Misr J. Ag. Eng., 25(3): 693-711 FARM MACHINERY AND POWER

DESIGN OF A SIMPLE UPRIGHT COMPOST TURNING MACHINE FOR SMALL FARMER

Abdel – Mottaleb A.,F. *

ABSTRACT

The aim of this study is to design and construct a simple upright compost turning machine suitable for small Egyptian farms .The performance of the designed machine was investigated as a function o
f forward speed (0.3 , 0.6 , 0.8 and 1.1m/sec) , rotor speed (240 , 350 , and 460 rpm) , number of compost turnings (1 , 2 , 3 and 4 times per month and pile shape (long pile and round pile) . Machine capacity , fuel consumption , power , energy and turning cost were determined .
The main results in this study can be summarized in the following points:

- *The composting time decreased from 24 weeks by manual method to 14 weeks by the new designed turning machine.*
- *The designed turning machine improves physical and chemical characteristics of the final compost comparing with the manual turning method.*

It is recommended to use the designed turning machine for small farmer projects under the following conditions : forward speed of about 0.3 m/sec , for turning round – shape piles , 0.8 m/sec for turning long – shape piles , rotor speed of about 460 rpm for both the two shapes of piles and 4 turnings per month .

INTRODUCTION

Field crop residues are considered one of the critical problems, which face the Egyptian farmer especially after harvesting. In Egypt, there are about 25 million tons yearly of the field raw material , the most important of which are rice straw (4million tons) , corn stalks (3.5 million tons) and cotton stalks (2 million tons).Ministry of Agr.(2001)

Therefore, the use of rice straw and other crop residues for making suitable and safe compost will reduce air pollution by avoiding field burning, reduce irrigation water by increasing water holding capacity, reduce mineral fertilizer consumption and finally help in producing safe healthy food.

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The good composting operation depends on the correct mixing and turning of materials . The compost turning and mixing in Egypt are still carried out manually, which is tedious and consumes long time with low production , Developed technologies such as front loader , tractor pulled and self propelled turning machine require high cost .

Rynk et al. (1992) stated that windrow composting consists of placing the mixture of raw materials in long narrow piles or windrows which are agitated or turned on a regular basis . Typically, the windrows , are initially from 0.9 m high for dense material like manures to 3.6 m high for fluffy materials like leaves . The width varies from 3 to 6 m. The equipment used for turning determines the size , shape , and spacing of windrow . They also added that a number of specialized machines have been developed for turning windrows . this machines greatly reduce the time and labor involved , mix the materials thoroughly and produce amore uniform compost . some of these machines are designed to attach to farm tractor or front – end loader , others are self – propelled .

Barington et al , (1997) investigated mixing and aeration performance during composting of apple residues mixed with saw dust . They reported that temperature of 60 to 65 C° could be reached with initial C / N ratio of 20 to 25 .

Yousef (2001) tested the feasibility of using fodder beet chopper as a dual purpose machine for turning and mixing the compost under local conditions comparing with the use of loader and manual methods . He concluded that the optimum conditions were peripheral speed of chopper between 4.54 and 5.34 m/s , cutting lengths of stalks less than 50 mm and compost moisture content less than 37.6 % for turning and mixing compost.

Abd El - Motalleb and Kotob (2004) stated that the most critical factors selecting the agitating system were the cost requirements and the economic returns from the operation . The tractor pulled agitating machine requires minimum value of cost estimated at about (76.7 L. E./ton) followed by the self propelled agitating (80.2 L.E./ton). The economic returns were estimated at about 18.6 % , 25% and 162 % for the self propelled agitating front loader and the tractor pulled agitating respectively.

Abd El–Mottaleb (2006) recommended to use self propelled turning machine for large projects and the tractor side – mounted machine for medium and small projects , under the following conditions :-

- Forward speed about 0.2 m/sec . For both side mounted and self – propelled turning machine–rotor speed of about 240 rpm .
- Number of compost turnings per month under all conditions was four times .

The objectives of this research are to :

- Design and construct of a simple upright compost turning machine suitable for small Egyptian farms .
- Optimize some different operating parameters affecting the manufactured machine performance .
- Compare the manufactured compost turning machine with the manual method with reference to final product quality .

MATERIAL AND METHODS

Field experiments were carried out through years of 2006 and 2007 in the Organization of land reform , Sharkia Governorate, to design , construct and evaluate a simple compost turning machine at appropriate for small Egyptian farmer :

Materials :-

Row material used :-

The materials used for composting were rice straw mixing with live – stock manure to accelerate Composting process .

The constructed compost turning machine :

A simple compost turning machine , suitable for small Egyptian farms , is constructed at low cost from local materials, to overcome the problems of high power and high cost requirements under the use of imported machines .

Several points were taken into consideration in the development of the new turning machine as follows :

- The manufactured machine should work with small compost piles and with different pile shapes .

- The manufactured machine is capable of reducing its width during transportation from one field to another.
- All moving shafts and gears are covered to achieve high degree of safety during work .

The compost turning machine design consists mainly of a frame , distribution unit , turning screws and transmission system as shown in figs : 1 , 2 , 3 , 4 and photograph : (5 , 6 and 7) .

