 m/s knife velocity and 1.13 km/h machine forward speed) is recommended to be adjusted for operating the manufacture litter removal machine with three knives per each group and four groups of knives or kinematic parameter of 1.27 (0.5 m/s knife velocity and 1.42 km/h machine forward speed) for machine with four knives per each group and four groups of knives

INTRODUCTION

The Animal wastes can adversely affect water, air, and animal resources in a variety of ways. Nutrients can kill fish and create algae blooms in surface water. In ground water, nitrates can make well water unfit for human consumption, particularly for infants. In addition, organic matter can cause dissolved oxygen problems in surface water, while bacteria and other microorganisms can contaminate wells

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and create health problems in recreational waters. Certain constituents in animal waste can create health problems in animals grazing cool-season grasses. In addition, the gases that are produced can have a number of adverse effects on the air resource and on animals in confinement **United States Environmental Protection Agency (1983)**. Although the dangerous and harmful effects of the poultry wastes on the surrounded environment but they considered a good source as a manure for fertilization the agricultural soils .**United States Environmental Protection Agency (1984).**stated that Animal waste contains a number of contaminants that can adversely affect surface and ground water. Also, these can impact grazing animals, harm terrestrial plants, and impair air quality. The excreta from animals have countless micro-organisms, including bacteria, viruses, parasites, and fungi. Some of these are disease causing, and carried by animals are transmittable to humans, and vice versa. **Barth (1985)** Demonstrated that Poultry that use a litter (floor) system. Bedding materials, whether wood, crop, or other residue, are largely organic matter that has little nutrient component. Litter moisture in a well managed house generally is in the range of 25 to 35 percent. Higher moisture levels in the litter result in greater weight and reduced levels of nitrogen. Most broiler houses are now cleaned out one or two times a year. Growers generally have five or six flocks of broilers each year, and it is fairly common to take the "cake" out after each flock. The cake is generally 1 to 2 inches of material. About 2 or 3 inches of new litter is placed on the floor before the next flock. **Westerman *et al* (1985)** mentioned that the two basic poultry confinement facilities include those to raise broilers used for meat and those to house layers. Broilers are grown on floors on beds of litter shavings, sawdust, or peanut hulls. Layers are confined to cages. Disease control is important in both systems. Waste associated with poultry operations include manure and dead poultry. Depending upon the system, waste can also include litter, wash-flush water, and waste feed. **Stephenson *et al.*(1989)** limited that the density and moisture content of the litter is different with a more frequent cleanout and the nutrients are less concentrated. The amount of nutrients is less compared to the litter volume because less time is allowed for the nutrients to accumulate. **Krider (1999)** The manure from broiler and turkey operations is allowed to accumulate on the floor where it is mixed with the litter. Near watering facilities the manure litter pack forms a "cake" that generally is removed between flocks. The rest of the litter pack generally has low moisture content and is removed once a year in the spring. The litter pack can be removed more frequently to prevent disease transfer between flocks. In layer houses, the manure that drops below the cage collects in deep stacks or is removed frequently using either a shallow pit located beneath the cages for flushing or scraping or belt scrapers positioned directly beneath the cages. **Kepner *et al.* (1972)** stated that the common way of the cutting forces was by means of two opposed shearing elements. In the way of applying the cutting forces by single cutting elements, the material being cut may transmit the force required to oppose a single cutting element. An impact cutter having a single high speed cutting element relies primarily upon inertia of the material being cut to furnish the opposing required force for shear. **Prasad and Cupta (1975)** found that the cross section area and moisture content of the cutted material had significant influence over shearing energy and maximum shearing force. **Morad (1981)** found that the required force for cutting any material may be divided into two parts. The first part is the inertia force required to move the cutting mechanism, and the second is the shearing force required to shear the material. Inertia force is affected by the square of knife velocity resulting in a sharp increase of cutting energy. The force was found to be affected by knife velocity, machine forward speed, and material moisture content. **Abo-habbaga (1994)** found that increasing the speed ratio (the ratio between rotary shaft rotational speed and its forward speed) decrease the clods size, and consequently increased the soil pulverization ratio. This reason behind this in increasing the speed ratio which decreased the tilling pitch and increased the impact between the clods and rotary knives So, The main objective of the present research is fabricating and manufacturing of a litter removal machine suits most poultry breeding farms in medium scale . The other objective is selecting the optimum operating conditions such as machine forward speed and litter moisture content, the optimum number of cutting group and number of knives per each group to evaluate the performance of the fabricated machine. Finally to evaluate the fabricated machine from the economic point of view.

