BIOLOGICAL ENGINEERING

CHEMICAL AND PHYSICAL PROPERTIES
OF COMPOST

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ABSTRACT

The objective of this research was to study the chemical and physical properties of compost with different materials. These properties include: pH, EC, total organic carbon, total organic matter, total nitrogen, total phosphorus, total potassium, C/N ratio, bulk density, moisture content, water holding capacity and porosity. The pH value ranged from 6.3 to 7.8 and EC values ranged from 2.6 to 4.1 dS m^{-1} for different compost types. The total organic carbon values ranged from 16.6 to 23.89 %. The total organic matter values ranged from 28.60 to 41.20 %. The total nitrogen values ranged from 0.95 to 1.68 %. The total phosphorus and total potassium values ranged from 0.27 to 1.13 % and 0.27 to 2.11 %, respectively, for different compost types. The C/N ratio values ranged from 14.22:1 to 18.52:1. The bulk density value ranged from 420 to 655 kg m^{-3}. The moisture content values ranged from 23.50 to 32.10 %. The water holding capacity values ranged from 3.50 to 4.40 g water/g dry. The porosity values ranged from 60.69 to 72.47 % for different compost types.
Keywords: chemical properties – physical properties - compost

INTRODUCTION

Composting is a technique which can be used to reduce the amount of organic waste through recycling and the production of soil fertilizers and conditioners. Compost is primarily used as a soil conditioner and not as much as a fertilizer because it contains a high organic content (90 - 95 %) but generally low concentrations of nitrogen, phosphorus, potassium as well as macro and micro nutrients compared to commercial fertilizers. It is comparable to peat moss in its conditioning abilities. Areas where composting can be beneficial is in the recycling of the organic fraction of the municipal waste.

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It reduces as much as 30% of the volume, in the form of organic matter, entering our already overcrowded landfill sites. Furthermore the composting process, if performed correctly, transforms wet and odorous organic waste into an aesthetically, dryer, decomposed and reusable product **(Knight, 1997)**.

Crop residues, unused bedding materials, silage, manures, and similar on-farm materials can be used as co-compost cover materials, along with many off-farm residues and wastes. Since a mortality compost pile cannot be turned until the bio-decomposition of the carcass body has been largely completed, the type and thickness of the cover and base layer materials play a key role in influencing the biodegradation of carcasses, and the development and retention of heat that is necessary for pathogen inactivation **(Fonstad *et al.,* 2003)**.

Quality control during compost production should ensure adequate chemical and physical properties **(Inbar *et al.,* 1993)**, as well as an adequate degree of stability and maturity **(Benito *et al.,* 2003)**. The beneficial effects on crop production and soil quality reported in literature **(Hoitink *et al.,* 1997; Atiyeh *et al.,* 2001)** are directly related to the physical, chemical and biological properties of the composts **(He *et al.,* 1995)**.

The physical and chemical properties of organic wastes and the factors that affect their performance in composting require easily identifiable and reliable methods to control the process in situ, in order to make proper decisions about its performance **(Hurerta-Pujol *et al.,* 2010)**.

Although the characteristics of yard waste will vary, depending upon the predominant vegetation in the area and the season of the year for its collection, composted green waste typically contains low levels of heavy metals, commonly present in sludge-based composts, which makes them more environmentally sound **(Bentio *et al.,* 2006)**.

To produce a sound and a good quality compost, chemical and physical properties of the compost should be determined by the end of processing period, therefore, the main objective of this research was to study the chemical and physical properties of compost with different materials. These properties include: pH, EC, total organic carbon, total organic

matter, total nitrogen, total phosphorus, total potassium, C/N ratio, bulk density, moisture content, water holding capacity and porosity.

MATERIALS AND METHODS

The experiment was carried out at compost unit at Experimental Research Station at the Faculty of agriculture, Moshtohor, Benha University. The raw materials properties that used in the manufacturing the compost are listed in tables (1 and 2).