The frame :-

The frame is made of good grade channel-section steel (U) of thickness (50 mm) and dimensions of (500–800 mm) . The frame comprises four rectangular component .

The first one is horizontal and the other three were fixed together in a trapezoidal shape . The horizontal one is used for fixing transmission system group , reducer , attaching to tractor and direction turntable . The other there rectangles contain turner tunnel with cater corner shape in horizontal position by the same size fixing of loading bearing for flexable joint , transmission system and gearbox .

Machine direction :-

Machine direction is divided into two positions: Tractor rear-mounting during moving at the road and side position for operation .

Distributing unit

Distribution unite is used for distributing both water and macro – organization solution .It consists of stop cock nozzle and distribution lines are mounted at the top level for turner. There is a top tank divided from inside into – two parts the first part for providing with necessary water for pile humidity during turning , and the other part for spraying the solution during turning process .Every part connected with hollow pipe at the level of machine for water or solution outgoing and stopcock to control spray rate.

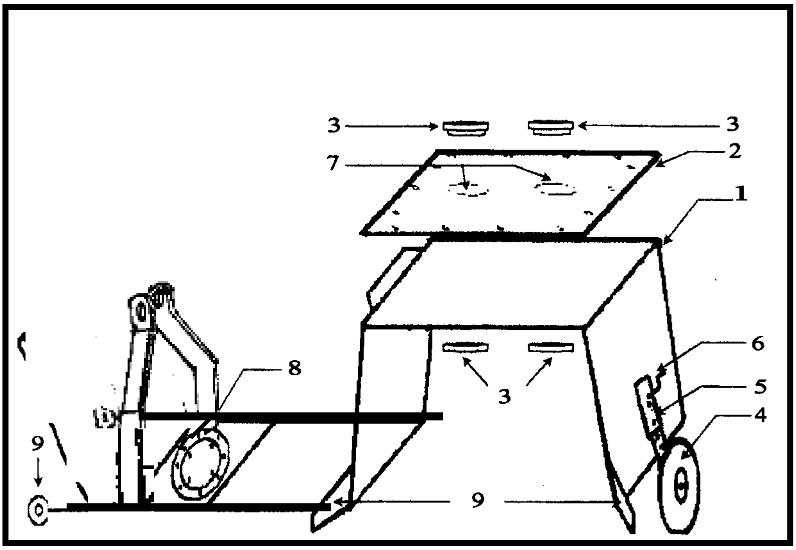


Fig. 1: Elvation view compose upright turning machine

1. 1chassis .
2. high cover
3. turn over bear (6207)
4. height adjusted wheel
5. height adjusted shaft
6. hand of height adjusted
7. fixing holes of loading
8. direction device
9. clasp device
10. a pile opener

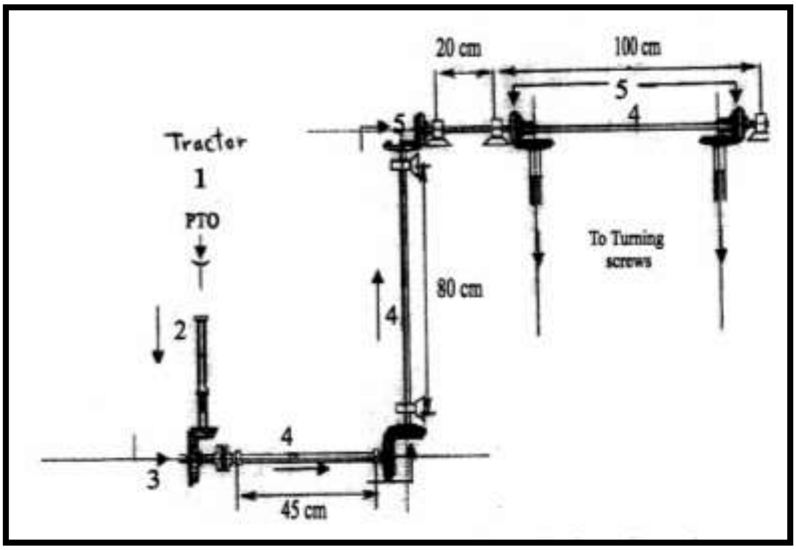


Fig. 2: diagram of transmission system in compost upright turning machine

1. PTO
2. flexable joint
3. reducer
4. connecting shafts
5. transmission bevel gears groups
6. fimbriate shaft to connect the movement to turning screws

