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EFFECTIVENESS OF THE AERATION METHOD AND PILE SHAPE DURING COMPOSTING PROCESS

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ABSTRACT

The current investigation was oriented to study the effectiveness of the aeration method and pile shape during composting process. Six piles of about 6m^3 were formed from the mixture of rice straw and cow dung during the composting process. Three piles had the shape of pyramidal frustum and three others had the semi-cylindrical one. Each geometrical shape of pile had three different methods of aeration; static pile, turned windrow and passive aeration. The results of the present investigation showed that the composting process has been accomplished with the highest rate in the semi-cylindrical pile with the passive aeration method. While the pyramidal frustum with the static pile showed the lowest values of composting parameters as compared to all the investigated treatments. During the mesophilic phase, the pile temperature declined to the ambient one quicker in the semi-cylindrical pile with the passive aeration by 166.67% than in the pyramidal frustum with the static pile. During the thermophilic phase, the semi-cylindrical pile with the passive aeration achieved lower peak temperature by 19.37% than in the pyramidal frustum with the static pile. During the cooling down phase, the semi-cylindrical pile with the passive aeration hastened the composting period by 143.75% as compared to the pyramidal frustum with the static pile. The C/N ratio of the finished compost in the semi-cylindrical with the passive aeration was lowered by 77.87% as compared to the pyramidal frustum with the static pile. The germination index was higher in the semi-cylindrical pile with the passive aeration by 30.81% as compared to the pyramidal frustum with the static pile. In general, the semi-cylindrical pile with the passive aeration achieved lower final moisture content and shortened the composting period by 109.38% as compared to the pyramidal frustum with the static pile.

INTRODUCTION

Composting is the biochemical degradation of organic materials to a sanitary, nuisance-free, humus-like material. Composting has been defined as a controlled-microbial aerobic decomposition process with the formation of stabilized organic materials that may be used as soil conditioners and/or organic fertilizers. Composting process must be passed through four successive phases: mesophilic (warming up, 20-40ºC), thermophilic (peak temperature, 40-75ºC), cooling down and maturing (Golueke, 1973; Wilson and Dalmat, 1986; Dalzell *et al*., 1987; Buchanan and Gilessman, 1991; Garcia *et al*., 1992; Schlegel, 1992 and Negro *et al*., 1999). The main factors affecting on composting process include environmental parameters (temperature, moisture content, aeration and pH) and substrate natural parameters (Carbon/Nitrogen ratio “C/N ratio”, particle size, and nutrient content) (Diaz *et al*., 2002). Aerobic composting is the decomposition of organic substrates in the presence of oxygen (Liang *et al*., 2003). The main products of biological metabolism are carbon dioxide, water and heat (Bari and Koenig, 2001). Oxygen is essential for the microbial activity in composting since it is an aerobic process. Aeration is defined as the most important factor in composting systems (Diaz *et al*., 2002). The lack of oxygen (anaerobic conditions) during composting will lead to different types of micro-organisms developing, causing either acidic preservation (similar to silage making) or putrefaction of the pile producing bad odors (Dalzell *et al*., 1987 and Brodie *et al*., 2000). Compost can be aerated by one of three methods: natural or windrow (static pile), passive and active (forced) aeration. Natural aeration is the cheapest and simplest one as it requires no installations. It occurs simply by diffusion and convection governed by the exposed surfaces and their respective properties (Fernandes *et al*., 1994). Although natural aeration can be rate limiting, passive aeration has proven just as efficient as active aeration, while being less costly. Passive aeration requires the installation of ducts under the compost piles to enhance the convective forces, created by the temperature differences between the composting material and the ambient air (Sartaj *et al*., 1997 and Barrington, *et al*., 2003). Sartaj *et al.* (1997) found that passive aeration had a higher composting rate than active aeration and did not produce adverse cooling effects and high N losses as with active aeration. The biological nature of composting demands an understanding of the key factors influencing the microbial ecosystem in order to achieve optimum composting process. One of these important factors affecting microbial metabolism during composting is temperature. It is either a consequence or a determinant of microbial activity (Vallini *et al*., 2002). Controlling process temperature optimizes the rate of composting provided that other parameters fall within reasonable limits in the starting material (McKinley and Vestal, 1985). Moisture content of the composting blend is an important environmental variable as it provides a medium for the transport of dissolved nutrients required for the metabolic and physiological activities of microorganisms (Stentiford, 1996; McCartney and Tingley, 1998). Very low moisture content values would cause early dehydration during composting, which will arrest the biological process, thus giving physically stable but biologically unstable composts (Bertoldi *et al*., 1983). On the other hand, high moisture may produce anaerobic conditions from water logging, which will prevent and halt the ongoing composting activities (Tiquia *et al*., 1996). Many investigators have conducted experiments and identify that 50–60% moisture content is suitable for efficient composting (Suler and Finstein, 1977; McKinley *et al.*, 1986 and Tiquia *et al.*, 1998). In addition to temperature, moisture content and aeration, other factors such as C/N ratio (nutrient balance), pH and available nutrients have been shown to have a significant impact on composting performance (Bertoldi *et al*., 1985; Jackson and Line, 1997). In Egypt, rice straw is annually produced from 3-4Million ton. About 55% from its total production is burnt by the farmers to clear the fields causing the environmental pollution (Agricultural Statistics, in Arabic, 2006). An adequate supply of air to all parts of a compost pile is the essential problem. Aeration is achieved by natural movement of air into the compost pile. One of the most important and rewarding problems during composting process is the use of unsuitable method for aerating the compost pile. However, this can fail to supply adequate oxygen in the phases of the process, leading to anaerobic conditions in the lower central regions of the pile of composting material. Therefore, the overall aim of the present study was to characterize the influence of three aeration methods (static pile, turned windrow and passive aeration) and two geometrical shapes of pile (Pyramidal frustum and Semi-cylindrical) on the effectiveness of composting process.