Five different types of compost were obtained by mixing cattle manure with herbal plants residues and sugar cane plants residues at different ratios to form:

1- C_1: cattle manure (100:0)

2- C_2: cattle manure and herbal plants residues (50:50)

3- C_3: cattle manure and sugar cane plants residues (50:50)

4- C_4: herbal plants residues (100:0)

5- C_5: sugar cane plants residues (100:0)

Table (1): Chemical properties of the raw materials used in compost making.

Raw materials Properties	cattle manure	herbal plants residues	Sugar cane plants residues
pH	8.10	4.30	7.10
EC (dS m^{-1})	4.20	1.30	3.10
Total organic carbon (%)	18.16	9.40	20.00
Total organic matter (%)	31.30	43.10	61.30
Total nitrogen (%)	0.93	1.35	1.62
Total phosphorus (%)	0.21	0.36	1.12
Total potassium (%)	0.17	0.42	1.36
C/N ratio	19.53:1	6.97:1	12.35:1

Table (2): Physical properties of the raw materials used in compost making.

Raw materials Properties	cattle manure	herbal plants residues	Sugar cane plants residues
Bulk density (kg m^{-3})	750.00	335.00	426.00
Moisture content (%)	58.30	16.20	36.20
Water holding capacity (g water/g dry sample)	3.00	3.50	3.30
Porosity (%)	41.57	80.62	69.96

The mixtures of wastes were composted in trapezoidal piles (1.5 m high, 3 m width and 80 m long). The piles were turned periodically to maintain adequate O_2 levels. The piles were turned weekly during the maturation phase in order to improve the O_2 level inside the pile. Pile moisture was controlled by adding enough water to keep the moisture content not less than 50%. Samples were taken at the end of the composting process to determine the chemical and physical properties.

Each sample was made by mixing five subsamples taken from five points in the pile. Samples were placed in polyethylene bags and transferred to the laboratory for analysis.

- **Chemical properties:**

Electrical conductivity and pH were analysed in a 1:5 (v/v) water extract using a glass electrode according to **Rayment and Higginson (1992)**. Total organic carbon (TOC) by the dry combustion method at 540 ◦C for 4 h according to **Abad et al. (2002).** Total organic matter was measured by combustion at 550 ◦C for 8 h according to **TMECC (2001)** and total nitrogen (TN) by Kjeldahl digestion **(Bremmer and Mulvaney, 1982)**. Potassium (K) was determined by atomic absorption and phosphorus (P)

was determined colorimetrically following the **Murphy and Riley (1962)** method.

- **Physical properties**
- **Moisture contents (MC):**

Moisture content (wet basis) throughout this study was measured by drying at 105 ◦C for approximately 24 h or at constant weight.

- **Water holding capacity (WHC):**

A wet sample of known initial moisture content was weighed (W_i) and placed in a beaker. After soaking in water for 1–2 days and draining excess water through Whatman #2filter paper, the saturated sample was weighed again (W_s). The amount of water retained by dry sample was calculated as the WHC. The water holding capacity (g water/g dry material) is calculated as (**Ahn *et al.,* 2008**):

$$WHC = \frac{\left\{ (W_s - W_i) + MC \times W_i \right\}}{\left\{ (1 - MC) \times W_i \right\}} \tag{1}$$

Where:

W_i is the initial weight of sample (g)

W_s is the final weight of sample (g)

MC is the initial moisture content of sample (decimal)

- **Bulk density and porosity**

Bulk density was measured using an approximately 10 liter volume container. The container was filled with material, and then the material was slightly compacted to ensure absence of large void spaces. The bulk density was calculated by dividing the weight of the material by the volume of material in the container.