MATERIAL AND METHODS

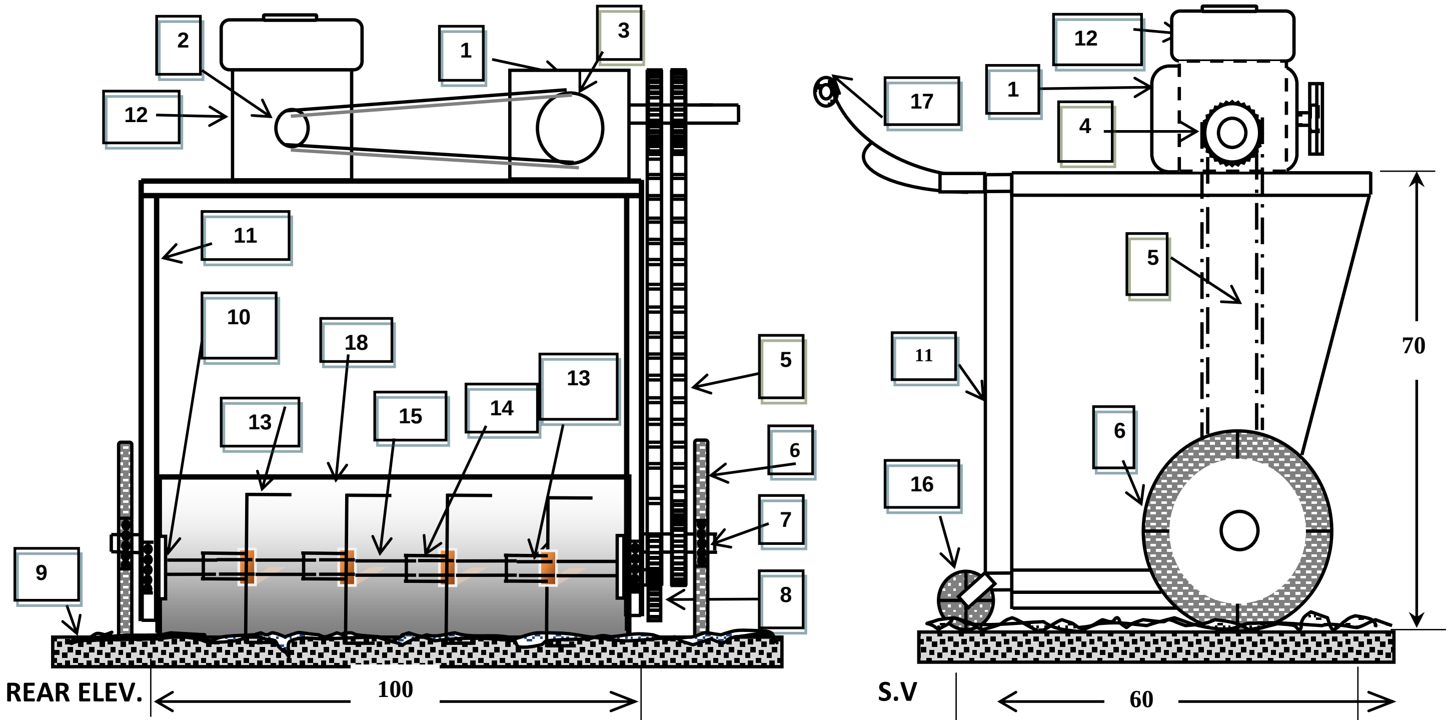
Experiments were carried out in a private poultry breeding farm at Abo-kaber province , Sharkia Governorate to fabricate and manufacture litter removal machine in general locally workshop. The poultry farm consists of four floors, each floor of 1000 m^2area **.**The main specification of the manufactured litter removal machine as shown in **Fig. (1)**. The fabricated machine consists of the following main parts;

1. **Frame** : it is made of rectangular iron steel sheet. The frame has dimensions of 100 cm length, 60 cm width, and 60 cm height .it included elements to fix the engine, gear box, removal units, scraper, and the transmission system. The fabricated machine was carried by two side ground wheels of 30 cm diameter and rear wheel of 12 cm. The small wheel replaced by duck foot share to increase the resistance during the operation. Driving handle was fixed in the frame as shown in **Fig (1).**

2. **Transmission system** : it consists of means of pulleys, belts, chains, and gears. The motion is transmitted from engine pulley (10 cm) to gear box with reduction of 1:25 by pulley of (20 cm). The output of gear box provided with two gears. The fist gear transmitted constant speed of (30 m / min) to removal unit by means of gear and bearing, while the second gear transmitted the speed to variable replaced gears fixed on the axe of ground wheel to control and adjust the forward speed of fabricated machine.

3. **Power unit:** the engine of Honda model**,** four cycle, and air cooling with 3.68 kW(5Hp) was used.

