Adding Cellulosic Ash to Composting Mix as a Soil Amendment

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ABSTRACT

Solid waste generation and composition in Baghdad is typically affected by population growth, urbanization, improved economic conditions, changes in lifestyles and social and cultural habits.

A burning chamber was installed to burn cellulosic waste only. It was found that combustion reduced the original volume and weight of cellulosic waste by 97.4% and 85% respectively.

A batch composting study was performed to evaluate the feasibility of co-composting organic food waste with the cellulosic bottom ash in three different weight ratios (w/w) [95/5, 75/25, 50/50].

The composters were kept in controlled aerobic conditions for 7 days. Temperature, moisture, and pH were measured hourly as process successful indicators. Maximum temperature ranged between (41 to 53) ºC.

Results showed that the blend of M2 [OFMSW: BCA] [75:25] was the most beneficial to composting. It maintained the highest temperature for the longest duration for 9hrs. at (53) ºC, achieved the highest nitrogen content(1.65%) , a C/N ratio of (14.18 %), nitrification index(N-NH4/N-NO3) of (0.29),nitrogen, phosphorous and potassium(NPK)(1.65, 1.22, 1.73)% respectively, seed germination 80% indicating that the achieved compost is mature and stable.

Heavy metal contents (Cd, Cr, Cu, Mn, Ni, Pb and Zn) were detected in the above compost and all were lower than the regulation limits of the metal quality standards for compost and stabilized bio-waste.

Key words: cellulosic and organic waste, incineration, bottom ash, composting, seed germination

اضافة رماد المخلفات السليلوزية الصلبة الى المادة العضوية المتحللة كمحسن تربة

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الخلاصة

تتاثر معدلات تولد النفايات الصلبة ومكوناتها في مدينة بغداد بالنمو السكاني والمستوى الحضاري وتطور الحالة الاقتصادية والتغيير الحاصل في نمط الحياة واخيرا بالعادات الاجتماعية والثقافية.

وقد تم تصميم و صنع محرقة بمواد اولية محلية لغرض حرق 1 كغم من المخلفات السليلوزية حصرا وانتاج الرماد . بلغت نسبة نقصان الحجم 97.4% من الحجم الاصلي ونقصان الوزن 85% من الوزن الاصلي مما يؤكد فعالية عملية الحرق في تقليل الاوزان والاحجام للمخلفات السليلوزية.
تم اجراء عملية تحلل بايولوجي لثلاث خلطات مختلفة من مخلفات الطعام مع رماد المواد السليلوزية وبالنسب التالية (95:5 , 75:25 , 50:50).
استمرت عملية التحلل 7 ايام وتم تسجيل قراءات الحرارة ومحتوى الرطوبة ودرجة الحموضة على مدى ساعات التجربة و تعد هذه القراءات مؤشرات لنجاح عملية التحلل البيولوجي حيث تراوحت اعلى قيم درجات الحرارة للمفاعلات الثلاثة (41,53) م^0.
اثبتت النتائج النهائية ان افضل خلطة هي [75:25] M2 اذ انها احتفظت باعلى درجة حرارة 53 م^0 لمدة 9 ساعات ، واعلى نسبة من النتروجين (1.65%) , وكانت فحوصات% (NPK)(1.65, 1.22, 1.73) ومؤشر انضاج البذور % 80 والذي يعد مؤشر على الخصوبة وفق المحددات المعتمدة في البحث.
تم الكشف عن محتوى العناصر الثقيلة (Cd, Cr, Cu, Mn, Ni, Pb and Zn) في السماد العضوي للخلطة M2 اعلاه وقد كانت دون المحددات ومعايير النوعية لهذا النوع من الاسمدة الحيوية.