Compost porosity (ε_a) was determined using the known density of water (ρ_w; 1000 kg m^{-3}) and estimated densities of organic matter (ρ_{om}; 1600 kg m^{-3}), and ash (ρ_{ash}; 2500 kg m^{-3}), as well as the moisture content and bulk densities of the sample (**Raman, 1995; van Cingel *et al.,* 1999; Richard *et al.,* 2002**). If the moisture content (MC), dry matter (DM), organic

matter (OM), and wet bulk density (ρ_{wb}) of samples are known, the porosity can be calculated using the following equation:

$$\varepsilon_a = 1 - \rho_{wb}\left(\frac{MC}{\rho_w} + \frac{DM \cdot OM}{\rho_{om}} + \frac{DM \cdot (1 - OM)}{\rho_{ash}}\right) \times 100$$

Where:

ε_a is the porosity (%)

ρ_{wb} is the wet bulk density (kg m^{-3})

ρ_w is the density of water (kg m^{-3})

ρ_{om} is the density of organic matter (kg m^{-3})

ρ_{ash} is the density of ash (kg m^{-3})

MC is the moisture content (decimal)

DM is the dry matter (decimal)

OM is the organic matter (decimal)

RESULTS AND DISCUSSION

- **Chemical properties:**

Table (3) shows the chemical properties (pH, EC, total organic carbon, total organic matter, total nitrogen, total phosphorus, total potassium and C/N ratio) of different types of compost (cattle manure, cattle manure and herbal plants residues (50:50), cattle manure and sugar cane plants residues (50:50), herbal plants residues and sugar cane plants residues). It could be seen that the pH value ranged from 6.3 to 7.8 for different compost types. The highest value of pH (7.8) was found for herbal plants residues compost, while, the lowest value of pH (6.3) was obtained for sugar cane plants residues compost. This pH range is in the optimum range for growing media as mentioned by **Bunt (1988)** who stated that the optimal range is from 5.2 to 7.3.

The EC values ranged from 2.6 to 4.1 dS m^{-1} for different compost types. The highest value of EC (4.1 dS m^{-1}) was found for cattle manure compost and the lowest value of EC (2.6 dS m^{-1}) was determined for the

herbal plants residues compost. This EC range is in the optimum range (2.0 to 4.0) for growing media as mentioned by **Hanlon (2012)**.

Table (3): Chemical properties of different compost types.

Compost types / Properties	C_1	C_2	C_3	C_4	C_5
pH	7.30	7.60	7.20	7.80	6.30
EC (dS m^{-1})	4.10	3.10	3.60	2.60	3.20
Total organic carbon (%)	16.60	18.98	20.64	20.93	23.89
Total organic matter (%)	28.60	32.70	35.60	36.10	41.20
Total nitrogen (%)	0.95	1.26	1.32	1.13	1.68
Total phosphorus (%)	0.31	0.27	0.51	0.32	1.13
Total potassium (%)	0.27	0.35	0.62	0.51	2.11
C/N ratio	17.47	15.06	15.64	18.52	14.22

C_1: cattle manure (100:0) C_2: cattle manure and herbal plants residues (50:50)
C_3: cattle manure and sugar cane plants residues (50:50)
C_4: herbal plants residues (100:0) C_5: sugar cane plants residues (100:0)

Regarding the total organic carbon results it was found that it ranged from 16.6 to 23.89 % for different compost types under study, where, the lowest value of total organic carbon (16.6 %) was found for cattle manure compost and the highest value of total organic carbon (23.89 %) was obtained for sugar cane plants residues compost. These results are in

agreement with (**Batjes., 1996**) who found that the optimum value of total organic matter higher than 10%.

The total organic matter values ranged from 28.60 to 41.20 % for different compost types. The lowest value of total organic matter (28.60 %) was found for cattle manure compost and the highest value of total organic matter (41.20 %) was found for sugar cane plants residues compost. These results are in agreement with (**Benito et al., 2006**) whose found that the highest value of total organic matter about 44%.

The total nitrogen values ranged from 0.95 to 1.68 % for different compost types under study. The lowest value of total organic carbon (0.95 %) was found for cattle manure compost and the highest value of total organic carbon (1.68 %) was found for sugar cane plants residues compost. These results are in agreement with those obtained by **Benito et al. (2006)** whose found that the total nitrogen rate ranged from 0.99 to 2.01%.