4. **The removal and cleaning unit:** the removal unit consists of shaft of 1oo cm length and 2.5 cm diameter provided with group of knives have a diameter of (32 cm).A semicircular metal sheet of 40 cm diameter and 100 cm length was bolted inside the main frame behind the rotating knives shaft to scrape and crumble the litter wastes. The shaft takes its motion from output gear box directly by means of gear and flange. Multi-systems of knives groups (three and four groups) and number of knives per each group (three knives with arrangement angle of 120^0 and four knives with arrangement angle of (90^0) were investigated under study as shown in **Fig. (2)**. The average operating depth of the unit was adjusted to be 5 cm which equal the average thickness of litters



1	Speed reducer	**6**	Main wheel	**11**	Main frame	**16**	Rear support wheel
2	Engine pulley(out)	**7**	Bearing	**12**	Engine	**17**	Operating hand
3	Reducer pulley(in)	**8**	Knives gear	**13**	Removal Knives	**18**	Scraper
4	Gear reduction(out)	**9**	Litter (bedding)	**14**	Assembly Knife		
5	Chain	**10**	Depth control flange	**15**	crumble shaft	Dim. in cm	

Fig. 1: The elevation and side views of a litter removal machine

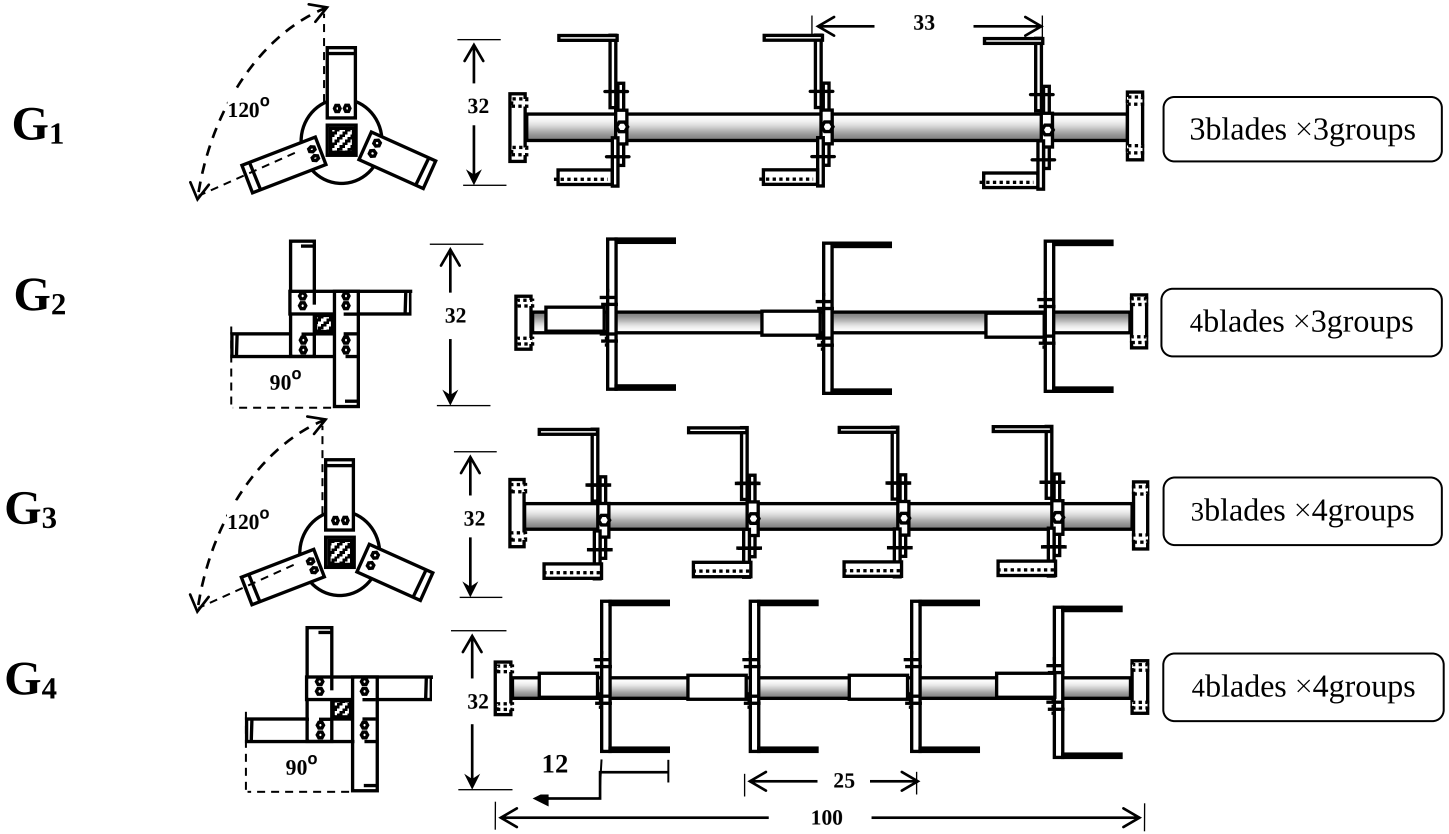


Fig.2: The arrangement of knives groups of the fabricated litter removal machine

Experimental procedure:

The evaluation of the manufactured machine was carried out through the terms of four litter moisture contents of 25.43, 28.15, 31.30, 35.58, and 38.82 %, five machine forward speeds of 0.57, 0.87, 1.13, 1.42, and 1.73 km/h, number of knives groups of 3 and 4 groups, and number of knives per each group of 3 and 4 knives .The arrangements of knives and number of group were symbolled **G_1, G_2, G_3, and G_4**.