الكلمات الرئيسية : المخلفات السليلوزية والعضوية , الاحتراق , الرماد السفلي , السماد , انبات البذور

1. INTRODUCTION

Incineration is a common technique for treating waste, as it can reduce waste mass by 70% and volume by up to 90%, as well as providing recovery of energy from waste to generate electricity. Generally, municipal solid waste incineration (MSWI) produces several streams of ash: bottom ash and fly ash. Treatment processes may be applied to the combined ash or to individual streams, **Lam, et al, 2010**.

Such ash could better be used as a supplement to fertilizers as it contains a variety of micro nutrients and abound of potassium and calcium. Wood ash fertilization for example increases pH and concentration of dissolved organic carbon (DOC) in the soil solution and enhances the activity of soil microorganisms, **Jokinen, et al., 2006; Maljanen, et al., 2006; Bougnom,** and **Insam, 2009**.

Using the ash from MSW incinerators for environmentally sound application not only provides a low cost aggregate but further reduces the need for landfill capacity**, Huang, et al., 2011.**

In particular, incineration of waste containing heavy metals should be avoided to maintain suitable slag quality (however, ordinary household waste does contain small amounts of heavy metals)**, Song, et al., 2004.**

All waste disposal alternatives eventually decompose organic materials into simpler carbon molecules such as CO_2 (carbon dioxide) and CH_4 (methane), while incineration provides the best way to eliminate methane gas emissions and furthermore, energy obtained from waste incineration projects provides a substitute for fossil fuel combustion, **Lam, et al, 2010**.

If the organic waste is buried in pits under partially anaerobic conditions, it will be acted upon by anaerobic microorganisms with the release of methane and carbon dioxide; the organic residue left is good manure. This process is slower than aerobic composting and occurs naturally in landfills. However, thermophiles digestion leads to energy recovery through biogas generation, **Giusquiani, et al., 1988**.

The final product after this conversion is called compost (humus), which is of high agricultural value. It is used as fertilizer, and it is odorless with no pathogens.

Because of this composting process, volume of the waste can be brought down to 50–85% **, Tchobanoglous,** and **Kreith, 2002**.

Composting could be manual or mechanical. Manual composting is adopted in smaller urban centers while mechanical composting is adopted in big cities, **Zhou,** and **Wong , 2001.**

The recycling of the organic matter contained in municipal solid waste (MSW) as an amendment for agricultural soils after composting is a feasible option for conserving the organic matter levels in soil and also for improving soil quality and productivity, **Araújo, et al., 2010.**

Compost has been reported as having a great potential for retaining trace elements in non-available forms potentially reducing their overall bioavailability and toxicity due to several processes, including raising soil pH, complication, sorption, precipitation, or a combination of them, thus providing an effective soil remediation technique, **Brown, et al., 2003; Brown, et al., 2004.**

However, some drawbacks may happen with this technique, namely the potential mobilization of some elements in particular Cu associated to dissolved organic matter and the re-release of the immobilized elements after compost organic matter mineralization in the long term, **Zhou, and Wong , 2001.**

Therefore, the aim of this of this research is to produce a compost of high quality as a solid waste management approach by analyzing heavy metals content in cellulosic ash and applying the compost process as a treatment method to make food waste and paper ash mixture as a soil amendment meeting applicable regulations

2. EXPERIMENTAL WORK

The experimental work consisted of two stages. The first stage was to incinerate separated cellulosic waste, while the second stage was to prepare compost by composting food waste with previously prepared bottom ash in definite ratios.

2.1 Incineration of Separated Cellulosic Waste

A schematic diagram of the incineration chamber that was used in the experiment and work is shown in **Fig.1**. Only cellulosic waste was burned in manageable volumes so the fire does not get out of control.

2.1.1 The basis of the design of the combustion chamber

Combustion chamber was designed on the basis of burning of 1 kg of cellulosic waste, which equals to 0.015 m^3. The burning chamber was designed to be 0.025 m^3, where the excess size is 0.01 m^3 to provide enough space for air and for easy flipping for the sake of completion of combustion process.