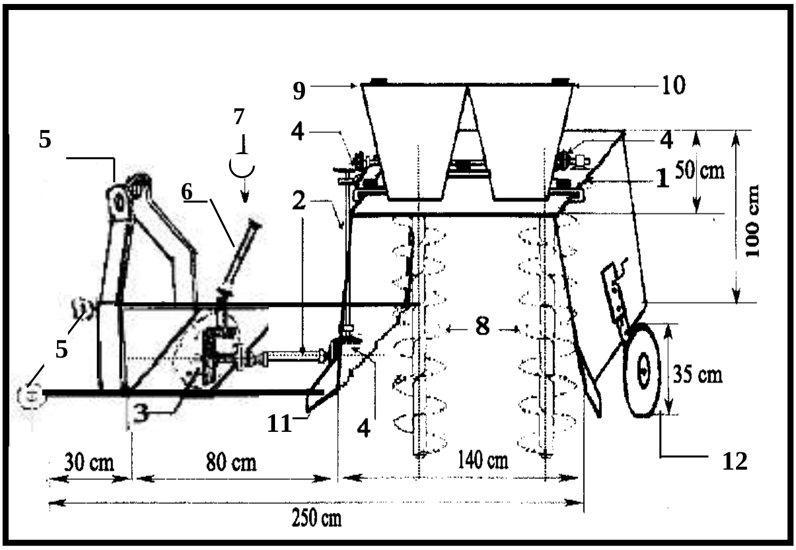


Fig. 3: Oblique sketch of compost upright turning machine

1. Chassis.
2. Connecting shaft.
3. Reducer.
4. Bevel gear.
5. Hitch points , Category II.
6. Flexible Joint .
7. PTO .
8. Screw .
9. Microbial tank .
10. Water tank
11. Apile opener
12. Height adjusted wheel

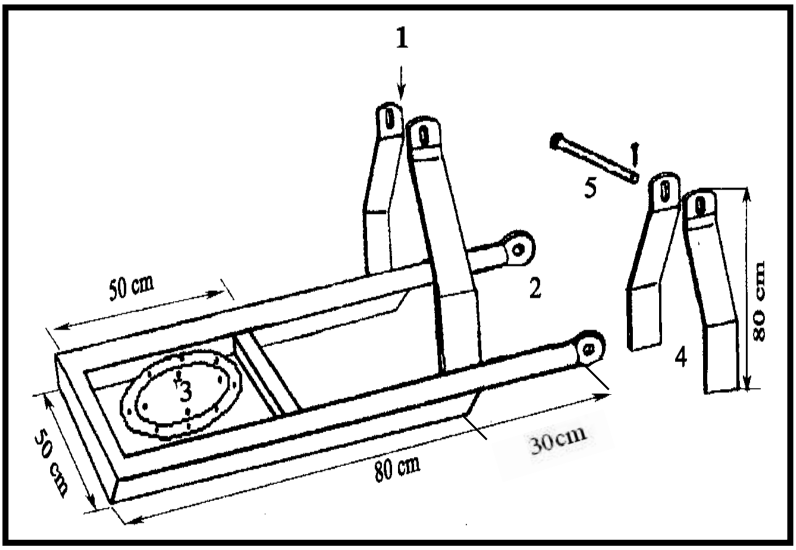


Fig. 4: Turning machine direction and clasp device in compost upright turning machine

1. Height clasp point .
2. Lower clasp point .
3. Splined coupling (35 mm) .
4. Clasp arms .
5. Pivot pin .

Fig.5: Photograph of upright turning machine .

Fig. 6 : Upright turning machine during work on long pile .

Fig. 7 : Upright turning machine during work on round pile .

Turning screws :-

Two turning screws fixed on two Tapered bearings (35 mm) with transmission system gear. Height of screw is 120 cm fixed on it are knives of diameter 21 cm, bit height is 11 cm.

Technecal Data :-

Item	During work	During Transport	Remark
mass (kg)	180	180	
Width (cm)	210	50	
Length (cm)	80	210	
Turning screw Number	2	2	Can be increased in the prototpe
Drum Length (cm)	110	110	
Steps Length (cm)		11	
Number of knives	15	15	
Drum Width , cm	20	20	

Turning screws speed from 240 to 460 rpm , forward speed from 0.3 to 1.1m/sec, power source 76 Hp = (56.3 kW) . Transmitted power : from PTO of tractor to turning machine by a flexible joint .

Methods :-

This investigation was divided into two separate experiments :

The first experiment :-

The first experiment was carried out to study the effect of the following variables on the performance of the developed compost turning machine .

1. Two pile shapes : long shape and round Shape .
2. Four machine forward speeds :- 0.3 , 0.6 , 0.8 and 1.1 m/sec. for the long-shape pile and one speed 0.3 m/sec.for around shape pile.
3. Three rotor speeds :- (240 , 350 , 460) rpm for both two pile shapes .
4. Number of compost turnings :- (1 , 2 , 3 and 4) Time per month.

To optimize the above mentioned parameters , the following indicators were taken into consideration :

1. **machine capacity :** Machine capacity (m^3 / sec) was determined using the following formula : machine capacity = A * V Where : A : is cross sectional area (m^2) and V : is forward speed (m / sec) .

2. **Fuel Consumption :**

Fuel consumption was recorded by accurately measuring the decrease in fuel level in the fuel tank, immediately after executing each operation . Fuel consumption in L / m^3 can be calculated as follows :- Fuel consumption (L / m^3) = Consumed fuel (L / h) / Machine capacity (m^3 / h)

3. **Power required :**

The required power (kW)was calculated by using The following Formula : P = Wf . CV . E_{th} . 427 . 1/ . 1 / 136 .(Barger et al .,1963) Where: Wf : fuel consumption (kg/s), CV: calorifice value of fuel (k.cal/kg) . Average C.V. of solar fuel is 10^4 k. cal /kg. 427 : thermo mechanical equivalent (kg .m/k. cal), E_{th} :Thermal efficiency of the engine (%),considered to be 30% for diesel engine .