MATERIALS AND METHODS

Six experimental piles were erected and constructed at the Animal Production Research Station, Sakha, Kafr El-Sheikh governorate in October 2007.These piles were formed from the mixture of rice straw and cow dung with a percent of 59.5 and 40.5% respectively. The dimensions of each pile were of 2.5m long, 2.5m wide and 1.25m high. After harvest, the rice (Giza 178 variety) straw was employed. Rice straw was chopped into about 5-8cm segments for all the experimented treatments. Some physicochemical parameters of the composted raw materials and their mixture are listed in Table 1.

Table 1: Some physicochemical parameters of the composted raw material and its mixture.

Parameter	Raw material		Initial composting mixture
	Rice straw	Cow dung	
Moisture content, %w.b.	61.28	67.34	63.42
pH	7.2	7.5	7.6
Electrical conductivity, dS/m	3.21	3.46	3.67
Total organic carbon, %d.b.	51.43	20.67	69.95
Total nitrogen, %d.b.	0.804	1.02	1.74
C/N ratio	63.97	20.26	40.20
Total organic matter, %	88.66	37.83	95.43

The six investigated piles were classified into two geometrical shapes and three different aeration methods. The two geometrical shapes were of the pyramidal frustum and semi-cylindrical piles. Besides, each pile had three aeration methods namely; static pile, turned windrow and passive aeration with perforated pipes. The volume of the composted materials was fixed for all the experimented piles. With respect to the turned windrow, the composted materials were agitated weekly by front-end loader. Whilst in the passive aeration, the perforated pipes were placed in the four horizontal directions of pile with another vertical pipe forming one unit. The material of pipes was resistant to high temperatures. These pipes were fixed on a 30cm high from the bottom of pile and in the middle of the pile along the horizontal direction. The diameter of the employed pipes was of 7.5cm. The holes of the pipes were of 50cm long for the horizontal pipes and 20cm long for the vertical one measured from the center of intersecting pipes.

The diameter ofthe holes was of 2cm. The perforated pipes were extended outside the pile for about 20cm through the horizontal and vertical directions of the pile to enhance aeration passages (Figs. 1 and 2). Table 2 indicates the mathematically calculated values of the pyramidal frustum and semi-cylindrical piles during composting process.

Investigated variables:

The present study was conducted to investigate the following compost factors:

a) Two geometrical shapes of compost pile namely; pyramidal frustum and semi-cylindrical (Quonset or hoop) and
b) Three aeration methods of compost pile namely; static pile (without any agitation), turned windrow (with weekly agitation) and passive aeration (with perforated pipes).

The influence of the investigated factors on the compost temperature and moisture content with the composting time was studied. As well as, some physicochemical properties of compost were measured and the germination assay was conducted for all the investigated treatments.

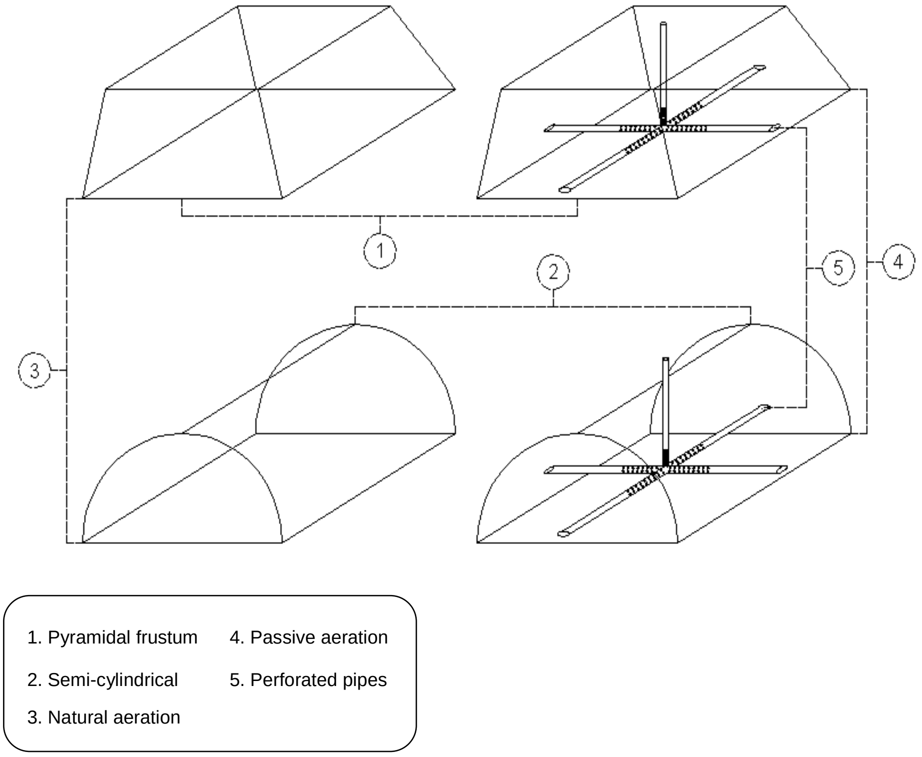

Fig. 1: A perspective drawing of the composting piles.