- **Kinematics parameters adjustment:** The kinematics parameter was defined as the ratio of knife peripheral velocity to machine forward speed

$$\lambda = \frac{(\nu)\ \text{Peripheral speed of rotating knives, m/min}}{(V)\ \text{Machine forward speed, m/min}}$$

The proper adjustment of the kinematics parameters during removing the litter is of great importance to decrease litter removing wastes and cleaning losses and consequently increase litter wastes removal efficiency. In the present study, the proper kinematic parameter was indicated experimentally. Experiments were run under a constant peripheral velocity of 0.5 m / s and five machine forward speeds as mentioned previously which corresponded to different kinematic parameters of 3.18, 2.08, 1.60, 1.27 and 1.05.

Measurements :

- **productivity (P):** It was calculated using the following equation;

$$p\ (m^2/h) = \frac{1}{\text{Effective time to remove the litter}\ (h/m^2)}$$

- **Removal (cleaning) efficiency(∫r):** it defined the percentage of area which removed and cleaned from the litter wastes

$$\zeta_r\ (\%) = \left(1 - \frac{\text{Area of non-removed (cleaned) treatment}\ (m^2)}{\text{Total area of treatment}\ (m^2)}\right) \times 100$$

- **Energy consumed**: To estimate the engine power during operation, the decrease in benzene fuel level in fuel tank accurately measuring immediately after each treatment. The following formula was used to estimate the engine power **(Hunt, 1983):-**

$$EP = \left[F.C\,(1/3600)\,PE \times L.C.V \times 427 \times \eta_{thb} \times \eta_m \times 1/75 \times 1/1.36\right],\ kW$$

Where: F.C = Fuel consumption, (l/h).

PE = Density of fuel, (kg/l), (for benzene = 0.72).
L.C.V = Lower calorific value of fuel (11.000 k.cal/kg).
η_{thb} = Thermal efficiency of the engine (for Otto engine, 25%,).
427 = Thermo-mechanical equivalent (Kg.m/k.cal).
η_{m} = Mechanical efficiency of the engine (for Otto engine, 85%).
The energy can be calculated as following:-

$$\mathbf{Energy\ requirement = \frac{Engine\ power,(kW)}{Productivity,(m^2/h)},\ kW.h/m^2}$$

- **Cost estimation:**

The machine cost was determined by using the following equation **(Awady et. al. 1982)**

$$\mathbf{C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (0.9\,W.S.F) + \frac{m}{144}}$$

Where:

C : Hourly cost, L.E/h.
P : Price of machine, L.E.
h: Yearly working hours, h/year.
a:Life expectancy of the machine, h.
i: Interest rate/year.
F:Fuel price, L.E/l.
t: Taxes, over heads ratio.
r:Repairs and maintenance ratio.
m:The monthly average wage, L.E
0.9:Factor accounting for lubrications.
W: Engine power, hp.
S: Specific fuel consumption, l/hp.h.
144 : Reasonable estimation of monthly working hours.

The operating cost of the litter removal machine was estimated using the following equation

$$\mathbf{Operating\ cost = \frac{Machine\ cost\,(L.E/h)}{Productivity\,(m^2/h)},\ (L..E/m^2)}$$

The criterion cost was estimated according to the following formula:
Criterion cost (L.E/m^2) = operating cost +Unremoved litter cost
N.B: The cost of removal the litter in area of 1000 m^2 which represents area of one floor in poultry breeding farm about 150 L.E for 3 labors for 3 days approximately.

RESULTS AND DISCUSSIONS

The performance of the litter removal machine under different operating parameters were discussed under the following headlines;

Effect of different operating parameters on the productivity

The production values of litter removal machine versus both forward speed, litter moisture content, number of knives groups on the unit , and the knives number per each group were illustrated in **Fig. (3).**

Concerning the effect of machine forward speed on machine productivity. The results referred a consequent rise in productivity as increasing the forward speed for all treatments. By increasing the forward speed from 0.57 to 1.73 km/h at litter moisture content of 31.30 %, the productivity increased by 31.55, 29.74, 30.66, and 30.34 %for groups G_1, G_2, G_3, and G_4 respectively. This increase is attributed to the high machine production rate per unit time.

Relating to the effect of the litter moisture content on machine productivity. Increasing the litter moisture content from 25.43 to 38.82 % at forward speed of 1.13 km/h increased the productivity by 13.34, 12.62, 11.37, and 11.61 % for groups G_1, G_2, G_3, and G_4 respectively. This increase is due to the ease in moving the knives through the litter by increasing the moisture content .

