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A NEW NETWORK DESIGN FOR FORCING AIR TO PRODUCE COMPOST

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ABSTRACT

The main objective of this study was to develop a network system for forcing air through the compost pile to facilitate production of good compost. Experiments were carried out using four forcing air network systems under three levels of flow rates. The four systems were transversal system (S1), longitudinal system (S2), width and length system (S3) and reciprocal system (S4). However, the three flow rates were 0.0098, 0.0196, and 0.0294 m^3/min Five parameters were used to judge the quality of produced compost. These were acidity (pH value), moisture content (%), total nitrogen (%), bulk density (kg/m^3) and the carbon to nitrogen ratio (C/N). The obtained results indicated that the most suitable design for a network to produce compost of acceptable quality was the width and length system (S3) within which air is forced at rate of 0.0196 m^3/min Moreover, results of a comparative study conducted among this system and with both of natural conveyance and self propelled agitator systems indicated that although the natural conveyance method gave the highest profit, yet the system that depended on forcing air (width and length system (S3)) seemed more preferable.

INTRODUCTION

In Egypt, lots of livestock manure and agricultural wastes are produced each year. This amounts are estimated at about 25 million tons annually. If the wastes are not treated properly, they will cause serious environmental pollution. In the past, there were five methods of dealing with organic wastes. These were: throwing them away directly into country roadsides, streams, and brooks; burning them; using them as feed; incorporating them directly into farmland; and composting them. The first two methods are not environment-friendly. The third method cannot be adapted for all organic wastes.

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The fourth method, though economical, may pose some sanitary problems, and may cause the soil to become too reductive, thus retarding the normal growth of crops. Only the fifth method is generally accepted by the people and the government. Therefore, composting is considered the best choice to get rid of the agricultural wastes. It aims at both conservation of the environment, human safety and economically convenient production. Also, through composting process, the malodorous and unstable organic wastes are converted to organic fertilizers and soil conditioners. Using composts increases soil fertility and saves on chemical fertilizer costs.

Based on studies by researchers and work experiences of farmers in Egypt, there are several composting methods for dealing with agricultural wastes. They are static pile, aerated static pile (active or passive), box chamber, open furrow with turning and aeration, and enclosed vessel with mechanical agitation and aeration. The aerated active pile system was used under this study. This system has been designed to work on the basis of there is no turning but through forced air for the purpose of producing the compost from a mixture of rice straw and cattle dung with ratio of 2:1.

Therefore, the main objectives of this study were to: 1) design a network for forcing air through the compost pile to facilitate production of good compost. 2) study the effect of both type of the networks design and the rate of forcing air through it on the end-product, i.e. the compost beside of saving labor and time of production. 3) evaluate the forcing air system of producing compost economically with both natural conveyance aeration and self-propelled agitator systems used under Egyptian conditions.

LETRATURE REVIEW

Owing to the hazardous potential of using the ordinary mineral fertilizers in the soil and its surroundings (ground waters, drains, etc.), organic manure was found to be a suitable substitute for such mineral fertilizers **(Abbas et al., 2006 and 2010)**. Composting is regarded as a fully sustainable practice, since it aims at both conservation of the environment, human safety and economically convenient production **(Sequi, 2000).** The use of compost contributes to conservation by reducing both utilization of non-renewable resources and consumption of energy for waste treatment of chemical fertilizers. Composting indirectly also contributes to human safety by avoiding an improper fate or disposal of organic wastes. Furthermore, due to its low cost, compost is convenient to the farmer, but even more to the society by avoiding the use of expensive solutions for waste disposal **(Bitton, 1999).** A large amount of solid wastes remains after the harvesting operations of different crops. These residues are commonly moved to dumps, where they pose a threat of environmental pollution. Owing to the increase of agricultural wastes annually, the disposal systems became unable to meet their huge volumes. The field residues are now the main cause of the most critical problems in air, ground, and water pollution. Egypt annually produces estimated crop residues weighting about 25 million tons on dry basis. The total amount of rice straw reaches about 3.6 million tons (dry matter) per year **(Abd El-Mottaleb and Kotob, 2005)**.