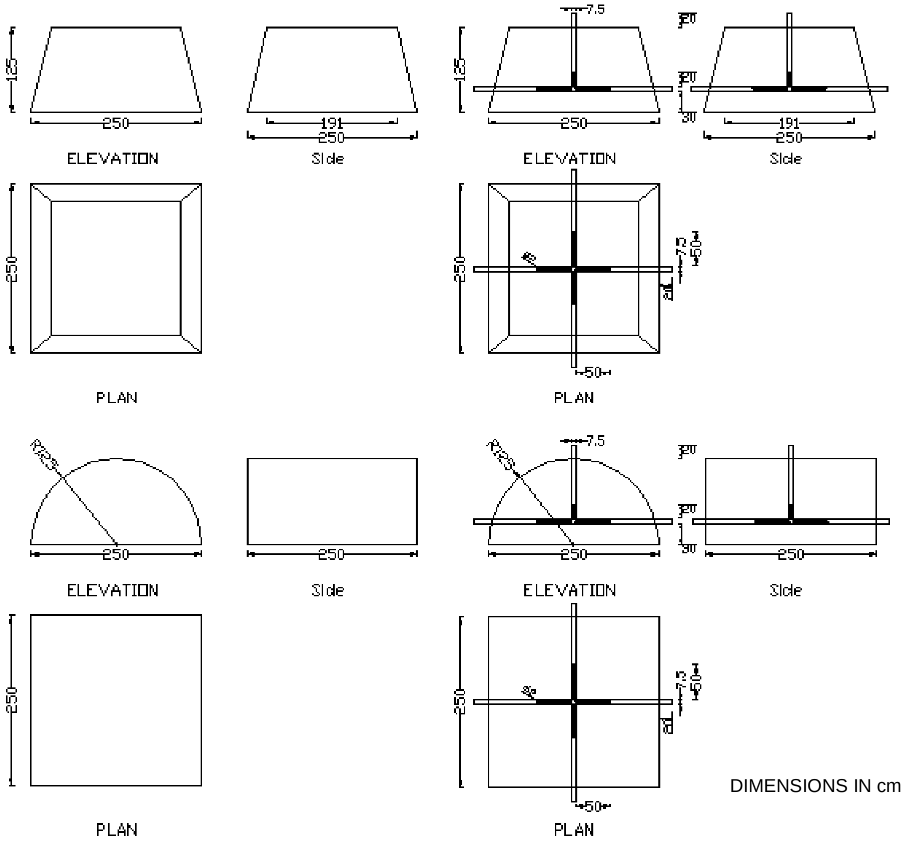

Fig. 2: A geometrical drawing of the composting piles.

Table 2: Mathematically calculated values of the two geometrical shapes used in composting piles.

Geometrical pile shape	Total surface area (S), m^2	Volume (V), m^3	S/V ratio, m^2/m^3	Mass of 1m^3 from composted material, kg	Total mass of pile, kg
Pyramidal frustum	11.6228	6.1138	1.90	134.13	820.04
Semi-cylindrical	14.7262	6.1359	2.40	134.13	823.01

Methods:

Calculation of total surface area and volume of the compost pile:

The total surface area (S) and volume (V) of the pyramidal frustum pile are given by the two following relations:

$$S = 2(a+b)\sqrt{\frac{1}{2}(a-b)^2 + h^2} \qquad (1)$$

$$V = \frac{1}{3}(a^2 + ab + b^2)h \quad \text{...} \quad (2)$$

Where;

a base side length of the truncated pyramid, m;

b top side length of the truncated pyramid, m and

h height of the truncated pyramid, m.

Similarly, the total surface area (S) and volume (V) of the Semi-cylindrical pile are given by the two following relations:

$$S = \frac{1}{2}(2\pi r^2 + 2\pi rh) \quad \text{...} \quad (3)$$

$$V = \frac{1}{2}(\pi r^2 h) \quad \text{...} \quad (4)$$

Where;

r height of the Semi-cylindrical pile, m and

h side length of the Semi-cylindrical pile, m.

Determination of the quantity of cow dung added to rice straw (mixture ratio):

The process of decomposition is hastened by adding nitrogenous material like cow dung to rice straw. This will take place a balance between the carbon ratio in the rice straw and nitrogen ratio in cow dung, and consequently obtain the convenient C/N ratio in the given mixture. The quantity of nitrogen or cow dung, which must be added to one ton of rice straw, can be calculated according to the following formula (Elgala, in Arabic, 2002).

$$N = \left[NRS - \left(\frac{ANRS}{100} x1000 \right) \right] x \left(\frac{100}{ANCD} \right) \quad \text{.......................................} \quad (5)$$

Where;

N quantity of nitrogen or cow dung which must be added to one ton of rice straw on dry basis, kg;

NRS quantity of nitrogen which is actually existed in one ton of rice straw, (15kg according to Elgala, in Arabic, 2002);

$ANRS$ the average percentage of nitrogen in rice straw, % and

$ANCD$ the average percentage of nitrogen in cow dung,%.

Pile shape forming:

For building the pile shape of pyramidal frustum and semi-cylindrical, two models for the geometrical shapes were designed using the flexible ditch-reed and thread forming the same dimensions of piles (2.5x2.5x1.25m). Each model was placed on the ground, and thereafter the compost mixture was placed in the form of successive layers inside the model to obtain the required geometrical shape of each pile. The bottom surface of each pile was declined by 0.03m/m longwise for facilitating the drainage of excessive water in the pile (if existed). For accumulating the drainaged water from the pile, there was a small pit along the circumference of the bottom of each pile. For the turned windrow, the pile shape was reformed after agitation immediately. Whereas for the passive aeration method, the perforated pipes were firstly fixed and thereafter forming the model around the pipes and finally placing the composting mixture inside the designed model to build the required pile.

Compost temperature:

To measure the compost temperature in the pile core, three thermocouples were fixed in the middle of each pile at 35, 70 and 105cm deep from the bottom surface of the pile. The J-type thermocouples were connected with a digital thermometer (Model: HH-26J-USA) to record the compost temperature at the three different levels and thereafter the averaged values can be obtained. Two thermocouples were connected with the digital thermometer to record the ambient temperature and the averaged values were calculated. Compost temperature was measured every three days during the composting process at 12N.

Compost moisture content:

Triplicate compost samples were taken every six days for determining the moisture content on a wet basis using the oven method (by drying at 105^{o}C for 24h). The three samples were taken in the middle of each pile at 50, 80 and 110cm deep from the bottom surface of the pile and the averaged values were calculated. By reducing the moisture content than 50%, a specific quantity of water was added to the pile to keep 60 to 55% through the mesophilic to thermophilic phases respectively. The highest microbial activity during composting process, was maintained in the range of 55-60% moisture according to Suler and Finstein, 1977; McKinley et al., 1986 and Tiquia *et al*., 1998. A sprinkler was employed to add water in the next day after taking the compost samples.