2.1.2 Incinerator design

The burning chamber is normally 0.025 m^3 with a removable side, devices or features for higher burning temperatures, better mixing of air and suitable holding time, were affixed to the chamber. This chamber is made of heavy sheets of locally available materials 4 mm-ferrous alloy, with a side-covering lid to help in heat retention, suitable holding time inside the chamber, feed cellulosic materials, entering the combustion flame, and flipping feed material during the burning process and provided with a chimney having a small slot for gas measuring that will be emitted during the process of burning.

A handmade waste distributer was used to turn burning material over and a handmade ash collector was used to collect totally burned waste.

A perforated steel plate was installed in the chamber, 10 cm a part from one end for ventilation to supply combustion air.

A pressure gage inlet air controlling gas and a compressor to pump air were provided for the combustion process.

Several burning test runs were held in order to optimize operational procedures and four runs were performed to collect bottom ash for analysis.

2.2 Composting Food Waste with Bottom Ash in Definite Ratios.

2.2.1 Materials and method

The preparation of the experimental samples was based on the representative components of MSW chosen from regular daily kitchen waste. The samples were mixed artificially according to definite ratios.

The composting system consisted of three plastic containers of 15 cm diameter and 30 cm height with screw covers as shown in **Fig.2**. The useful volume of each composter is 5.2 liter while the degree of initial filling is 75%. Approximately 2 kg of feed materials were introduced in each composter with different organic food municipal solid waste to bottom cellulosic ash (OFMSW: BCA) ratios according to definite C/N values.

C/N values were calculated using the following equation, **Tchobanoglous, et al., 1993**:

$$\frac{\text{C in 1 kg in OFMSW} + \text{C in x kg in BCA}}{\text{N in 1 kg in OFMSW} + \text{N in x kg in BCA}} = \text{C/N} \quad (1)$$

Where:
C: Carbon percentage
N: Nitrogen percentage
OFMSW: Organic Food of Municipal Solid Waste in kg
BCA: Bottom Cellulosic ash in kg
X: weight of BCA in kg

Biodegradable (organic) waste was segregated at household level minced into pieces of <5 mm in diameter using a food processor (Brown, China), and mixed well with definite proportions of bottom cellulosic ash so as to achieve different C/N ratios. As leachate was formed during the composting process holes were made in the bottom of the composters for the release of this leachate. Temperature and moisture content were measured using sensors with platinum probe installed in the center inside each composter. Leaves were added as a bulking agent and as a source of nitrogen. Garden soil was also added to the mixture to provide more desired microorganisms, **Lin, et al., 2008**.Water was added as needed to facilitate the mixing and composting processes.

Experiments were carried out all together at one time to assess the effect of adding ash to the composting processes. Composting material was rolled every 12 h, for 5 min each time with open cover to ensure oxygen contact into the center of the composter and regenerating heat. Composting is essentially completed when mixing no longer produces heat in the mixtures inside and temperature stands still, **Bass, et al., 1994 and Giannis, et al., 2012.**

2.3. Analytical Procedure

2.3.1 Characterization of the composting process

a. Temperature, pH and Moisture contents

The compost temperature, pH and moisture content were measured at regular time intervals throughout the composting period, using a digital thermometer. Measurements proceeded until the termination of the composting processes.

2.3.2 Characterization of the compost

a. Determination of organic matter and carbon

Organic matter was determined using combustion method, **ASAE, 2004**:

Two grams of sample were weighed and dried in an air oven at 105° C for 24 hr. The dried sample was weighed to determine dry weight (A). Then burned in afurnace at 550°C . After cooling,the sample was weighted to measure the ash weight (B).