Different systems of composting wastes have been evaluated by several researchers. Manure and other organic wastes contain naturally occurring microorganisms capable of decomposing material anaerobically or aerobically. Although there exists a number of different composting methods and technologies, there are three main systems of centralized composting: aerated static pile process, windrow process and enclosed systems **(Martin and Gershung, 1992, and Hong et. al.,1997).** **Merkel (1981)** reported that the rate at which organic matter decomposes is affected by the moisture content, C/N ratio of the organic matter, temperature, availability of oxygen, pH value, and particle sizes. **Hansen et al. (1989)** pointed out that there are about 20 factors that might potentially affect the composting process. The most important factors include carbon to nitrogen ratio (C/N), physical structure of the raw material, moisture content (M.C), pH, temperature, and degree of aeration. Two aeration rates (0.850 and 1.70 L/min) were investigated by **Hatem and Ghaly (1994).** The results indicated that both aeration rates produced good quality compost, but the aeration rate of 1.7 L/min produced less odors during the composting process. In all cases, the final products had similar appearance. **Eldridge and Shane (1993)** pointed out that the forced aeration method of composting has relatively large start-up costs. Energy costs for operating the fans is off-set by reduction in windrow turning labor and associated costs. Savings occur in the form of reduced composting area requirements, rapid composting time, and potential reduction of odors.

Sartaj et al. (1995) stated that based on the method of aeration, composting technologies can be classified as natural aeration (NA), passive aeration (PA), forced aeration, termed windrow and in-vessel composting. **Sartaj et al. (1997)** stated that in essence, during composting, microorganisms consume oxygen, nutrients, and organic matter to produce new cells, stable organic residues, energy in the form of heat, carbon dioxide, water, ammonia, and some minor end products. For efficient composting, operational parameters such as available nutrients, moisture, temperature, aeration, and pH have to be optimized to create an environment that will maximize aerobic thermophilic activity **(Das and Keener, 1997)**. **Walker et al. (1999)** stated that the differences between these classes of technology are largely based on how intensely the heterogeneous, poly phases environment is managed to achieve the desired perfection. Windrows are the simplest and the least intensively managed. The two process variables are most frequently used to manage this natural process with aeration rate missing frequency. **Rync, R. (1992)** reported that aerobic composting consumes a large amount of oxygen. In addition for providing oxygen, aeration removes heat, under vapor and other gases trapped within the composting materials. The required air flow rates depend on how aeration is managed. Therefore, the current investigation was conducted to provide an efficient system for aeration of the composting pile aiming to achieve a good quality of compost produced on one hand and of a high economic value on the other hand.

MATERIALS AND METHODS

Experimental procedures

Experiments were carried out at the Factory of the Super-Bio Company, Dakahlyia Governorate, during the year of 2008. Four network systems of forcing air in the composting piles were designed. The schematic designs of the different network forcing air systems are shown in Figure (1). These systems were transversal system (S1), longitudinal system (S2), width and length system (S3) and reciprocal system (S4). The four network systems were evaluated under three levels of air flow rates.

These were 0.0098, 0.0196 and 0.0294 m^3/min Engineering calculations were carried out to determine the appropriate air flow rate, the pipe specifications (area, diameter and perforated pipe length) and the hole diameter in the pipe according to the volume of material in each pile and the final dimensions of the pile (length, width and height). Therefore, each system was designed using 20 bar PVC pipes of 63.5 mm. diameter and 3.9 mm. thickness, with 2.62 m. length and 1.3 m. width. The length and width were drilled with holes at equally divided distances of 300 mm. (center to center) in two parallel rows. The raw materials used under the experimental work were rice straw and cattle dung with a mixed ratio of 2:1. Samples were randomly taken from raw materials (dung and rice straw) to determine the physical and chemical properties of raw materials before forming the composting piles. These properties are illustrated in the Table (1).

Table 1. Physical and chemical properties of raw materials.

Acidity (pH) 1:10	Moisture content %	Organic matter %	Organic carbon %	Dry matter %	Total N %	Total Fe mg/kg	Total Mn mg/kg	Total Zn mg/kg	Total Cu mg/kg	Bulk Density kg/m³
Cattle Dung										
8.7	82	82	43.9	18	0.7	145	45	29	25	378
Rice Straw										
6.37	8.2	82.19	47.67	91.8	0.61	632	67	103	41	72

Twelve compositing piles were prepared using the following steps:

1. Rice straw was collected from the field after harvesting operation. It was dried and pulverized into three fractions (3-5, 5-7 and 7-10 cm. length). Then, it was mixed immediately with the cattle dung by a ratio of 2:1 (by weight).
2. A compost substrate was formed and produced at site by the mechanical aeration method with a 3.4m. length, 1.8m. width and 10 cm. height.
3. The piping networks which were designed for this study were placed over the above mentioned substrate.