Compost sampler:

A cylindrical tool, for compost sampling from the pile core, was manufactured in a workshop at the Industrial Region, Kafr El-Sheikh city. The total length of sampler was of 270cm and the effective length at sampling was of 150cm. The maximum capacity of compost sample inside the sampler was about of 2209cm^{3}. The front of sampler was manufactured from a conical head to facilitate its penetration into the pile. The iron shaft of sampler was fixed on two bearings to move the shaft manually in and out easily. In case of sampling, a specific auger was attached with the end of shaft before the conical head with 50cm long. The outer tube of sampler was accurately graduated to determine the right position of compost sampling inside the pile (Fig. 3).

Determination of the physicochemical properties for the composted materials:

pH: samples of 5g from each composting material were shaken in 50 ml distillated water (1:10 dry weight/volume) for 30min, then pH was measured using Bekman pH meter as reported by Page *et al.* (1982). Electrical conductivity (EC, dS/m) was determined according to the method described by Chen et al. (1988). 5g sample was mixed with 50ml distilled

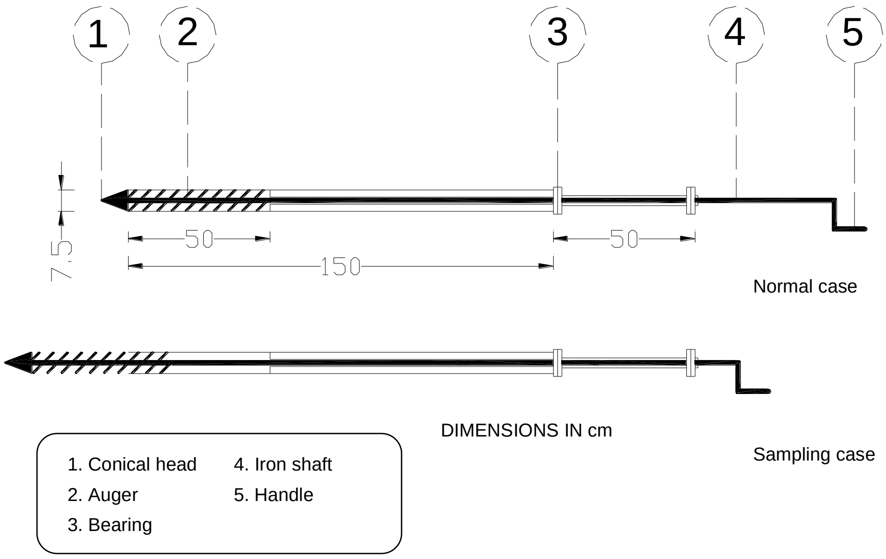

Fig. 3: Compost sampler.

water, shaken for 2h and filtered. The EC was measured in the filtrate using conductivity meter (Jenway PcM^3, Germany). Total organic carbon (C, g/kg) was determined by Walkley–Black method as outlined by Page *et al.* (1982). Total organic matter (%) was calculated from the total organic carbon as described by Page et al. (1982). Total nitrogen (N, g/kg) was determined by the semi-micro Kjeldahl method as described by Page *et al.* (1982). C/N ratio was calculated as the ratio between total organic carbon and total nitrogen. The compost samples were analyzed at the Animal Production Research Laboratories, Sakha, Kafr El-Sheikh governorate.

Germination assay:

Plant bioassays are considered the most direct test for compost maturity, since it shows the effect of compost maturity on plant growth and other maturity tests are correlated with plant growth performance (Iwegbue *et al*., 2006). The germination experiment (in quintuplicate) was carried out on filter paper in Petri dishes. Two milliliters of the corresponding aqueous extract from the composts were introduced into dishes, with distilled water used as control in the other dishes. Ten seeds of rice (*Oryza sativa L.*) were then placed on the filter paper and the dishes placed in a germination chamber maintained at 20-30ºC in darkness (Morsi and Abdelgawad, in Arabic, 1964). Results were expressed as percentages of germination and root elongation. The germination percentages with respect to the control and root lengths were determined after 10 days. The germination index ($GI,\%$) was calculated according to the formula proposed by Zucconi et al. (1985) as follows:

$$GI,\% = G\left({}^{L_e}\!/_{L_c} \right) \qquad \text{……………………………..……………………………… (6)}$$

Where;

G percentage of germinated seeds in each extract with respect to the control, %;

L_e mean total root length of the germinated seeds in each extract, mm and

L_c mean root length of the control, mm.

RESULTS AND DISCUSSION

Temperature profile:

The temperature has been widely recognized as one of the most important parameters in the composting process. The rise and fall of temperature have been reported to correlate with the rise and fall of microbial activities (Tiquia et al., 1996 and Tiquia and Tam, 2002). The changes in temperature within the composting material during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods are illustrated in Fig. 4. The piles went through four phases: mesophilic (warming up), thermophilic (peak temperature), cooling down and maturing (Fig. 4). At the beginning of composting process, the temperature of the piles fell with the ambient temperature. For the pyramidal frustum pile, the temperature of composting material reached the ambient temperature after about 24, 18 and 12 days of composting for the static pile, turned windrow and passive aeration respectively. Whilst for the semi-cylindrical one, it reached after about 21, 15 and 9 days of composting for the static pile, turned windrow and passive aeration respectively. On the other hand, for the passive aeration method, the temperature of composting material reached the ambient temperature after about 12 and 9 days of composting for the pyramidal frustum and semi-cylindrical piles respectively. This means that temperature differences between the temperature of composting material and ambient temperature reached its minimum values and they were of 0.73, 0.12 and 0.23^{o}C for the pyramidal frustum pile and of 0.59, 0.01 and 0.57^{o}C for the semi-cylindrical one under the conditions of static pile, turned windrow and passive aeration respectively. It implied that the aeration modes might have significant effects on the pile temperature, and passive aeration was the most effective way to provide aeration passages for the pile among the aeration methods. During the mesophilic phase (warming up), the pile temperature tended to be increased and reached about 40^{o}C. For the pyramidal frustum pile, the compost temperature reached 44.85, 40.55 and 42.79^{o}C after 36, 24 and 21 days of composting under the conditions of static pile, turned windrow and passive aeration respectively. Whereas for the semi-cylindrical pile, the compost temperature reached 41.57, 44.28 and 40.25^{o}C after 27, 24 and 15 days of composting under the same conditions of the three successive aeration methods. In addition, the compost temperature rose rapidly for the semi-cylindrical pile and hence shortened the mesophilic phase by 40% as compared to the pyramidal frustum one under the passive aeration method.