The total phosphorus and total potassium values ranged from 0.27 to 1.13 % and 0.27 to 2.11 %, respectively, for different compost types. The lowest value of total phosphorus (0.27 %) was found for herbal plants residues and cattle manure (50:50) compost and the highest value of total phosphor (1.13 %) was found for sugar cane plants residues compost. The lowest value of total potassium (0.27 %) was found for cattle manure compost and the highest value of total potassium (2.11 %) was found for sugar cane plants residues compost.

Regarding the C/N ratio, it ranged from 14.22:1 to 18.52:1 for different compost types. The lowest value of C/N ratio (14.22:1) was found for sugar cane plant residues compost and the highest value of C/N ratio (18.52:1) was found for herbal plant residues compost. These results are in agreement with the results obtained by (**Rosen et al., 1993**) whose found that the C/N ratio ranged from 15:1 to 20:1 is ideal for ready-to-use compost.

- **Physical properties:**

Table (4) shows the physical properties (bulk density, moisture content, water holding capacity and porosity) of the different types of compost

(cattle manure, cattle manure and herbal plants residues (50:50), cattle manure and sugar cane plants residues (50:50), herbal plants residues and sugar cane plants residues).

The results indicate that the bulk density value ranged from 420 to 655 kg m^{-3} for different compost types. The highest value of bulk density (655 kg m^{-3}) was found for cattle manure compost and the lowest value of bulk density (420 kg m^{-3}) was found for sugar cane plants residues compost. **Hurerta-Pujol *et al.* (2010)** found that the bulk density values were between 447 and 502 kg m^{-3} for different compost types, as agreed with **(Raviv et al., 1986, 1987; Larney *et al.*, 2000; Mohee and Mudhoo, 2005; Romeela *et al.*, 2008)** results.

Table (4): Physical properties of different compost types.

Compost types Properties	C_1	C_2	C_3	C_4	C_5
Bulk density (kg m^{-3})	655.00	625.00	573.00	582.00	420.00
Moisture content (%)	25.60	23.50	30.10	31.20	32.10
Water holding capacity (g water/g dry sample)	3.50	3.70	4.10	3.90	4.40
Porosity (%)	60.69	62.67	63.52	66.56	72.47

C_1: cattle manure (100:0) C_2: cattle manure and herbal plants residues (50:50)
C_3: cattle manure and sugar cane plants residues (50:50)
C_4: herbal plants residues (100:0) C_5: sugar cane plants residues (100:0)

It could be seen that the bulk density of compost decreases with increasing the compost total organic matter. Figure (1) shows the relationship between the bulk density and the total organic matter. It decreases from 655 to 420 kg m^{-3} when the total organic matter increased from 28.6 to 41.2 %.
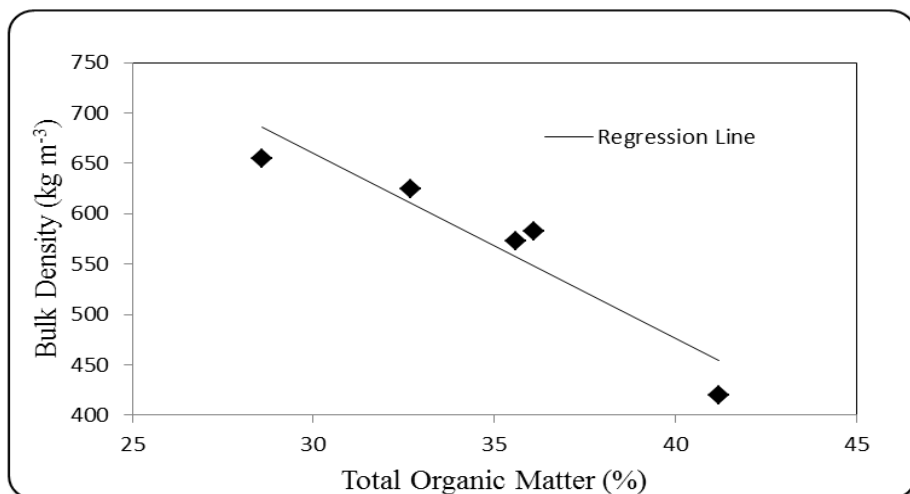
Figure (1): The relationship between the bulk density and the total organic matter.