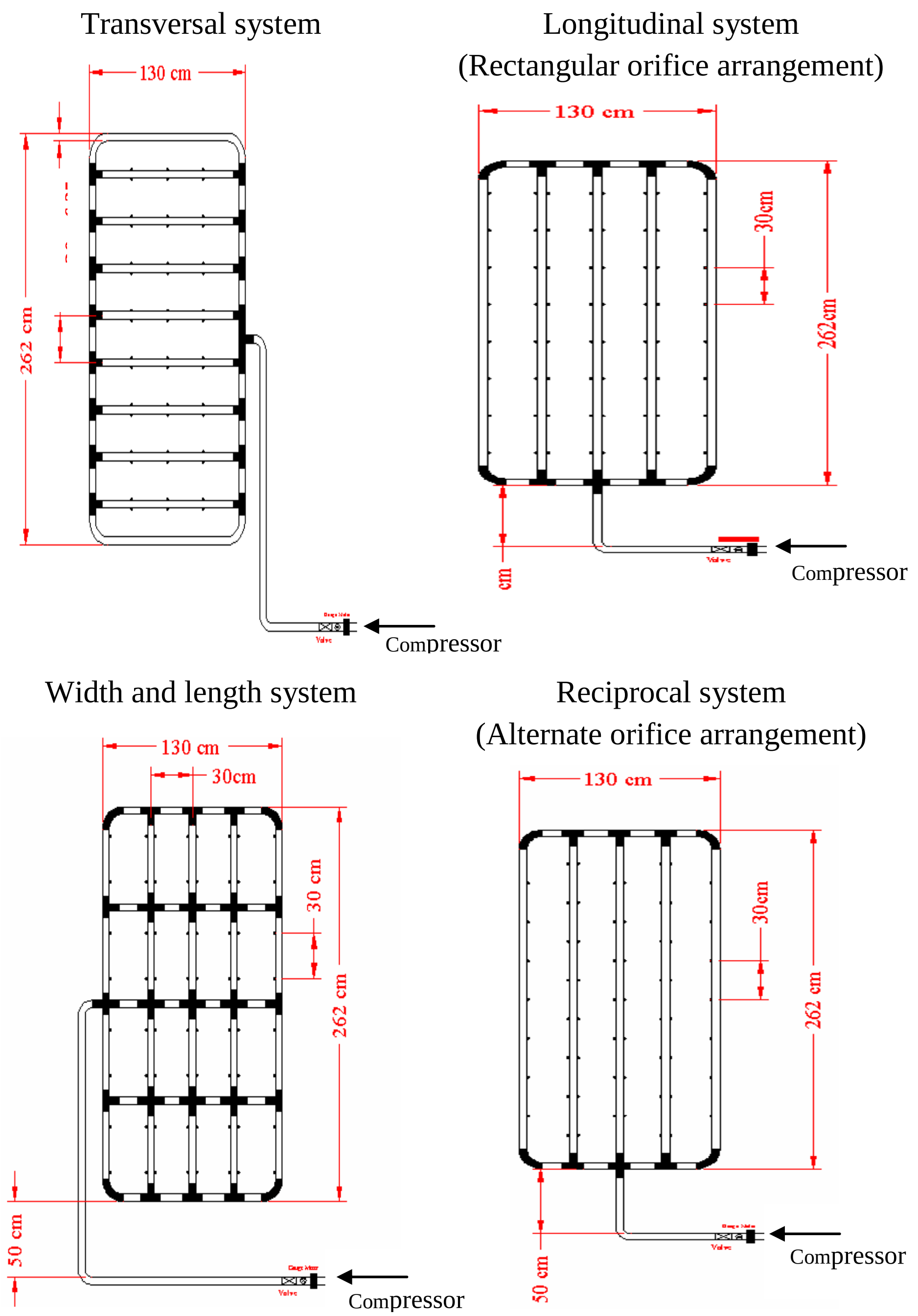

Figure (1): Schematic designs of the different network forcing air systems used in the current study.

4. The mixed raw materials were placed directly over the piping networks and the formed piles having a 1.05 m. height and covered with a 10 cm. thick compost layer.
5. The previous calculated air flow was forced through the network for 15 minutes daily during the period of composting.

Measurements

Measurements were taken for the following parameters to judge the quality of produced compost under this study.