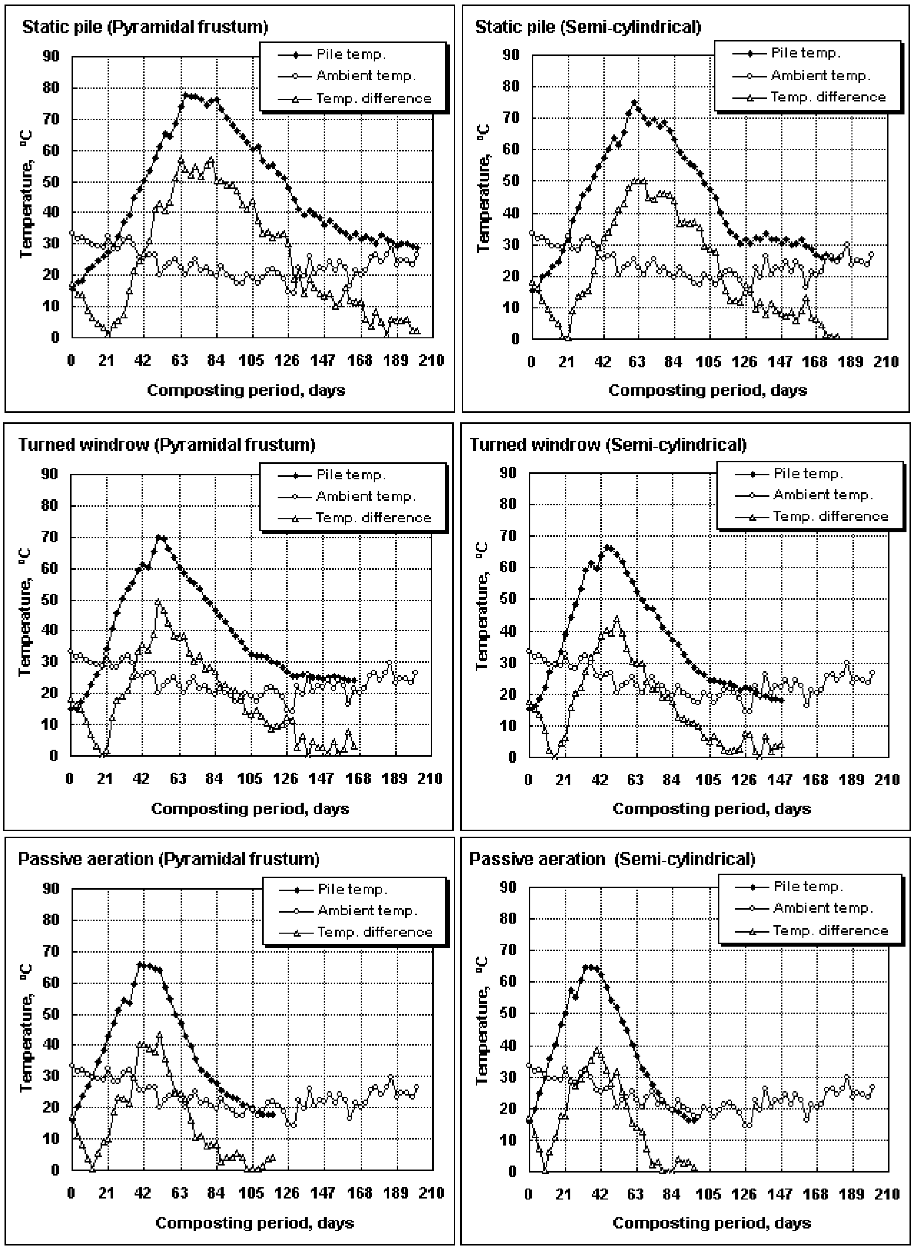

Fig. 4: Variation of temperature during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods.

In contrast, the compost temperature rose rapidly for the passive aeration method and consequently shortened the mesophilic phase by 60 and 80% as compared to the turned windrow and static pile respectively for the semi-cylindrical pile. During the thermophilic phase (peak temperature), the temperature exceeded the tolerant limit of the mesophilic phase (above 40ºC) and promoted the development of the thermophilic one. In this study, the thermophilic phase proceeded about 3-4 weeks in all piles. In all the investigated piles, the peak temperature and the rate of increase during the thermophilic phase were different.