4. **Energy requirements** :

Calculated by using the following equation :

Energy requirements (kW.h/m^3) =Turning power (kW) / machine capacity m^3 / h .

5. **Turning Cost :-**

Machine Cost was determined by using the following formula :

C = P/ h (1/ a + 1/2 + t + r) + (0.9 w* f *s) + m / 144 . (Awady , 1978) .

Where : C : hourly cost ; P : price of the machine ; h : yearly working hours ; a : life expectancy of the machine ; I : interest rate / year ; t : taxes and overheads ratio; r : repairs and maintenance rat;w : Power ;f :Specific Fuel consumption.(about 0.4l/kW.h); s:Fuel price (L.E/L) ; m : operator monthly wage ; 0.9 : Factor accounting for ratio of rated power and lubrication ; 144 : The monthly average working hours.

Turning cost can be determined using the following equation :

Turning cost (L.E/ m^3) = machine cost (L.E / h) / machine capacity (m^3 / h) .

6. Composting Time :-

The required time from begining until compost maturity (stability inside pile) was recorded .

1. Compost density :-

Compost density was determined according to the following formula : P = M/V

Where : P: Compost density , g / cm^3 , M:Compost sample mass , g
V:Compost sample volume , cm^3 .

The second experiment :-

The second experiment was conducted to compare between the action of the developed compost turning machine and the manual turning method in respect to final product quality . Final product quality was assessed in terms of the following indicators :

- Percentage of Nitrogen , organic carbon , organic material and Water holding capacity .

RESULTS AND DISCUSSION

The discussion will cover the results obtained under the following headings :-

1. Effect of forward speed on machine capacity at different rotor speeds :

Machine capacity (m^3/h) is highly affected by both machine forwared speed , as shown in fig . 10 : Concerning turning long –shape pile results show that increasing machine forwared speed from 0.3 to 1.1 m/ sec. at rotor speeds of (240 , 350 and 460 rpm) increased machine capacity from 12 to 43 , from 18 to 60 and from 22 to 71.4 m^3 / h . during turning long -shape piles (windrows) .

Experimental work showed that the machine did not work well above , forwared speed of 1.1 m / sec . due to the high vibration in turning screws.

The increase in machine capacity by increasing forwared speed is attributed to the increase in quantity of turning windrows per unit time .

As to turning round -shape piles , the machine was operated at only forwared speed of 0.3 m / sec. and different rotor speeds of 240 , 350 and

460 rpm . Data show that the machine capacity values were 12 , 18 and 22 m^3 / h . at rotor speeds of 240 , 350 and 460 rpm respectively .
The reason of turning round shape – piles at one forwared speed : is because the driving around them with high forwared speed has a bad effect on both tractor and machine .

2. **Effect of machine forwared speed on fuel consumption at different rotor speeds :-**

Results in fig. 11: show that the fuel consumption per hour and fuel consumption for preparing one compost cubic metre are greatly affected by both machine forward speed and machine rotor speed . Considering turning long -shape piles , experimental data obtained show that increasing forwared speed from 0.3 to 1.1 m/sec . at various rotor speeds of 240 , 350 and 460 rpm . increased hourly fuel consumption from 4.8 to 6.4, from 5 to 7 and from 5.4 to 7.4 L/h , while decreasing fuel consumption for one cubic meter of compost from 0.4 to 0.2 , from 0.33 to 0.17 and from 0.29 to 0.155 L/m^3 .
As to turning round – shape pile , results show that the machine was operated at only one forwared speed and three different rotor speeds .
Hourly fuel consumption values were 4.8 , 5 and 5.4 L/h at rotor speeds of 240 , 350 and 460 rpm respectively , while fuel consumption values per cubic meter were 0.4 , 0.33 and 0.29 L/m^3 under the same previous conditions .

The increase in hourly fuel consumption by increasing forwared speed is attributed to the increase in the amount of turned compost per unit time . The same trend was noticed with rotor speeds , increasing rotor speed increased hourly fuel consumption due to the increase in screw revolutions per unit time, that requires high power resulting in more fuel consumption .
The decrease in fuel consumption per cubic meter by increasing forwared speed is attributed to the increase in machine capacity but only to a certain extent, because fuel consumption per cubic meter slightly increased after the forwared speed of 0.8 m/sec.

3. **Effect of machine forwared speed on power and energy requirements at different rotor speeds :-**

Results in fig.12 show that power and energy requirements are affected by both machine forwared speed and rotor speed with regard to turning long – shape piles obtained show that increasing forwared speed from 0.3 m/sec. to 1.1 m/sec at various rotor speeds of 240,350 and 460 rpm , increased power requirements from 60.3 to 90.5 from 70.1 to 90.5 kW and from 75 to 92.9 kW , while decreased energy requirement from 5 to 3.5 , from 3.5 to 2.5 and from 3.0 to 1.9 kW. h/m^3 .

As to turning round- shape piles , at one forwared speed 0.3 m/sec and different rotor speeds of 240 , 350 and 460 rpm . The required power values are 60.3 , 70.1 and 75 kW . At The same time, the energy requirement values are 5.0 , 3.5 and 3.0 kW . h/m^3 .