Regarding to the increase of knives groups on the unit from three to four , the productivity increased by 4.42 and 8.07 % for unit of three knives and four knives per each group respectively at a litter moisture content of 31.30% and machine forward speed of 1.13 km/h. Also increasing the number of knives per each group from three to four increased the production by 5.29 and 8.96 % for unit of three and four groups respectively under the same conditions. This increase in productivity because of increasing the impact number of knives per time unit as increasing the knives groups and number of knives per each group.

Effect of different operating parameters on the removal efficiency

Removal efficiency is affected by many operating parameters. Un- controlling these parameters may caused a trouble in removing the litter that leads to increase the Unremoved area and decrease the removal efficiency. The removal efficiency versus the parameters under study were shown in **Fig (4).**

Stating the effect of machine forward speed on removal efficiency, the results showed increasing the removal efficiency as increasing the forward speed up to 1.13 km/h for groups G_1 and G_3, any further increase in forward speed up to1.42 km/h removal efficiency will significantly

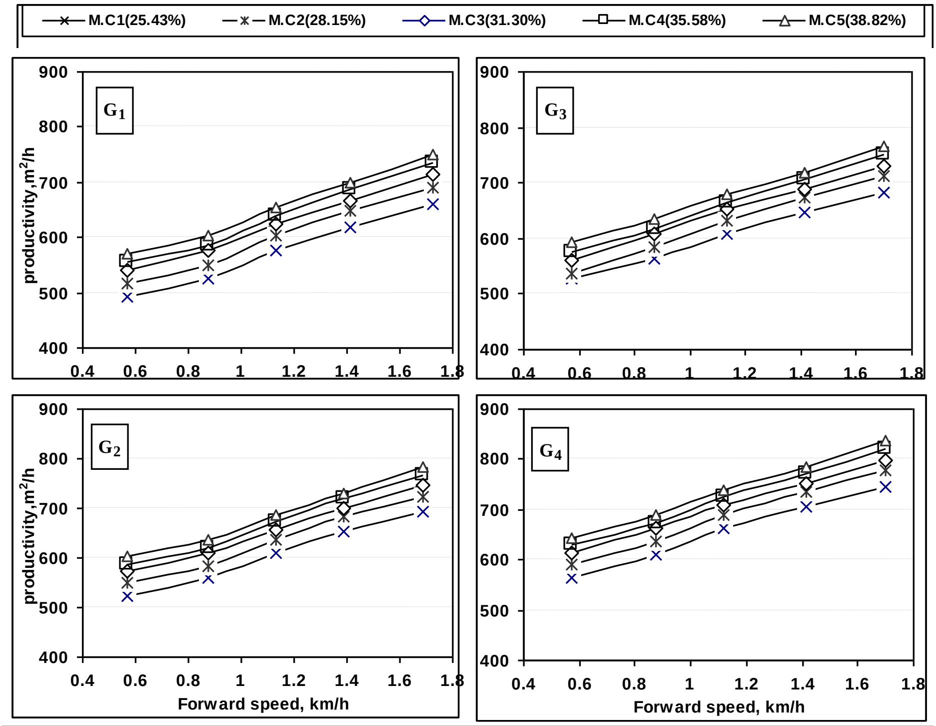


Fig.(3):Effect of different operating parameters on productivity.

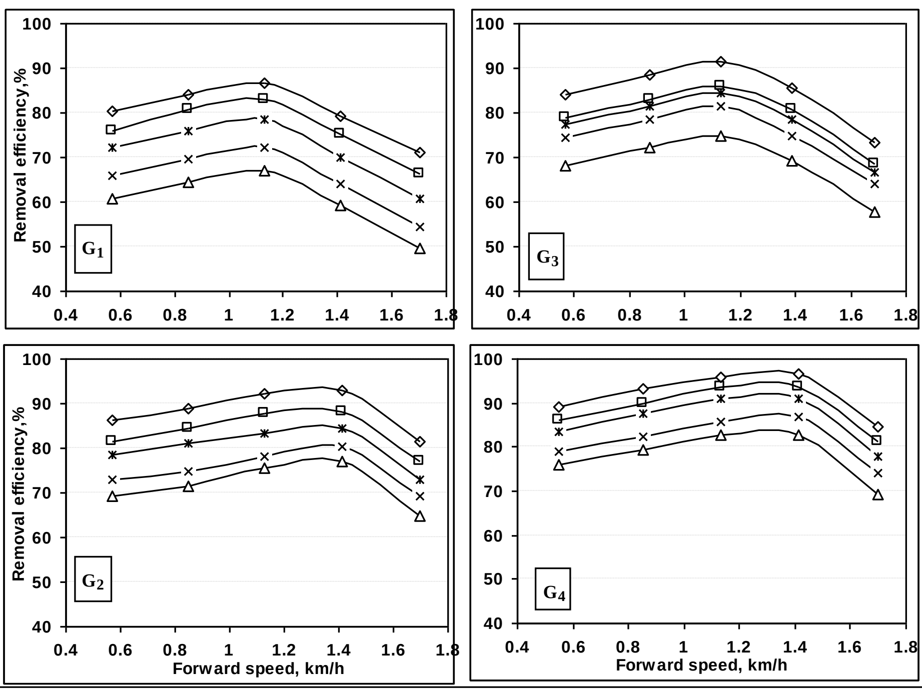


Fig.(4):Effect of different operating parameters on removal efficiency.