The temperature in the pyramidal frustum pile increased to a peak of about 77.46, 69.78 and 65.78ºC at day 66, 51 and 39 and remained at a peak temperature for about 30, 27 and 18 days for the static pile, turned windrow and passive aeration respectively (Fig. 4). Meanwhile, the temperature in the semi-cylindrical pile increased to a peak of about 75.13, 66.35 and 64.89ºC at day 60, 45 and 36 and remained at a peak temperature for about 33, 21 and 21 days for the static pile, turned windrow and passive aeration successively. In the case of the semi-cylindrical piles, the peak temperatures were reached at a faster rate (3-9 days earlier) and lower peak temperatures were achieved as compared to the pyramidal frustum ones. In addition, the passive aeration method was able to reach maximum temperature faster than the static pile and turned windrow, presumably because increased aeration maximized the decomposition rate common in the initial phases of composting. Under the condition of turned windrow, the semi-cylindrical pile hastened the thermophilic phase by 28.57% as compared to the pyramidal frustum one. On the other hand, for the pyramidal frustum pile shape, the passive aeration method hastened the thermophilic phase by 50 and 66.67% as compared to the turned windrow and static pile respectively. In this work, the geometrical pile shape proves to be an essential factor, but its effect is less influential than the aeration method on the composting process. The temperature of pile decreased sharply after the thermophilic phase and entered a cooling phase. In other words, it starts after the highest peak temperature of each pile. During this phase, the composting temperature dropped and remained at a lower level (Fig. 4). In the pyramidal frustum pile, the cooling down phase lasted 117, 87 and 69 days of composting for the static pile, turned windrow and passive aeration successively. While in the semi-cylindrical pile, the cooling down phase lasted 117, 90 and 48 days of composting for the same three successive aeration methods. In contrast, for the passive aeration method, the compost temperature could be reached the ambient temperature after about 69 and 48 days of composting in the pyramidal frustum and semi-cylindrical piles respectively. In addition, the semi-cylindrical pile hastened the cooling phase by 43.75% as compared to the pyramidal frustum one for the passive aeration method. As well as, in the semi-cylindrical pile, the passive aeration method hastened the cooling phase by 87.5 and 143.75% as compared to the turned windrow and static pile respectively. As depicted in Fig. 4, the maturing phase could be reached when the compost temperature declined to be very close to the ambient one. At the beginning of maturing phase, the temperature differences were of 0.83, 0.08 and 0.62ºC in the static pile, turned windrow and passive aeration respectively for the pyramidal frustum pile. While in the semi-cylindrical pile, those differences were of 0.88, 0.21 and 0.03ºC for the same three successive aeration methods. In the pyramidal frustum pile, the composting periods were of 201, 165 and 117 days of composting for the static pile, turned windrow and passive aeration methods respectively. Meanwhile, in the semi-cylindrical pile, the composting periods were of 180, 147 and 96 days of composting under the same three successive aeration methods. In addition, the semi-cylindrical pile accelerated the composting period by 11.67, 12.24 and 21.88% for the static pile, turned windrow and passive aeration methods respectively as compared to the pyramidal frustum one. On the other hand, the passive aeration method accelerated the composting period by 53.13 and 87.5% as compared to the turned windrow and static pile respectively in the semi-cylindrical pile. In other words, the composting process proved more efficient in the semi-cylindrical pile than in the pyramidal frustum one and in the passive aeration than in the turned windrow and static pile methods. The semi-cylindrical shape was the most effective as compared to the pyramidal frustum one. This can be attributed to that as the pile volume was fixed at about 6m^3, the surface area to volume ratio was greater in the semi-cylindrical shape by 26.32% than in the pyramidal frustum one. For this reason, the chance of heat exchanging between the pile surface and the surroundings has been enhanced in the semi-cylindrical pile more than that in the pyramidal frustum one.

Moisture content:

Because of the strong relationship of moisture content with the decomposition rate, moisture content provides an important indicator of composting process efficiency. Fig. 5 shows the variation of moisture content during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods. In the initial phases of composting, the initial moisture contents of about 63%w.b. decreased in all piles during the composting process. The moisture content decreased gradually, and reached 48.43, 48.26 and 48.05%w.b. at the 54th, 42nd and 30th day in the static pile, turned windrow and passive aeration respectively for the pyramidal frustum pile. Whereas, in the semi-cylindrical pile, the moisture content reached 47.25, 46.78 and 47.31%w.b. at the 48th , 36th and 24th day. In the order to maintain perfect microbiological activity, water was sprayed to keep 50-60%w.b. moisture content. So the water was added to adjust moisture content back up to approximately 60%w.b. on the days stated above. As depicted in Fig. 5, the compost moisture content in the semi-cylindrical pile decreased more rapidly than in the pyramidal frustum one for all the investigated aeration methods. Besides, the compost moisture content in the passive aeration also decreased more rapidly than in the turned windrow and static pile for the two investigated pile shapes. In the semi-cylindrical pile, the compost moisture content decreased faster by 25% than in the pyramidal frustum one for the passive aeration method. On the other hand, for the semi-cylindrical pile, the compost moisture content decreased faster in the passive aeration method by 50 and 100% than in turned windrow and static pile respectively. During the medium phases of composting, the moisture content decreased again gradually, and reached about 48%w.b. in all piles.