Moisture Content

Four samples of moisture content from each pile were taken at 50 cm. depth and at a distance of 75 cm. apart along pile at the beginning of experiments. Then, it was repeated every week during the period of composting. Samples were weight before and after drying at 70C° for 48 hours in an electrical oven. After that, the moisture content (M.C %) was determined using the following equation.

$$M.C\,(\%) = ((Mw - Md) / Mw) \times 100 \qquad (ASAE, 1997)$$

Where:

M.C = moisture content, (%),

M_w = mass of the wet sample; (g), and

M_d = mass of the dry sample, (g).

Bulk Density

Samples of bulk density were handled as the samples of moisture content without drying. The bulk density (B.D) was determined using the following equation.

Bulk density = Dry mass (g) / Total volume (cm^3) **(ASAE,1997)**

Acidity (pH value)

The acidity (pH value) of the composting media was determined using the acidity (pH) meter. Four samples of the acidity were taken every week from each pile. Five grams from each sample was placed in the glass baker of 50 cm3 capacity and 30 mL of water was added and agitated together according to the method of **Hong et al.,** (**1983**).

Carbon to Nitrogen Ratio (C/N)

Samples from each pile were taken every week during the period of composting to determine the percentages of both carbon and nitrogen. All samples were analyzed chemically at the "Soil Laboratory Centre of Mansora Uni." Then, the carbon to nitrogen ratio was estimated.

Evaluation Parameters

To evaluate the forcing air system used in this study in terms of the cost of one cubic meter and the characteristics of produced compost, a comparative study was conducted between this system and the other two systems widely used for producing compost in Egypt. These systems were the natural conveyance system conducted by the authors **(Ahmed, 2010)** and self propelled agitation system **(Abd El-Mottaleb and Kotob, 2005)**.

RESULTS AND DISCUSSION

Five parameters were used to judge the quality of produced compost under this study. These were acidity (pH value), moisture content, total nitrogen, bulk density and the C/N ratio.

Acidity (pH value)

Figure (2) shows the effect of the forcing air systems on the pH value at various levels of flow rates. It is indicated that there is no appreciable change in the pH values of produced compost at various levels of air flow rates. However, the flow rate of 0.0196 m^3/min produced the lowest values of the pH at different forcing air systems. This may have been due to that the composting periods for producing compost were 9, 8 and 7 weeks at the flow rates of 0.0098, 0.0196 and 0.0294 m^3/min, respectively. The width and length system (S3) of forcing air resulted in the highest values of the pH at various levels of air flow rates. These values were 8.33, 8.24 and 8.35 at the flow rates of 0.0098, 0.0196 and 0.0294 m^3/min, respectively. On the other hand, there is no potential difference in the pH values among the other three forcing air systems at various levels of air flow rates. These results are in agreement with previous findings by **(Conti, et al.1996 and Hong et al.1985)**.

Moisture Content

The effect of the forcing air systems on the moisture content of the produced compost are illustrated in Figure (3). Data show that the highest values in the moisture content were obtained with the flow rate of 0.0098 m^3/min for the four systems of forcing air. However, the differences in the moisture content values between the other two flow rates (0.0196 and

0.0294 m^3/min) are not significant. This result is due to the change in the temperature through the period of composting process (from starting to end) which decreased by 38%, 31% and 27% for 0.0098, 0.0196 and 0.0294 m^3/min flow rates, respectively **(Hatem and Ghaly, 1994)**. The comparison among the four systems of forcing air showed that the width and length system (S3) resulted in the lowest values of moisture content under different flow rates. On the other hand, the highest values of the moisture content were obtained with the reciprocal system (S4). Moreover, there was no potential change in the moisture content values between the transversal (S1) and longitudinal (S2) systems under different flow rates. This may have been attributed to the ability of the width and length system (S3) for providing oxygen and removing the heat is better than other systems **(Inbar et al., 1993).**

Total Nitrogen

Figure (4) shows the effect of the forcing air systems on the total nitrogen at various flow rates. Data indicated that the two flow rates of 0.0196 and 0.0294 m^3/min produced the highest values of total nitrogen at different systems of forcing air. On the other hand, the lowest values of total nitrogen were obtained with the flow rate of 0.0098 m^3/min under different systems of forcing air. These results are in agreement with previous findings by **Hong et al., (1985)**.

They observed that, for static pile, the total nitrogen of produced compost is increased when the aeration rate increased. There were no potential differences in the values of total nitrogen among the four systems of forcing air except with the longitudinal system (S2), which was slightly high under different flow rates.