The contents of organic matter and carbon are measured as follows**, Girovich, 1996**:

$$\% \text{ Organic matter} = (A-B)/A \times 100 \quad (2)$$

$$\% \text{ Carbon} = (\% \text{ organic matter}) / 1.8 \quad (3)$$

b. Determination of N-NH_4, N-NO_3 and Phosphorus

The content of nitrogen as ammonium and as nitrate and total phosphorous as P_2O_5 was determined by using Multi-Direct Photometer for multi-parameter analyses (lovibond) at Engineering Collage of Baghdad University / post graduate laboratories

c. pH

Ten grams of each sample were weighted and strewed into Erlenmeyer flasks with 100 ml of distilled water. The prepared sample was placed in an auto shaker for 30 min. pH of samples was measured by using a pH meter (Inolab WTW series)**, ASAE, 2004.**

d. Potassium and heavy metals concentrations

Potassium and heavy metals concentrations in BCA and in the final compost products were analyzed using Niton (XRF), Thermo scientific 900 heavy metals analyzer.

e. Germination Test

In order to employ the evaluated composts as plant growing media, the Germination Index (GI) was measured.

The germination test was performed for 48 h at 25^{o}C in the dark with 20 radish seeds placed on a 9 cm filter paper (Whatman No. 1) soaked with 4 ml of compost extract and placed in a Petri dish, **Bertran, et al., 2004** as shown in **Fig. 3**.

The germination test was repeated with de-ionized water as a control, and repeated with extract of commercial compost.

The following equations were used to calculate the relative seed germination, relative root growth, and germination index (GI), **Zucconi, and Marco, 1997;Tiquia, et al., 1996** and **Marek, et al., 2003**:

$$\text{Relative seed germination }(\%) = \frac{\text{Number of seeds germinated in compost extract}}{\text{Number of seeds germinated in control}} \text{ x } 100 \qquad (4)$$

$$\text{Relative rootgrowth}(\%) = \frac{\text{Mean root length in compost extract}}{\sqrt{\text{Mean root length in control}}} \text{ x } 100 \qquad (5)$$

$$\text{GI }(\%) = \frac{(\text{Relative seed germination })\text{x}(\text{Relative root growth})}{100} \qquad (6)$$

3. RESULTS AND DISCUSSION

3.1 Incineration of Separated Cellulosic Waste

3.1.1 Volume and weights percentage reduction

Table 1. represents volume and weight reduction of cellulosic waste due to the combustion process.

It can be noticed that combustion reduces the original volume and weight of the cellulosic waste by 97.4% and 85% respectively, still incineration is not very much practiced in Iraq.

3.2 Composting Food Waste With Bottom Ash in Definite Ratios.

3.2.1 C/N ratios

The C/N ratio was assumed to be 25 as a starting ratio using Eq. (1)**, Tchobanoglous, et al., 1993**:

(C/N) for mixing = 25: 1
(C/N) for OFMSW = 25.5:1
(C/N) for BCA = 20.5: 1
1. Moisture content of OFMSW= 60%
2. Moisture content of BCA = 8%
3. Nitrogen content of OFMSW = 2.6%
4. Nitrogen content of BCA= 0.5%

The percentage composition for OFMSW and BCA .

(a) For 1 kg of OFMSW
Water = 1 kg (0.60) = 0.60 kg
Dry matter = 1 kg - 0.60 kg = 0.40 kg
N = 0.40 kg (0.026) = 0.0104 kg
C = 25.5 (0.0104 kg) = 0.2652 kg

(b) For x kg of BCA:

Water = x kg (0.08) = 0.08 x kg

Dry matter = x kg - 0.08 x kg = 0.92 x kg

N = 0.92 x kg (0.005) = 0.0046 x kg

C = 20.5 (0.0046 x kg) = 0.0943 x kg

The amount of BCA to be added to 1 kg of OFMSW to achieve a C/N ratio of 25:

where x = weight of BCA required

$$\frac{0.2652\ \text{kg}\ +0.0943\ (\text{x})\ \text{kg}}{0.0104\ \text{kg}+0.0046(\ \text{x}\ )\text{kg}}= 0.25\text{kg}$$

x = 0.25 kg BCA /1 kg OFMSW

Data are summarized in **Table 2.**

3.2.2 Physicochemical parameters of the composting process

a. Temperature

The temperature profile of the composting mixtures in each composter was measured at regular time intervals through the composting periods.