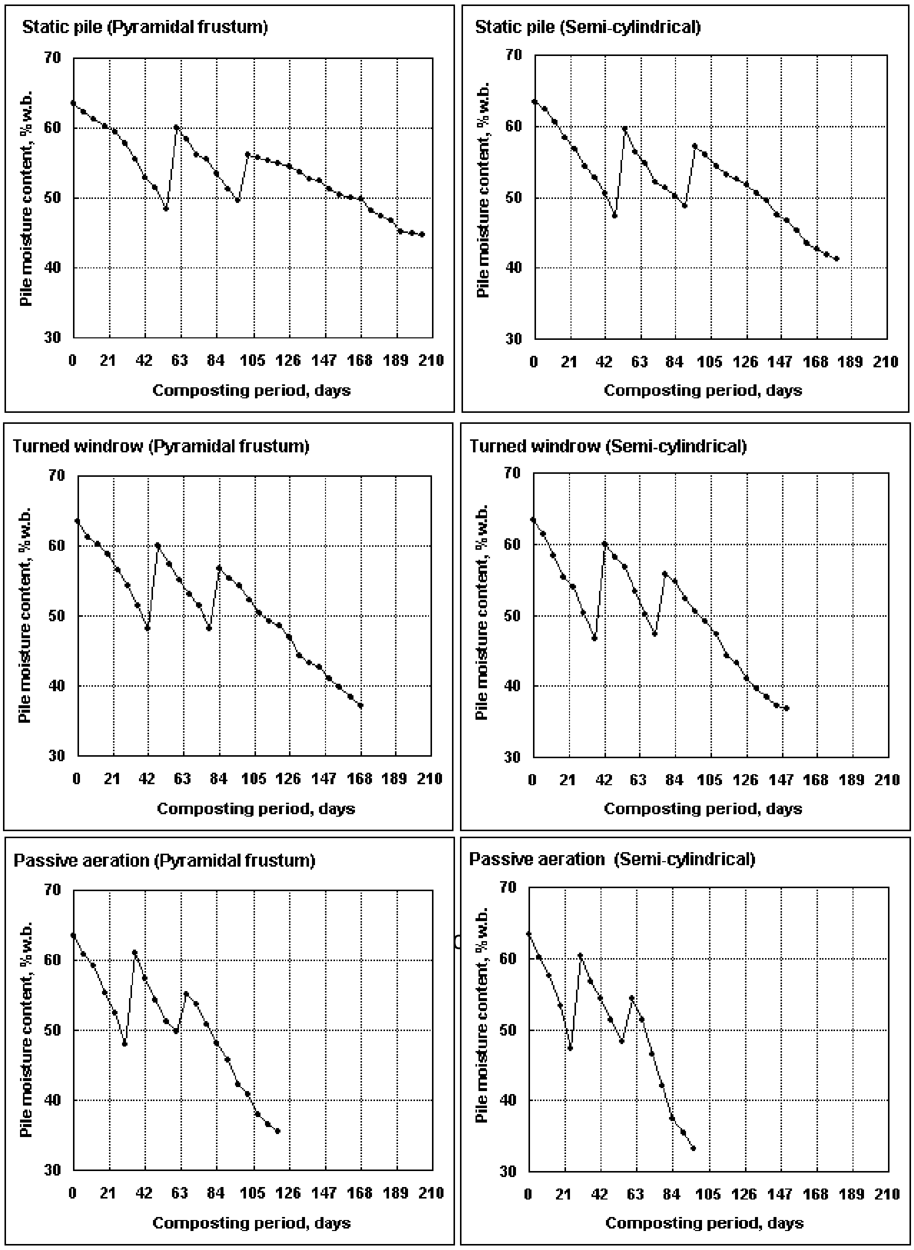

Fig. 5: Variation of moisture content during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods.

The increases can be realized by increasing moisture content alone. Therefore, the water was added at the 90th, 72nd and 54th day in the static pile, turned windrow and passive aeration respectively for the semi-cylindrical pile. In addition, for the passive aeration method, the water was added at the 60th and 54th day in the pyramidal frustum and semi-cylindrical piles respectively. In the last phases of composting, the compost moisture content decreased rapidly until reached 44.72, 37.11 and 35.41%w.b. at the 204th, 168th and 120th day in the static pile, turned windrow and passive aeration respectively for the pyramidal frustum pile.

Meanwhile, the moisture content reached 41.23, 36.86 and 33.25%w.b. at the 180th, 150th and 96th day respectively for the semi-cylindrical pile in the same three successive aeration methods. As outlined in Fig. 5, in the semi-cylindrical pile, the final moisture content was lower in the passive aeration method by 10.86 and 24% than in the turned windrow and static pile successively. In contrast, in the passive aeration method, the final compost moisture content was lower in the semi-cylindrical pile by 6.5% than in the pyramidal frustum one. In short, both of the pile geometrical shape and aeration method proved to be important factors affecting the compost moisture content, but the effect of pile shape was less influential than that of the aeration method.

Table 3: The composting parameters of the initial and final compost.

Parameter	Initial composting mixture	Finished compost					
		Pyramidal frustum pile			Semi-cylindrical pile		
		Static pile	Turned windrow	Passive aeration	Static pile	Turned windrow	Passive aeration
Moisture content, %w.b.	63.42	44.72	37.11	35.41	41.23	36.86	33.25
pH	7.6	8.6	8.1	7.9	8.5	7.9	7.8
Electrical conductivity, dS/m	3.67	4.81	4.25	3.98	4.75	4.16	3.95
Total organic carbon, %d.b.	69.95	51.78	34.31	33.95	51.41	33.99	33.74
Total nitrogen, %d.b.	1.74	1.76	1.87	1.95	1.79	1.90	2.04
C/N ratio	40.20	29.42	18.35	17.41	28.72	17.89	16.54
Total organic matter, %	95.43	89.12	59.11	58.45	88.54	58.47	58.16

Table 3 indicates the most important parameters of the initial and final compost for the pyramidal frustum and semi-cylindrical piles and three different aeration methods. For the pyramidal frustum pile, the C/N ratio was lowered in the passive aeration method by 5.12 and 40.82% as compared to the turned windrow and static pile respectively. Whereas, for the semi-cylindrical pile, the C/N ratio was reduced in the passive aeration method by 7.55 and 42.41% as compared to the turned windrow and static pile successively. This means that the semi-cylindrical pile has achieved lower values for the C/N ratio as compared to the pyramidal frustum one. As well as, the nearest values to the optimum for the C/N ratio were obtained in the case of the passive aeration method with the semi-cylindrical pile.

Compost maturity evaluation:

Compost stability can be taken as an indicator of maturity. Compost maturity was tested by the seed germination index. The averaged seed germination index of the finished compost for the pyramidal frustum and semi-cylindrical piles and three different aeration methods is shown in Fig. 6. In the semi-cylindrical pile, the seed germination index was of 78.35, 93.25 and 98.45% for the static pile, turned windrow and passive aeration methods respectively. Meanwhile, in the pyramidal frustum pile, their values were of 75.26, 91.72 and 97.63% for the same three successive aeration methods. In the passive aeration method, the seed germination index was of 97.63 and 98.45% for the pyramidal frustum and semi-cylindrical piles respectively. This means that the seed germination index was higher in the semi-cylindrical pile by 4.11, 1.67 and 0.84% than in the pyramidal frustum pile for the static pile, turned windrow and passive aeration method respectively. On the other hand, the seed germination index was higher in the passive aeration method by 5.58 and 25.65% than in the turned windrow and static pile respectively for the semi-cylindrical pile.