Bulk Density

Figure (5) shows the effect of the forcing air systems on the bulk density at various levels of flow rates. The width and length system (S3) of forcing air gave the highest values of bulk density under various levels of flow rates. However, the lowest values of the bulk density were obtained by the reciprocal system (S4).

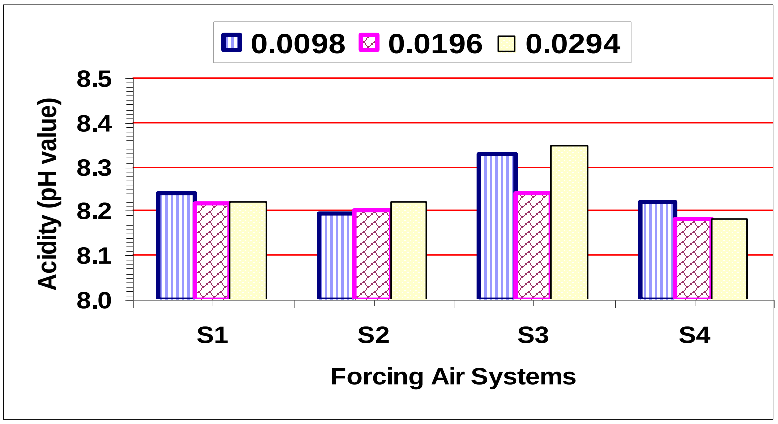

Figure 2. Effect of forcing air systems on the pH value of produced compost at different flow rates.

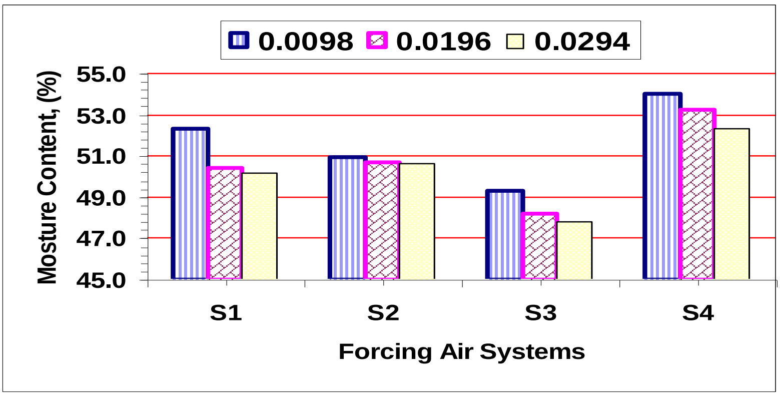

Figure 3. Effect of forcing air systems on moisture content of produced compost at different flow rates.

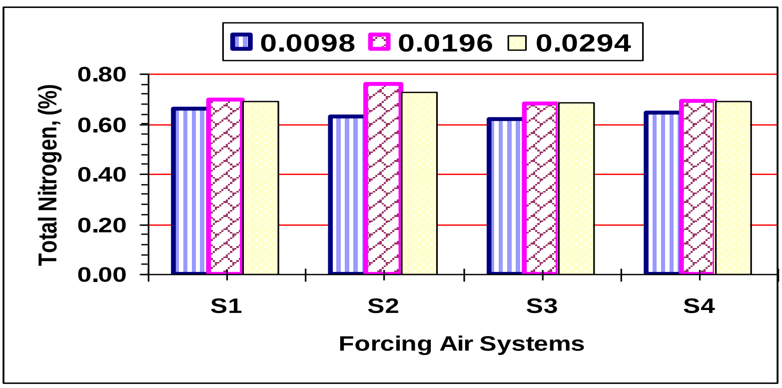

Figure 4. Effect of forcing air systems on total nitrogen of produced compost at different flow rates.

The increase in the flow rate from 0.0098 to 0.0294 m^3/min produced an increase in the bulk density values of about 8% for all systems of forcing air. The highest values of the bulk density were obtained from the flow rate of 0.0294 m^3/min with the width and length forcing air system (S3). These results could be attributed to the following reasons:

- The increasing in bulk density with increasing the flow rates may be due to the compression effect of air flow which may decrease in the pore volume of produced compost **(Bunt, 1976)**.
- The width and length forcing air system (S3) produced the highest values of bulk density due to its ability to force air better than other systems under this study **(Chang et al., 1981).**

Carbon to Nitrogen Ratio (C/N)

Data in Figure (6) show that the C/N ratio in the produced compost decreased with increasing the air flow rate at all the forcing air systems. These results are due to the following reasons:

- Retertion of nitrogen as the flow rate increased **(Hong et al., 1985)**.
- The decreasing in the required time for composting as the flow rate increased **(Hatem and Ghaly, 1994)**.