decrease. Increasing the forward speed from 0.57 to 1.13 km/h increased the removal efficiency by 7.83, and 8.69 at a litter moisture content of 31.30 % for groups G_1 and G_3 respectively. Higher values of forward speed more than 1.31 km/h were more effective in increasing the productivity but tended to increase unremoved area which in turn decrease the removal efficiency because of increasing the forward speed more than the constant peripheral speed of knives (low kinematic parameter) that may gave area knives (low kinematic parameter) that may gave area without removing the litter. On the other hand, reducing the forward speed less than 1.13 km/h caused an increase in the ratio of constant peripheral speed to forward speed (high kinematic parameter) that led to excessive impact number per time unit on the litter resulting in some damage in the farm ground. On the other hand, the treatments groups G_2 and G_4 at litter moisture content of 31.30 % increased the removal efficiency increased by 7.75 and 8.17 % by increasing the machine forward speed from 0.57 to 1.42 km/h. Any further increase in forward speed up to 1.71 km/h for groups G_2 and G_4 , removal efficiency will significantly decrease because of the difference in kinematic parameter between the machine forward speed and constant peripheral speed of knives.

Considering to the effect of litter moisture content on the removal efficiency. Data showed increasing the removal efficiency as increased the litter moisture content from 25.43 to 31.30 %, any further increase in moisture content up to 35.58 % removal efficiency will decrease and increased the losses. Increasing the litter moisture content from 25.43 to 31.30 %increased the removal efficiency by 20.22, 16.69, 12.39, and 12.47 % at forward speed of 1.13 km/h for groups G_1, G_2, G_3,and G_4 respectively. This increase in the removal efficiency is due to increase the impact force of knives to interact strongly with the litter and consequently decrease the unremoved area, while increasing the litter moisture content than 31..30 % leads to decrease the removal efficiency because of wheel slippage and increasing impact number per time unit in small area.

As to the effect of increasing knives groups on the unit from three to four , the removal efficiency increased by 5.31 and 3.90 % for unit of three knives and four knives per each group respectively at a litter moisture content of 31.30% and machine forward speed of 1.13 km/h. Also increasing the number of knives per each group from three to four increased the removal efficiency by 6.45 and 5.02 % for unit of three and four groups respectively under the same conditions. This increase because of increasing the impact number of knives per time unit as increasing the knives groups and number of knives per each group that led to decrease the unremoved area.

Effect of different operating parameters on power and energy

Representative data in **Fig. (5)** showed increasing the consumed power as increased the forward speed , number of knives groups, and number of knives per each group in the removal unit for all treatment ,while the vise versa is noticed with the litter moisture content. This increase in consumed power is due to the increase in fuel consumption to overcome the soil resistance to knives of machine .On the other hand, increasing the forward speed from 0.57 to 1.13 km/h decreased the energy requirement by 5.45 and 6.48 % at a litter moisture content of 31.30 % for groups G_1, and G_3 respectively, and Also, the energy requirements decreased by 7.36 and 6.96 % for groups G_2 , and G_4 respectively as increasing the machine forward speed from 0.57 to 1.42 km/h and the same litter moisture content. any further increase in forward speed more than 1.31 km/h for the treatment of G_1, and G_3 and more than 1.42 km/h for the treatments groups of G_2 , and G_4 increased the energy requirements for all treatment because of increasing the fuel consumption and consequently the power to increase the speed.

As to the effect of litter moisture content on the energy requirements. Increasing the litter moisture content from 25.43 to 38.82 % decreased the energy requirement by 40.83, 40.06, 39.83, and 37.70 % for treatments groups G_1, G_2, G_3,and G_4 respectively at forward speed of 1.13 km/h. This due to increase the machine capacity as increased the litter moisture content.

Remarking to the effect of increasing knives groups on the unit from three to four increased the energy by 6.45 % for group of three knives while decreasing the energy by 1.64 % for group of four knives at litter moisture content of 31.30 % and machine forward speed of 1.13 km/h because of high machine capacity, while increasing the number of knives per each group from three to four increased the energy by 26.73 % and 17.10 % for unit of three and four groups respectively under the same conditions.

Effect of different operating parameters on criterion cost

The criterion cost is considered one of the main parameters that connect the different operating parameters and gave accurate and clear data represent the optimum operating parameters under different conditions.