The increase in the required power by increasing forwared speed is due to the increase in the quantity of turned compost per unit time . At the same time, required power is also increased by increasing rotor speed and resistance torque that tend to increase fuel consumption as well .

The decrease in the energy requirements by increasing forwared speed is attributed to the high increase in machine capacity . But at the same time, energy requirements increased slightly by increasing forwared speed more than 0.8 up to 1.1 m/sec .

4. <u>Effect of machine forwared speed on turning cost at different rotor speeds :-</u>

Fig.13 shows that both hourly cost and turning cost (L.E/m^3) are highly affected by both machine forwared speed and rotor speed . With regard to turning long – shape piles , data obtained show that increasing forwared speed from 0.3 m/sec. to 1.1 m/sec at various rotor speeds of 240 , 350 and 460 rpm increased hourly cost from 106.1 to 309 , 131.1 to 325 and from 211 to 350 L.E/h while decreasing turning cost from 13 to 11.3 , 12.5 to 8.35 and from 18.3 to 7.1 LE/ m^3 .

As to turning round shape piles, data were recorded at only one forwared speed 0.3 m/sec. under three rotor speeds (240, 350 and 460 rpm). The hourly cost values were 106.1 , 131.1 and 211 L.E/h while turning cost values were 13 , 12.5 and 11.3 L.E/m^3 . Hourly cost increased by increasing both forwared and rotor speeds, and resistances requiring more fuel and power and resulting in high cost . while the decrease in turning cost by increasing forwared speed up to 0.8 m/sec. is attributed to the increase in machine capacity . Increasing forwared speed more than 0.8 m/sec. up to 1.1 m/sec. tends to increase turning cost .

5. Effect of Number of turns on composting time , moisture content and density of the final product :-

Results in Fig.14 show that composting time , compost dnesity and moisture content are highly affected by number of turns for both long and round– shape piles .

Data show a remarkable decrease in composting time from 26 to 14 weeks and from 27 to 15 weeks for both number of turns per month from 1 to 4 times.

Also, the density decreased from 690 to 560 kg/m^3 and from 690 to 580 kg/m^3 with a decrease in compost moisture content of final product from 55 % to 34 % and from 55 % to 35.3 % under the same previous conditions .

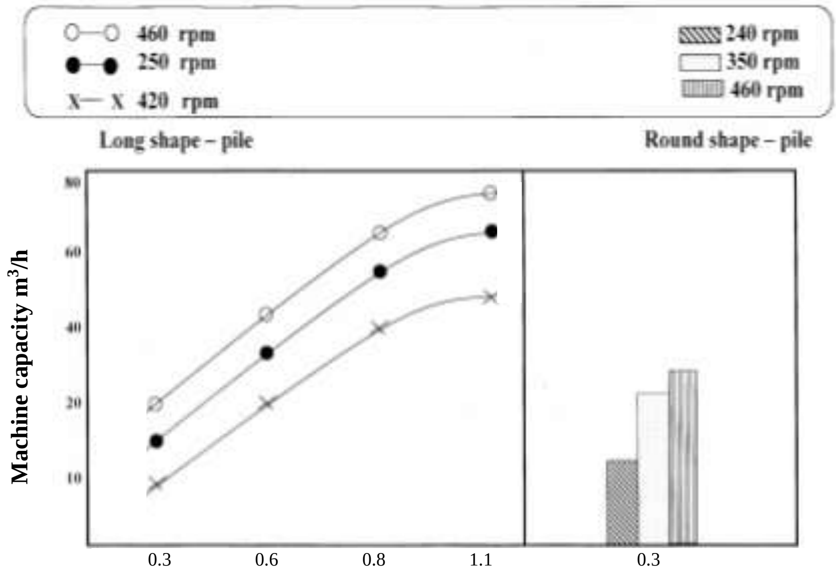
The decrease in composting time , density and moisture content for final product is attributed to the increase in aeration rate and active composting that generates considerable heat , large quantities of carbon dioxide , and water vapor .

6. Effect of turning method on some physical and chemical properties of final product :-

Fig.15 shows the effect of turning method on some physical and chemical specifications of final product in terms of Nitrogen, organic carbon , organic material and water holding capacity percentage .Relating to nitrogen percentage, results show that nitrogen percentage were 1.31 and 1.03 % in turning long – shape piles using turning machine and manual turning respectively .