The comparison among the four systems of forcing air showed that the lowest carbon to nitrogen ratios were obtained with both the width and length system (S3) and the transversal system (S1) under different flow rates. Meanwhile, the highest carbon to nitrogen ratio (C/N) was obtained with the longitudinal system (S2) and lowest rate of air flow (0.0098 m^3/min). This may have been attributed to the ability of the width and length system (S3) to loss carbon more than other systems **(Wilson and Hummel, 1972)**.

Evaluation Parameters

Two parameters were used to evaluate the forcing air system used under this study with the other systems of producing compost under Egyptian conditions. These parameters were the characteristics of the produced compost and its cost per cubic meter.

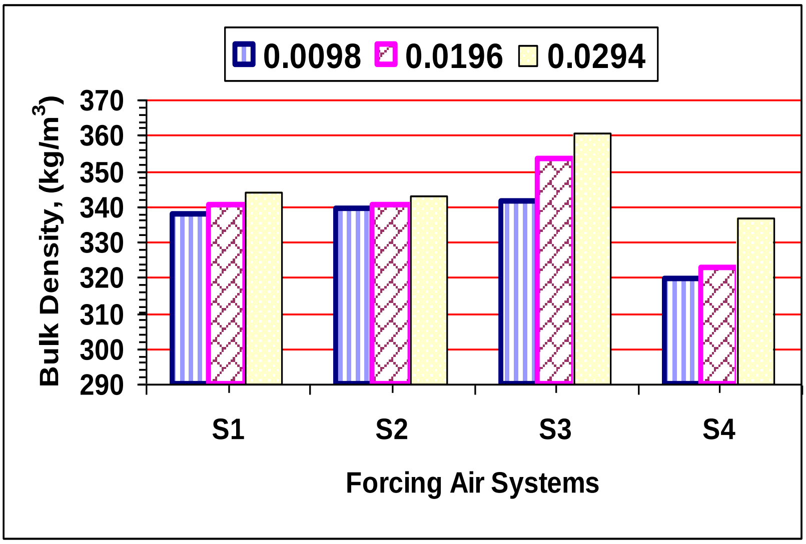

Figure 5. Effect of forcing air systems on bulk density of produced compost at different flow rates.

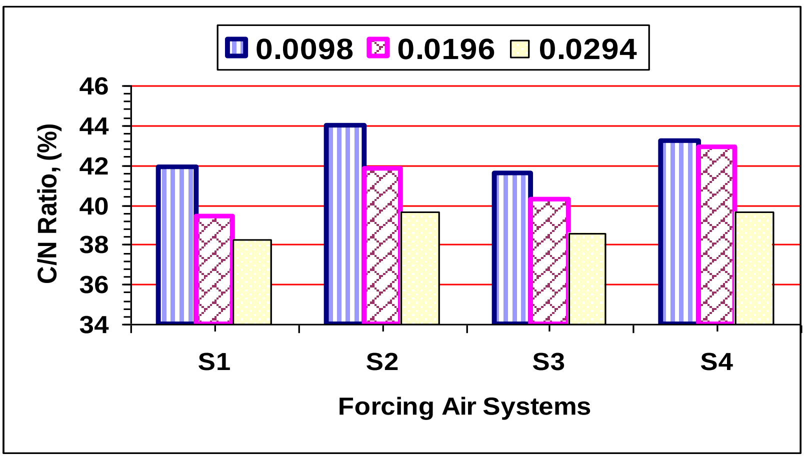

Figure 6. Effect of forcing air systems on carbon to nitrogen ratio of produced compost at different flow rates.

Characteristics of produced compost

Data in Table (2) show the effect of compost production systems on the final characteristics of compost. The composting period of the width and length system decreased by 27% and 8% as compared with natural conveyance and self-propelled agitator systems, respectively. This may be due to the ability of the forcing air system to provide oxygen and remove the heat better than other systems. In terms of the parameters used to judge the quality of produced compost, results of comparison showed that:

1. There is no appreciable change in the pH values among the three systems of produced compost.
2. The moisture content values with the width and length systems decreased by 10 % and 17% when compared with natural conveyance and self-propelled agitator systems, respectively.
3. The total nitrogen does not increase by more than 3% among the three systems.
4. The highest bulk density was obtained with the width and length system. However, there is no potential change between the natural conveyance and self-propelled agitator systems.
5. The width and length system gave the highest carbon to nitrogen ratio (C/N) compared with natural conveyance and self-propelled agitator systems.