The regression between the bulk density of compost and the compost total organic matter is show the following equation:

$$BD = -18.399\ TOM + 1212 \qquad R^2 = 0.89 \qquad (3)$$

Where:-

BD is the bulk density (kg m^{-3})

TOM is the total organic matter (%)

The moisture content values ranged from 23.50 to 32.10 % for different compost types. The lowest value of moisture content (23.50 %) was found for cattle manure and herbal plants residues (50:50) compost and the highest value of moisture content (32.10 %) was obtained for sugar cane plants residues compost.

Regarding the water holding capacity values ranged from 3.50 to 4.40 g water/g dry sample for different compost types. The lowest value of water holding capacity (3.50 g water/g dry sample) was found for cattle manure compost and the highest value of water holding capacity (4.40 g water/g dry sample) was found for sugar cane plants residues compost.

The porosity values ranged from 60.69 to 72.47 % for different compost types. The lowest value of the porosity (60.69 %) was found for cattle manure compost and the highest value of the porosity (72.47 %) was found for sugar cane plants residues compost. The porosity depends on

bulk density and moisture content of compost. The porosity decreased with increasing bulk density and moisture content. Figures (2 and 3) show the relationship between the porosity and bulk density and the porosity and moisture content. The results indicate that the porosity of compost decreased from 72.47 to 60.69% when the bulk density increased from 420 to 655 kg m^{-3}. The results indicate that the porosity of compost decreased from 72.47 to 60.69% when the moisture content increased from 25.6 to 32.1%. This results agreed with those obtained by **Ahn** *et al.* **(2008)**.
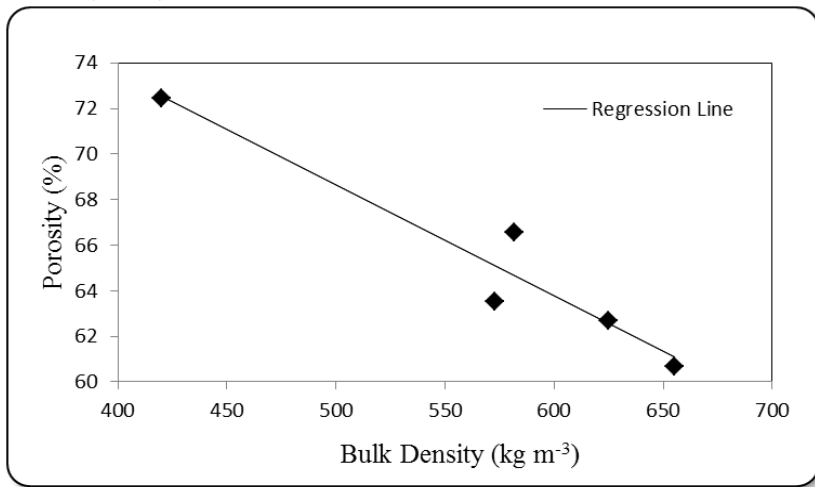

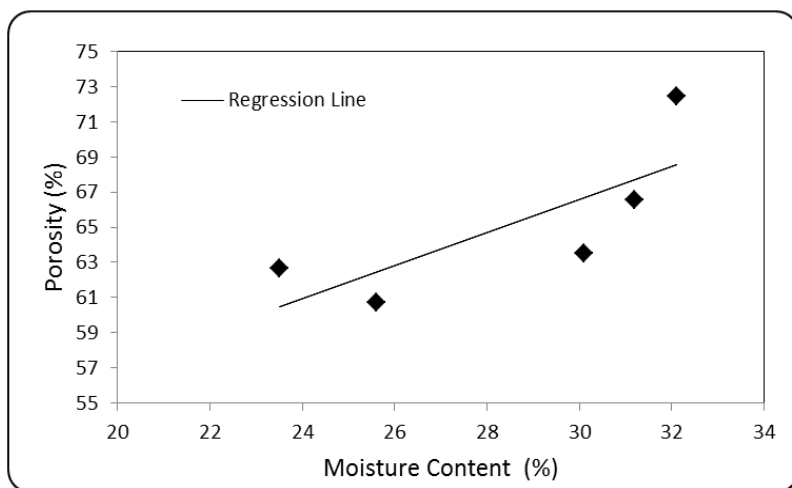Figure (2): The relationship between the porosity and bulk density.