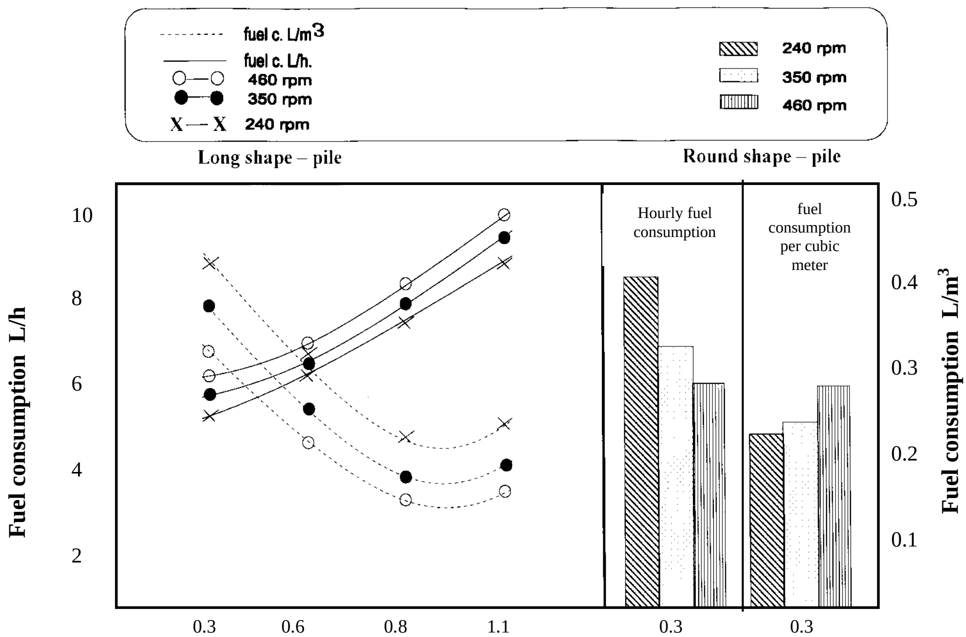
Meanwhile Nitrogen percentages were 1.1 and 0.7 % in turning round – shape piles under the same previous conditions.

Considering organic carbon, data show that organic carbon percentages were 19.9 and 17.5 % in turning long-shape piles using turning machine and manual methods respectively, while organic carbon percentages were 18.6 and 14 % during turning round –shape piles under the same previous conditions.



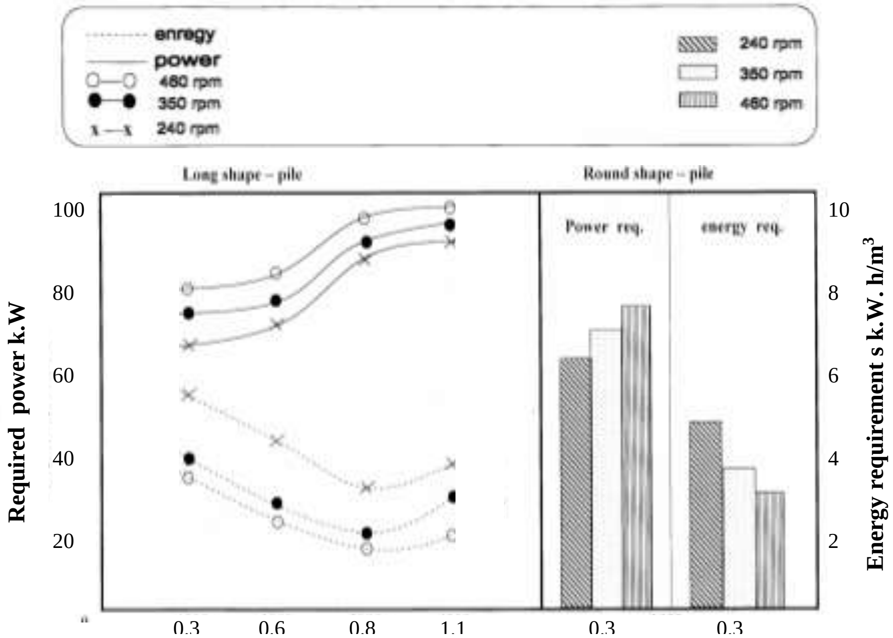
Forwared speed , m / sec .

Fig.8 : Effect of forwared speed on turning machine capacity at different speeds



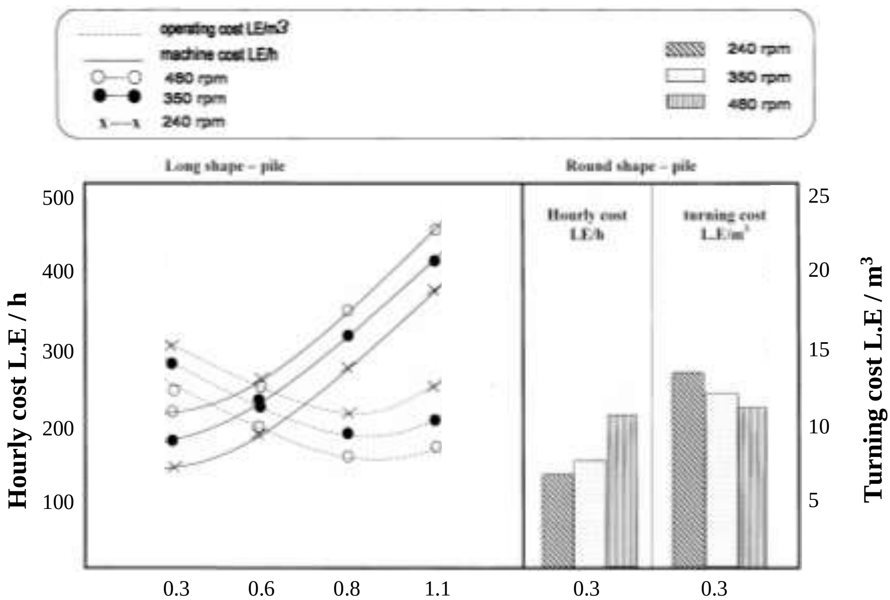
Forwared speed , m / sec .