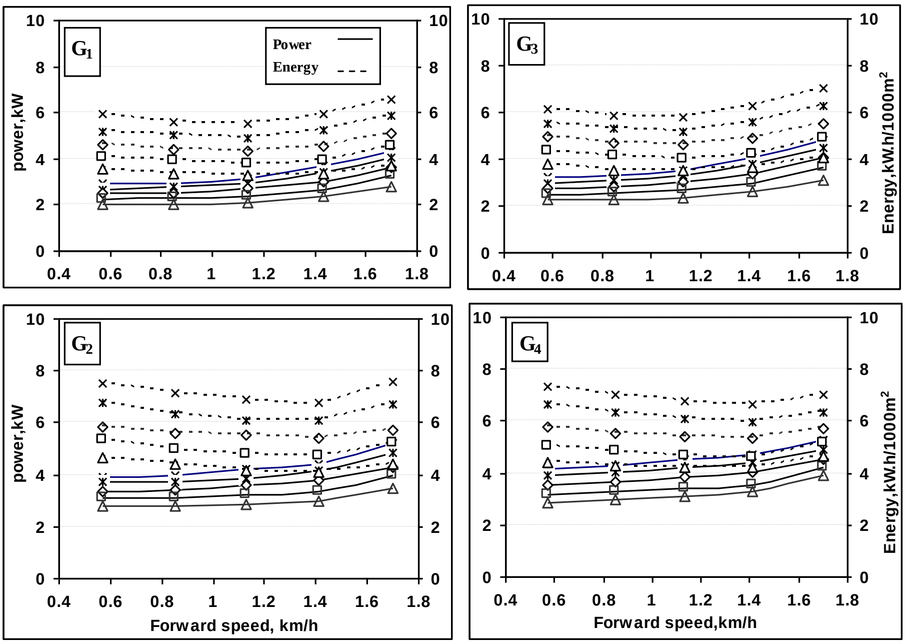


Fig.(5):Effect of different operating parameters on power and energy.

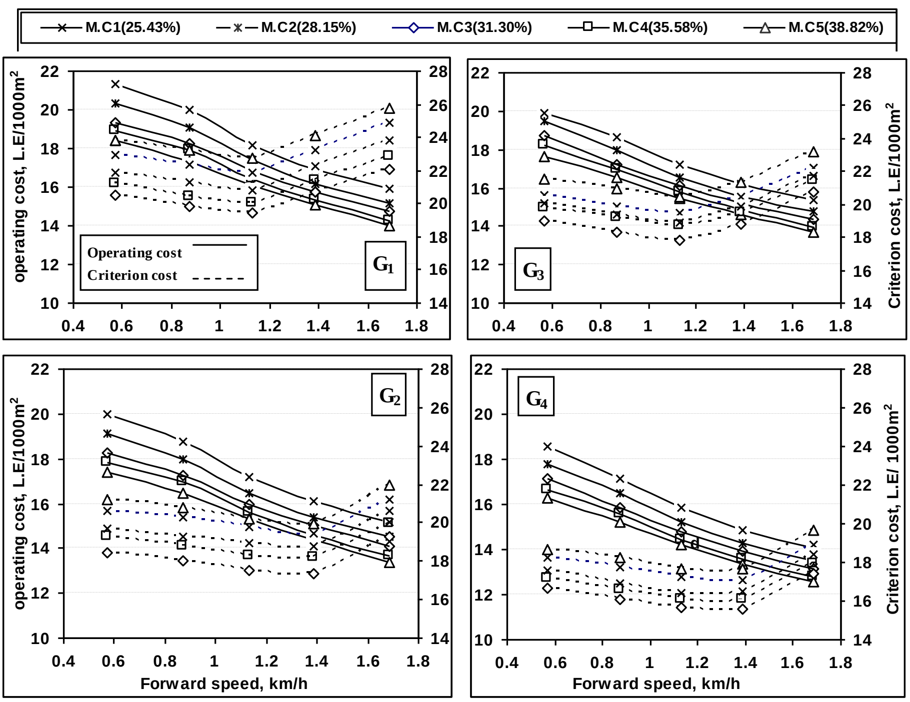


Fig.(6):Effect of different operating parameters on operation and criterion cost.

Observed data in **Fig. (6)** showed effect of machine forward speed on criterion cost. It is noticed that increasing the forward speed from 0.57 to 1.13 km/h decreased the criterion cost by 5.27 and 6.16 % at litter moisture content of 31.30 % for groups G_1 and G_3 respectively. Also increasing the forward speed from 0.57 to 1.42 km/h decreased the criterion cost by 5.85 and 6.58 % at litter moisture content of 31.30 % for groups G_2 and G_4 respectively at the same moisture content. Any further increase in forward speed more than 1.31 km/h for treatments groups G_1 and G_3 , and more than 1.42 km/h for treatments groups G_2 and G_4 increased the criterion cost for all treatment because of increasing the unremoved litter cost.