Fig. 4 shows the composting temperature variations as a function of composting time. The temperature follows a typical temperature profile for composting (mesophylic-thermophylic-mesophylic) phases. As seen, the temperature increased from ambient temperature to more than 40 °C, showing rapid initiation of the compost process. The substrates passed from an initial mesophylic phase (<30 °C) to the thermophylic phase after 18 hr. for mixture 1(M1), 15 hr. for mixture 2(M2), and 21 hr. for mixture 3(M3).

Comparing the mixtures it seems that higher temperature was achieved in the mixture of M2 (75% food waste:25% bottom cellulosic ash) by weight.

As the organic compounds were degraded, the mixture became richer in more stable compounds which were less accessible to the microorganisms. As a result corresponding temperature begun to decrease gradually reaching almost ambient temperature which represents a second mesophylic phase on the 36hr ofM1, the 42hr ofM2, and on the 30hr of M3.

Elevated temperatures (>50 °C) were maintained in one composter M2 for 9 hr. which is sufficient time for the sanitation of the substrate and to get rid of pathogenic microorganisms that exist in food waste. While lack of increasing in compost temperature of M1 and M3 may indicate low compost stability . Similar temperature profile was observed in related pilot scale composting experiments held locally by **Al-Zubaidi, 2013; Talib, 2014** and globally by **Tang, et al., 2007; Lu, et al., 2008; Elango, et al., 2009** and **Gao, et al., 2010**.

b. pH

Analysis of the pH curve on the basis of time in **Fig. 5** shows that the compost initial pH, was 9.0, 10.0 and 11.5 for M1, M2 , M3 respectively and declined over time and was moderated to the neutralization level.

The pH of the mature compost was near neutral (6.0–7.5) indicating a good quality compost and within the suggested range of (6–8.5) **(CCQC, 2001).**

This finding was closely related to **Sánchez-Mondero, et al., 2001; Huang, et al., 2011.**

c. Moisture content (Mc)

Moisture content is the most important factor that promotes and accelerates decomposition process.

The initial substrates were prepared to have relative high moisture content (75%, 72% and 80% for M1, M2 and M3 respectively). The moisture content was sustained at optimal levels around 50–70% to sustain the rmophylic phase.

At the final stage of composting water quantity was gradually decreased reaching at 54%, 39% and 59% at the final day of the process on the 7th, for M1, M2 and M3 respectively. Water, product of degradation, was expected to vaporize inside the composters and condensed on inner surface of containers and remained in the system. **Fig. 6** shows moisture content profiles.

d. Nitrogen content

Nitrogen content was measured at the end of each trial i.e. on the 7^{th} day, it was found to be 1.5%, 1.65% and 1.04% for M1, M2 and M3 respectively as shown in **Table 3.**

During composting, nitrogen is metabolized mainly to ammonium while the non-soluble complexes of nitrogen decompose to soluble nitrogen forms that are readily available for metabolic activities. Gaseous nitrogen losses during composting occur mainly as ammonia but may also occur as nitrogen and nitrates oxides, **Eklind,** and **Kirchmann, 2000**.

On the other hand, in terms of dry weight, there is an increase in total nitrogen concentration due to the mineralization of organic matter and consequent loss of weight in the mass being composted through losses of CO_2 and H_2O, **Bane gas, et al., 2007** .

The initial substrate acquired 17.6, 21.2 and 31.0 C/N ratio, forM1, M2, and M3 respectively, while at the end of the process the C/N ratio had decreased to 14.13, 14.18 and 23.6 for M1, M2 and M3 respectively due to carbon consumption, which are qualified as good quality compost, **CCQC, 2001** and thus can be applied in agricultural land.