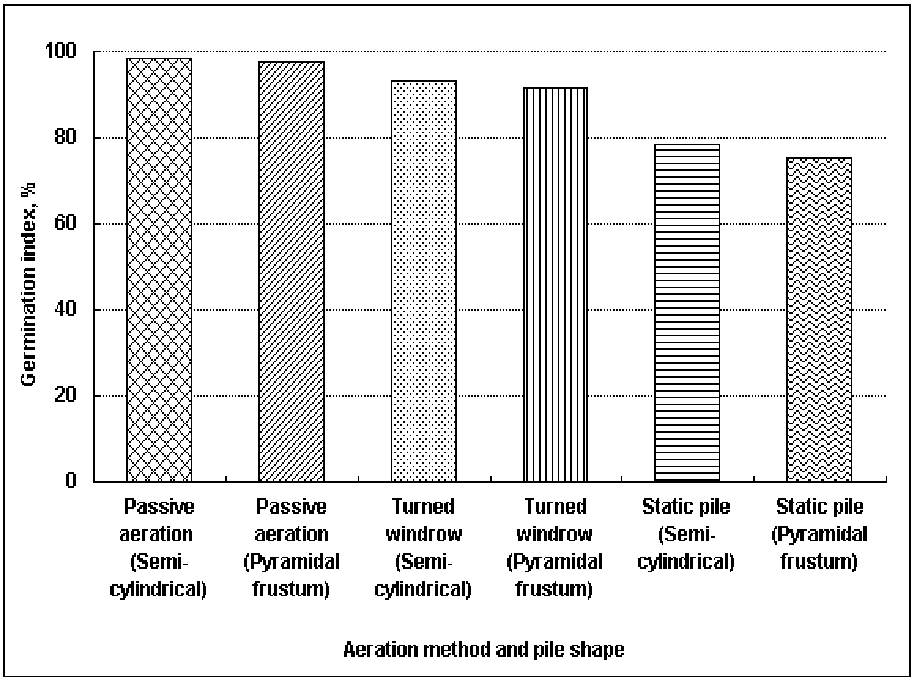

Fig. 6: The averaged seed germination index of the finished compost for the pyramidal frustum and semi-cylindrical piles and three different aeration methods.

Conclusion:

From the outlined results, it can be concluded that the semi-cylindrical pile with the passive aeration method have achieved the best indicators during composting process. In contrast, the worst parameters have been obtained in the pyramidal frustum with the static pile as compared to all the investigated treatments. The most important indices, during the composting process, could be stated as follows:

Composting phases and indices	Semi-cylindrical pile with the passive aeration method	Pyramidal frustum pile with the static pile
Temperature:		
1) Mesophilic phase:		
Composting period, days	15	36
Pile temperature range, °C	15.86 - 40.25	15.74 - 44.85
Time through which pile temperature declined to ambient one, days	9	24
Temperature difference (ambient and pile), °C	0.57	0.73
2) Thermophilic phase:		
Peak pile temperature, °C	64.89	77.46
Time through which pile temperature reached to the peak one, days	36	66
Composting period, days	21	30
3) Cooling down phase:		
Composting period, days	48	117
4) Maturing phase:		
Temperature difference (ambient and pile), °C	0.03	0.83
Time through which pile temperature declined to ambient one, days	84	183
Final moisture content, %w.b.	33.25	44.72
Final composting period, days	96	201
Final C/N ratio	16.54	29.42
Final pH	7.8	8.6
Final electrical conductivity, dS/m	3.95	4.81
Germination index, %	98.45	75.26

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فاعلية طريقة التهوية وشكل الكومة أثناء عملية إنتاج الكمبوست

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يمثل قش الأرز مشكلة ذات بعد بيئي في جمهورية مصر العربية ، حيث يتم إنتاج حوالي من 3-4مليون طن سنوياً ويتم حرق حوالي 55% من الإنتاج بواسطة المزارعين لتنظيف حقولهم والتخلص منه مما يؤدى إلى تلوث البيئة (إحصائيات وزارة الزراعة، 2006). ويعد إنتاج السماد العضوي الصناعي (الكمبوست) أحد طرق الاستفادة من قش الأرز. ولكن عملية إنتاج الكمبوست تتوقف على التحلل الهوائي لمخلفات المزرعة العضوية مثل مخلوط قش الأرز وروث البقر تحت الدراسة. وكومة الكمبوست على سطح الأرض هي أحد طرق إنتاجه ولكن يعاب على هذه الطريقة ضعف عملية التهوية داخل الكومة وهى عملية أساسية لتزويد الكومة بالأكسوجين اللازم لعملية التحلل الهوائي لقش الأرز ، كما أن بناء شكل الكومة يتم بطريقة عشوائية وليس له أساس هندسي. لذا كان الهدف الرئيسي من هذا البحث هو دراسة تأثير ثلاث طرق تهوية للكومة (الكومة الساكنة – تهوية الكومة بواسطة التقليب مرة أسبوعيا – التهوية السالبة بواسطة الأنابيب المثقبة) ، وشكلين هندسيين للكومة (الهرم الناقص ونصف الأسطوانة) على عملية إنتاج الكمبوست. وفى جميع المعاملات كان حجم الكومة ثابت حوالي 6م^{3} ونسبة قش الأرز إلى روث البقر في الكومة 59,5% إلى 40,5% على الترتيب. وتتلخص أهم النتائج فيما يلي:

1) تمت عملية إنتاج الكمبوست بأعلى معدل لها في الكومة النصف اسطوانية مع طريقة التهوية السالبة بأنابيب مثقبة ، حيث انخفضت نسبة C/N في الكمبوست الناضج بنسبة 77,87% وزادت قيم دليل الإنبات بنسبة 30,81% ، إذا ما قورنت بالكومة الساكنة ذات الهرم الناقص من بين المعاملات تحت الدراسة0
2) وصلت درجة حرارة الكومة ، في المرحلة الأولى (mesophilic) من عملية إنتاج الكمبوست ، إلى درجة حرارة الجو المحيط أسرع في الكومة النصف اسطوانية مع طريقة التهوية السالبة بأنابيب مثقبة بنسبة 166,67% ، بينما حققت أثناء المرحلة الثانية (thermophilic) درجة حرارة قصوى أقل بنسبة 19,37% ، إذا ما قورنت بالكومة الساكنة ذات الهرم الناقص0
3) حققت الكومة النصف اسطوانية مع طريقة التهوية السالبة بأنابيب مثقبة محتويات رطوبية أقل للكمبوست الناضج وساهمت في تقصير فترة إنتاج الكمبوست بنسبة 109,38% ، إذا ما قورنت بالكومة الساكنة ذات الهرم الناقص0