Relating to the effect of litter moisture content on the criterion cost, results stated that increasing the litter moisture content from 25.43 to 31.30 % decreased the criterion cost by 11.38, and 8.33 % at forward speed of 1.13 km/h for treatments of groups G_1 and G_3.Also decreased the criterion cost by 10.55 and 8.55 % at the same increase in litter moisture content and machine forward speed of 1.42 km/h for treatments of groups G_2 and G_4 .Any further increase in litter moisture content than more 31.30 up to 38.82 % criterion cost significantly increased because of increasing unremoved litter cost.

Viewing the effect of increasing knives groups on the unit from three to four on criterion cost. It decreased the criterion cost by 8.14 and 10.29 % for group of three and four knives at litter moisture content of 31.30 % and machine forward speed of 1.13 km/h. Also increasing the number of knives per each group from three to four decreased the criterion cost by 9.79 % and 11.90 % for unit of three and four groups respectively under the same conditions.

CONCLUSION

This study aimed to fabrication and manufactured a litter removal machine to exciting , removing and cleaning the litter in poultry farm. The results can be concluded in the following item;

1. The maximum of removal efficiency, the minimum of energy requirement and criterion cost were achieved at machine forward speed of 1.42 km/h , litter moisture content of 31.30 %, four groups of knives, four knives per each group on the unit

2. The kinematic parameter of 1.6 is recommended to be adjusted for operating the manufacture litter removal machine with three knives per each group and four groups of knives or kinematic parameter of 1.27 for machine with four knives per each group and four groups of knives

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الملخص العربى

تصنيع وتجميع آلة لإزالة الفرشة فى مزارع تربية الدواجن

محمود خطاب عفيفي*

تعتبر مشكلة التخلص من فضلات مزارع تربية الدواجن من المشكلات الأساسية التي تواجه مربى الدواجن نظرا لما تسببه من تلوث للبيئة المحيطة بصفة عامة وللإنسان وللطيور الموجودة بالمزرعة بصفة خاصة ومصدر رئيسي لانتقال الإصابة بمرض أنفلونزا الطيور بالإضافة إلى حاجة مربى الدواجن للتخلص من هذه المخلفات والحيوانات النافقة عند كل دورة تربية .بالإضافة إلى انه بناءا على مكونات الفرشة ودرجة تفتيتها ليسهل أضافتها للتربة وتعبئتها ونقلها ويتم تسعيرها من صاحب المزرعة والمشترى لبيعها كسماد عضوي.

تهدف هذه الدراسة إلى تصنيع وتجميع آلة تقوم بتفتيت الفرشة عن طريق مجموعة من الأسلحة الدورانية مركبة على عمود دوراني، يوجد قصابية مثبتة في الإطار من الداخل خلف مجموعة الأسلحة وعلى مسافة ٨ سم تساعد على تفتيت الفرشة المنزوعة بالإضافة إلى كسح الفرشة المفتتة بسهولة إلى مكان تجميع وتأخذ حركتها من موتور خاص (٥ حصان).

تم إجراء التجارب على خمسة سرعات أمامية للآلة (٠,٥٧)،(٠,٨٧)،(١,١٣)،(١,٤٢)،(١,٧٢) كم/ساعة وخمس نسب رطوبة للفرشة(٢٥,٤٣)،(٢٨,١٥)،(٣١,٣٠)،(٣٥,٥٨)،(٣٨,٨٢)% وعدد مجاميع الأسلحة الدورانية (ثلاثة وأربع مجموعات) وعدد أسلحة لكل مجموعة (ثلاثة وأربع أسلحة) وتم قياس تأثير هذه المتغيرات على إنتاجية الآلة وكفاءة نزع الفرشة والفاقد والقدرة والطاقة المستهلكة والتكاليف الحدية .وقد أظهرت النتائج أن السرعة (١,٤٢)كم/ساعة ونسبة محتوى رطوبى للفرشة(٣١,٣٠) % وعدد أربع مجاميع الأسلحة الدورانية وعدد أربعة أسلحة لكل مجموعة تحقق عندها أعلى كفاءة نزع للفرشة ٩٦,٦٠% وأقل استهلاك للطاقة ٥,٣٥ كيلوات.ساعة/١٠٠٠م^{٢}وأعلى إنتاجية ٧٥٢ م^{٢}/ساعة وأقل تكاليف حدية ١٥,٦١جنية/١٠٠٠ م^{٢} عند معامل كينامتيكى١,٢٧أفضل لتشغيل الآلة.كما يمكن تشغيل الآلة على معامل كينامتيكى ١,٦٠بأربع مجاميع للأسلحة الدورانية وعدد ثلاثة أسلحة لكل مجموعة بكفاءة٩٥,٤ % وإنتاجية ٦٥٧ م^{٢}/ساعة وتكاليف حدية ١٧,٥٠جنية/١٠٠٠ م^{٢} وسرعة امامية١,١٣كم/ساعة وعلى نفس المحتوى الرطوبى للفرشة.

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