Fig.9 : Effect of forwared speed on fuel requirment at different rotor speeds



Forwared speed , m / sec .

Fig .10: Effect of machine forwared speed on power and energy requirment at different rotor speeds



Forwared speed , m / sec .

Fig.11: Effect of machine forwared speed on hourly cost and turning cost .

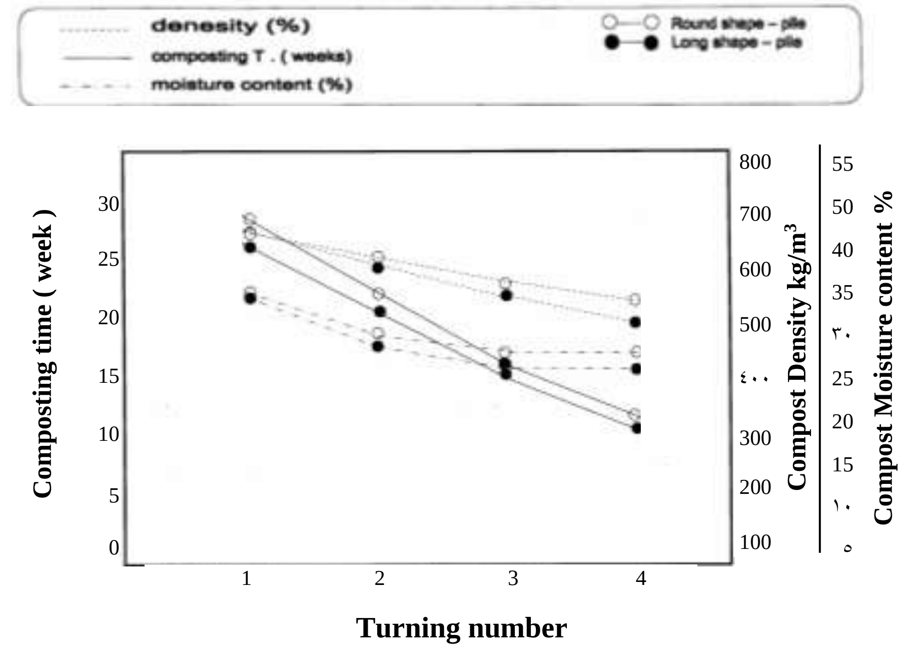


Fig.12: Effect of turnng number on composting time, moisture content and density of the final product

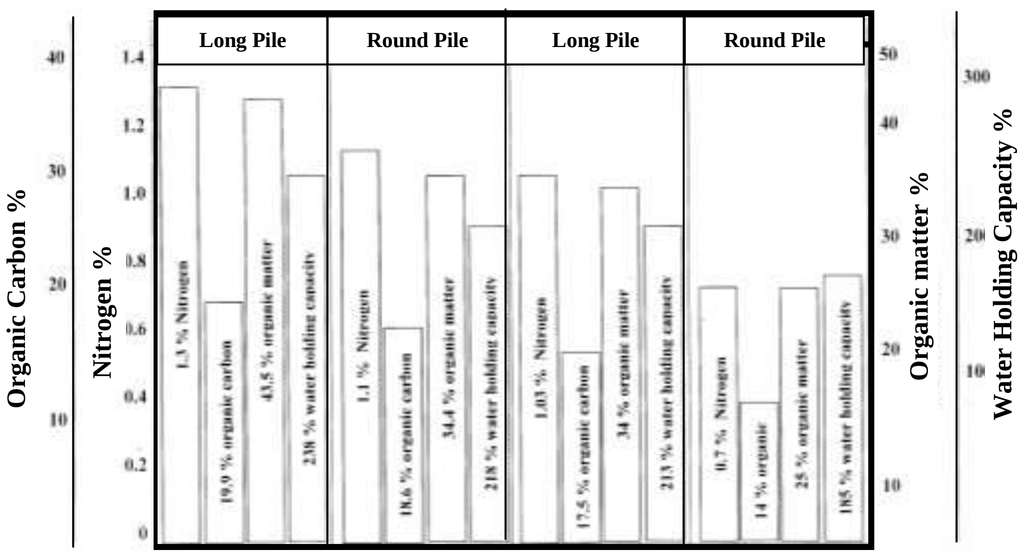


Fig.13: Effect of turning method on some physical and chemical specifications of find product