Figure (3): The relationship between the porosity and moisture content.

The regression between the porosity and the bulk density of compost and the porosity of compost and the compost total organic matter are shown in the following equations:

$$\varepsilon_a = -0.0487 \text{ BD} + 92.981 \qquad R^2 = 0.93 \qquad (4)$$

$$\varepsilon_a = 0.9407 \text{ TOM} + 38.373 \qquad R^2 = 0.60 \qquad (5)$$

SUMMARY AND CONCLUSIONS

An experimental study was carried out successively to determine the chemical and physical properties of different compost types. The obtained results indicate that the pH value ranged from 6.3 to 7.8 and EC values ranged from 2.6 to 4.1 dS m^{-1} for different compost types. The total organic carbon values ranged from 16.6 to 23.89 %. The total organic matter values ranged from 28.60 to 41.20 %. The total nitrogen values ranged from 0.95 to 1.68 %. The total phosphorus and total potassium values ranged from 0.27 to 1.13 % and 0.27 to 2.11 %, respectively, for different compost types. The C/N ratio values ranged from 14.22:1 to 18.52:1. The bulk density value ranged from 420 to 655 kg m^{-3}. The moisture content values ranged from 23.50 to 32.10 %. The water holding capacity values ranged from 3.50 to 4.40 g water/g dry. The porosity values ranged from 60.69 to 72.47 % for different compost types.

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<u>الملخص العربى</u>

الخصائص الكيميائية والطبيعية للسماد العضوى (الكمبوست)

السيد جمعه خاطر *

نظرا لعدم وجود معلومات كافية عن الخواص الكيميائية والطبيعية للسماد العضوى (الكمبوست)، ولانتاج سماد عضوى ذات صفات جودة عالية يجب دراسة الخصائص الكيميائية والهندسية فى نهاية دورة الانتاج، ولذلك كان الهدف من هذا البحث هو دراسة الخصائص الكيميائية والطبيعية لعدة انواع مختلفة من السماد العضوى. وتشمل هذه الخصائص: رقم الحموضة والتوصيل الكهربى والكربون العضوى الكلى المادة العضوية الكلية والفوسفور والبوتاسيوم ونسبة الكربون الى النيتروجين والكثافة الظاهرية و المحتوى الرطوبى والقدرة على الاحتفاظ بالماء والمسامية.

وكانت أهم النتائج المتحصل عليها أن رقم الحموضة تراوح ما بين ٦.٣ - ٧.٨، وتراوح التوصيل الكهربى ما بين ٢.٦ – ٤.١ ديسسيمنز/م لكل الانواع المختلفة من السماد العضوى. وتراوح الكربون الكلى ما بين ١٦.٦٠ – ٢٣.٨٩%. وتراوح النيتروجين الكلى ما بين ٠.٩٥ – ١.٦٨%، بينما تراوحت المادة العضوية الكلية ما بين ٢٨.٦٠ - ٤١.٢٠%. وتراوح الفوسفور والبوتاسيوم ما بين ٠.٢٧ – ١.١٣ و ٠.٢٧ – ٢.١١% على التوالى لكل الانواع المختلفة من السماد العضوى. وتراوحت نسبة الكربون إلى النيتروجين ما بين ١٤.٢٢ : ١ – ١٨.٥٢ : ١، وتراوحت الكثافة الظاهرية ما بين ٤٢٠ – ٦٥٥ كجم/م³ ، وتراوحت القدرة على الاحتفاظ بالماء ما بين ٣.٥٠ – ٤.٤٠ جم ماء/ جم من المادة الجافة من العينة، وتراوحت المسامية ما بين ٦٠.٦٩ – ٧٢.٤٧% لكل الانواع المختلفة من السماد العضوى.

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