Total costs of one cubic meter of produced compost

Data in Table (3) show the effect of compost production systems on the total costs of one cubic meter of the produced compost. It is indicated that the natural conveyance system gave the lowest total costs. However, the moderate and the highest values of total costs were obtained with the width and length and self-propelled systems, respectively. These results may have been attributed to the following reasons:

1. The cost elements of rent for land (1.77 L.E/m^3), pure soil (20.65 L.E/m^3), plant residues (14.75 L.E/m^3) and plastic cover (5.9 L.E/m^3) are constant for the three systems. The value of common cost elements represented almost 93%, 97% and 91% of the total

costs for the width and length, natural conveyance and self-propelled systems, respectively.

2. The aerated tubes cost for natural conveyance system was a third of the cost of the width and length system. However, there is no cost for this element with the self-propelled system.
3. The cost of turning machine for the self-propelled system was 4.22 L.E/m^3 and this value represented about 10% of the total costs for the three systems.

Table 2. Effect of compost production systems on the characteristics of produced compost.

System	Composting Period (day)	pH	M.C %	T.N %	B.D kg/m^3	C/N %
			Production specifications			
Width and length	56	8.62	41.60	0.87	407.60	20.01
Natural conveyance	77	8.76	46.18	0.86	373.94	16.40
Self propelled agitator	60	8.70	49.90	0.85	372.83	18.00

Table 3. Effect of different compost production systems on the total costs of one cubic meter and one ton of produced compost.

Items of cost	Width and length system		Natural conveyance system		Self propelled agitator	
	L.E/ton	L.E/m^3	L.E/ton	L.E/m^3	L.E/ton	L.E/m^3
Rent for land	3	1.77	3	1.77	3	1.77
Pure soil	35	20.65	35	20.65	35	20.65
Plant residues	25	14.75	25	14.75	25	14.75
Plastic cover	10	5.9	10	5.9	10	5.9
Aeration tubes	5	2.95	1.7	1.003	-	-
Turning machine	-	-	-	-	7.16	4.22
Total costs	**78**	**46.02**	**74.7**	**44.1**	**80.16**	**47.29**

SUMMARY AND CONCLUSION

Results of this study could be summarized as follows:

- There is no appreciable change in the pH values of produced compost at various levels of air flow rates. However, the flow rate of 0.0196 m^3/min produced the lowest values of the pH at different forcing air systems. The width and length system (S3) of forcing air resulted in the highest values of the pH at various levels of air flow rates.
- The highest values in the moisture content were obtained with the flow rate of 0.0098 m^3/min for the four systems of forcing air. However, the differences in the moisture content values between the other two flow rates (0.0196 and 0.0294 m^3/min) are not significant. The width and length system (S3) resulted in the lowest values of moisture content under different flow rates.
- The two flow rates of 0.0196 and 0.0294 m^3/min produced the highest values of total nitrogen at different systems of forcing air. However, there are no potential differences in the values of total nitrogen among the four systems of forcing air except with longitudinal system (S2), which was slightly high under different flow rates.
- The highest values of the bulk density resulted with the flow rate of 0.0294 m^3/min followed by 0.0196 m^3/min and 0.0098 m^3/min, respectively. On the other hand, the width and length system (S3) of forcing air gave the highest values of bulk density under various levels of flow rates.
- The lowest values of carbon to nitrogen ratio were obtained with both the width and length system (S3) and also with the transversal system (S1) under different flow rates. However, the moderate values of carbon to nitrogen ratio were obtained with 0.0196 m^3/min flow rate.
- In comparison among the three systems of producing compost, results showed that:
  - The composting period of the width and length system decreased by 27% and 8% as compared with natural conveyance and self-propelled agitator systems, respectively.
  - The width and length system resulted in the highest values of the carbon to nitrogen ratio (C/N) compared with other systems.

- The natural conveyance system resulted in the lowest values of total costs. However, the moderate and highest values of total costs were obtained with the width and length and self-propelled systems, respectively.

- Final results indicated that the most suitable design for a network to produce compost of acceptable quality was the width and length system (S3) within which air is forced at rate of 0.0196 m^3/min Moreover, results of comparative study conducted among this system and with both of natural conveyance and self propelled agitator systems indicated that although the natural conveyance method gave the highest profit, yet the system depended on forcing air (width and length system (S3)) which seemed more preferable.