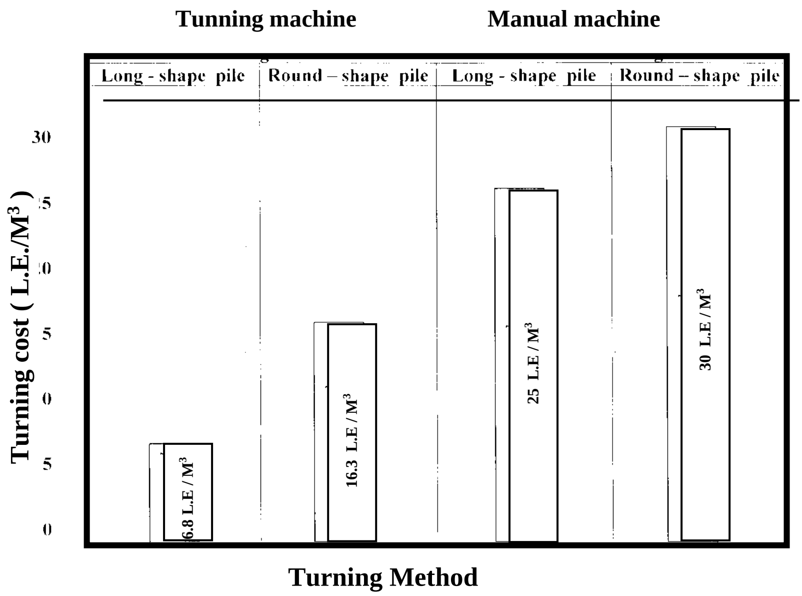


Fig.14: Effect of turning method on turning cost

Concerning organic material , obtained data show that organic material percentage values were 43.5 and 34% in turning long-shape piles using turning machine and manual turning . Meanwhile these were 34.4 and 25% in turning round-shape piles under the same previous conditions .

As to water holding capacity , data show that water holding capacity were 238 and 213% in turning long-shape pile using turning machine and manual turning respectively . Meanwhile these were 218 and 185 % in turning round-shape piles under the same previous conditions .

It is obvious from the above mentioned results that turning compost using the manufactured turning machine improves physical and chemical properties of the final product comparing with the manual method .

7. Effect of turning method on turning cost :-

Turning costs were considered the major factor in reducing the price of the final product and principal factor in selecting the composting method . Results in fig .16 show that turning costs were 6.8 , and 25 L.E /m^3 during turning long – shape piles by using the designed upright turning machine and manual turning respectively .

Meanwhile turning costs were 16.3 , 30 L.E/m^3 in turning round – shape piles under the same previous methods .

The reduction of turning cost by using the turning machine in both long and round piles was attributed to the higher machine capacity comparing with the manual turning .

CONCLUSION

From the obtained results it is recommended to use the new design turning machine for small and middle farmers under the following conditions :-

1. Forwared speed of about 0.8 m/sec. for turning long – shape piles and 0.3 m/sec. for turning round – shape piles .
2. Rotor speed about 460 rpm for turning both long and round – shape piles .

Number of compost turnings per month of (4), for both long and round shape piles .

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الملخص العربي

تصميم آلة رأسية بسيطة لتقليب الأسمدة العضوية لصغار الزراع

د/ أحمد فؤاد عبد المطلب

فى الوقت الذى أصبحت فيه الزراعة العضوية إحدى سمات الزراعة الحديثة للاستفادة من المخلفات الزراعية فى إنتاج أسمدة عضوية . ولما كانت النظم المستخدمة فى إنتاج وصناعة الأسمدة العضوية بطريقة الكمر فى مصر لا تصلح للتوسع فى هذه العملية على مستوى صغار الزراع إما لارتفاع التكاليف الاستثمارية أو إرتفاع المستوى التكنولوجى للنظم المنتشرة أو إحتياجها لمساحات كبيرة فى التنفيذ ، فقد تم تصميم آلة بسيطة التركيب سهلة الاستخدام والصيانة رخيصة التكاليف تجعل إنتاج السماد العضوي لدى صغار ومتوسطى الزراع عملية سهلة ميسرة ، مما يزيد من إنتشار الزراعة العضوية النظيفة .

وقد تم إستخدام آلة التقليب الرأسية على مستوى صغار الزراع على شكلين مختلفين للكومات السمادية : المستديرة إذا كان رأس الحقل صغيرا ،والكومات الطويلة أو المصفوفة إذا كان رأس الحقل طويلا وفى الحالتين تم مقارنة ذلك بنظام التقليب اليدوي .

وكانت أهم نتائج إستخدام الآلة هو تخفيض تكلفة إنتاج م^{٣} الواحد من السماد العضوى إلى ما يقرب من ٧٢ % بالإضافة إلى تخفيض فترة الانضاج إلى ما يقرب من ٦٠ % وذلك بالمقارنة بالطريقة اليدوية .

وكذلك أمكن إنتاج سماد عضوى جيد تقترب مواصفاته من المواصفات القياسية للأسمدة العضوية حيث إحتوى السماد الناتج على ١,٣١ % نيتروجين , ١٩,٩ % كربون عضوى وكانت نسبة c/n (١ : ٢٠,٢) , ١٣,٥ % مادة عضوية , ٢٣٨ % درجة التشبع بالماء , والكثافة ٥٦٠ سم / م^{٣} .

وأوصى البحث بتشغيل الآلة فى الكومات الطولية عند سرعة تقدم ٠,٨ م/ ثانية , والكومات المستديرة عند ٠,٣ م/ ثانية وعند سرعة ٤٦٠ لفة / دقيقة لدرفيل التقليب . ٤ مرات تقليب كل شهر فى كلا الحالتين . ويوصى الباحث أيضا باستمرار تطوير النموذج الأول لهذه الآلة حتى تصل إلى إنتاجها تجاريا وتخفيض تكاليف تصنيعها مما يساعد على إنتشار إستخدامها والتوسع فى إنتاج السماد العضوى على مستوى المزارع الصغيرة والمتوسطة .

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