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الملخص العربي

تصميم جديد لشبكات دفع الهواء لإنتاج السماد العضوي(الكومبوست)

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إن الهدف الرئيسى من هذا البحث هو تصميم نظـام هندسى لشبكة يتم من خلالها دفع الهواء مباشرةً إلى الكومة بمعدلات تحقق الإنتاج السريع والجيد للسماد العضوى (الكومبوست) وكذلك دراسة بعض العوامل الهندسية المؤثرة على عملية الإنتاج للكومبوست باستخدام هذا النظام مثل معدلات مختلفة لدفع الهواء ، بالإضافة إلى عمل مقارنة بين هذا النظام والأنظمة الأخرى لإنتاج السماد العضوي تحت الظروف المصرية (نظام الحمل الطبيعي للهواء ونظام التقليب باستخدام آلة ذاتية).

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وللوصول إلى تحقيق الهدف من هذا البحث فقد تم تصميم وتصنيع وتركيب أربع شبكات متماثلة فى المحيط الخارجى كنماذج تجريبية لدفع الهواء داخل كومات السماد العضوي (شبكة عرضية (S1) - شبكة طولية (S2) - شبكة عرضية وطولية (S3) - شبكة على شكل رجل غراب (S4)) بحيث كان طول الشبكة الواحدة 2.62 m. وعرضها 1.3 m. ، كماتم دفع الهواء داخل الكومات بمعدلات مختلفة ($0.0098\ m^3/min$- $0.0196\ m^3/min$- $0.0294\ m^3/min$). وقد تم تحضير كومات الكمبوست من قش الأرز مع روث الماشية الطازج بنسبة خلط مقدارها ١:٢. وكانت أهم النتائج التى تم التوصل إليها هي:

- أعطى نظام الشبكة العرضية والطولية (S3) أعلى قيمة لرقم الحموضة (pH) في السماد العضوي الناتج مقارنة بالأنظمة الأخري. بينما لم تكن هناك فروق معنوية لقيم رقم الحموضة (pH) بين المعدلات المختلفة لدفع الهواء.
- أعطى نظام الشبكة العرضي والطولي (S3) أدنى قيمة للمحتوى الرطوبي في السماد العضوي الناتج مقارنة بالأنظمة الأخري. بينما كانت أعلى قيمة للمحتوى الرطوبي في السماد العضوي الناتج باستخدام معدل دفع الهواء $0.0196\ m^3/min$.
- كانت أعلى القيم لنسبة النيروجين الكلية في السماد العضوي الناتج باستخدام معدلي دفع الهواء $0.0196\ m^3/min$ و $0.0294\ m^3/min$. بينما لم تكن هناك فروق معنوية بين القيم المختلفة لنسبة النيروجين الكلية في السماد العضوي الناتج باستخدام الأنظمة الشبكية المختلفة لدفع الهواء.
- أعطى نظام الشبكة العرضي والطولي (S3) أعلى قيمة للكثافة الظاهرية في السماد العضوي الناتج مقارنة بالأنظمة الأخري. بينما أعطى معدل دفع الهواء$0.0196\ m^3/min$ القيم المتوسطة للكثافة الظاهرية في السماد العضوي الناتج مقارنة بمعدلات دفع الهواء الأخرى.
- أعطى نظام الشبكة العرضي والطولي (S3) أدنى قيمة لنسبة الكربون إلى النتيروجين (C/N ratio) في السماد العضوي الناتج مقارنة بالأنظمة الأخري. بينما أعطى معدل دفع الهواء $0.0196\ m^3/min$ القيم المتوسطة لنسبة الكربون إلى النتيروجين (C/N ratio) في السماد العضوي مقارنة بمعدلات دفع الهواء الأخرى.
- أوضحت دراسة المقارنة بين الأنظمة المختلفة لانتاج السماد العضوي تحت الظروف المصرية أن طريقة التهوية عن طريق الحمل الطبيعي للهواء قد حققت أدنى تكاليف للمتر المكعب، وعلي الرغم من ذلك فإن طريقة دفع الهواء عن طريق الشبكة العرضية والطولية تعتبر أكثر تفضيلاً حيث أنها أدت إلي نوعية أعلي من الكمبوست الناتج فضلاً عن أنه لم تكن هناك فروق معنوية بين التكاليف الكلية للنظامين.