Researchers have suggested various ideal C/N ratios from more than 12 to lower than 25, **Brewer,** and **Sullivan, 2003; Rihani, et al., 2010** and **Al-zubaidi, 2013** depending on the initial feedstock. The ratios obtained in this survey for M1, M2 and M3 may be considered satisfactory**, CCQC, 2001**.

The degree of stability of the compost is also strictly related to the nitrification index N.I ($N\text{-}NH_4/N\text{-}NO_3$), and can be considered as an indicator of a high degree of compost stabilization**, Brinton, 2000; CCQC, 2001; Abouelwafa, et al., 2008** and **Huang, et al., 2011**.

In this survey, the acquired ratio was 0.2, 0.28 and 0.31, for M1, M2, and M3 respectively. ratios lower than 0.5 are the best mature compost**, Brinton, 2000** and **CCQC, 2001**.The nitrification index of 0.29 suggesting that M2 has the higher stability among the three mixtures as shown in **Table 4.**

e. Nitrogen, phosphorous and potassium (NPK)

Plants require more than a dozen different chemical elements. Nitrogen, phosphorus and potassium are the three main elements commonly supplied in fertilizers, while boron, copper, and manganese are sometimes also added in small quantities.

Ash is rich in two out of three of these main nutrients: phosphorous and potassium (nitrogen is lost during the combustion)**, Lam, 2010**. This means that ash can potentially supply P and K, replacing commercial fertilizers. Levels (NPK value) in the finished compost are important in determining the quality of compost, since those elements are essential nutrients for plant growth, **CCQC, 2001**.

Iyengar and Bhave in 2006 reported that the nitrogen, phosphorous and potassium (NPK) contents for compost should be more than 1% each.

The total N% was found to be 1.5%, 1.65% and 1.04% for M1, M2 and M3 respectively as previously mentioned in **Table 3**. The results shown in **Table 5** revealed that initial values of nutrient P as percentages decreased to 1.03, 1.22, and 0.87 for trials M1, M2, and M3 respectively. While the percentages of P in the original mixtures were 1.61 1.33, and 1.07 as percentages respectively . This reduction may be attributed to consumption of phosphoric compounds in cell growth .The amount of K values increased to 1.91, 1.73, and 1.89 as percentages for the three trials respectively. Accordingly the nutrients level of the end-product composts appeared to be sufficient for plant growth for all mixtures**, TMECC, 2002**.

f. Heavy metals

The concentration of heavy metals in BCA and in the end-product resulted from M1, M2 and M3 composting trials have been examined and presented in **Table 6**.The heavy metals concentrations in the composts were generally low and did not exceed the suggested limits by TMECC, Composting Council, 2002 as presented in **Table 6.**

High levels of aforementioned heavy metals in the composts represent an obvious concern if they are to be applied to food crops. Heavy metals do not degrade throughout the composting process, and frequently become more concentrated due to the microbial degradation and the loss of carbon and water from the compost, **Richard ,and Woodbury 1992.**

Compost produced from M1, M2 and M3 trials may be classified as first class compost based on the metal quality standards for compost, **Brinton, 2000** as shown in **Table 7**.

Total metal contents in compost are of concern when repeated applications to land occur. Field trials involving MSW compost application to soil have all reported an increase in soil and plant metal concentrations (e.g., Ni, Pb, Zn and Cu) **, Smith, 2009**.

g. Germination test

The compost obtained from M2, trial, after 7 days of composting of 72% moisture content and C/N ratio of 14.18 was used to carry out the germination test, to check the phytotoxic effect on plant growth**, Brinton, 2000**. .

The outcomes of the germination test are given in **Table 8** that shows 80% relative seed germination and 89 % root growth; the calculated value of germination index (GI) is 71.2 %, almost near to commercial compost extract outcomes having relative seed germination (70 %), root growth (76%) and GI (53.2%) as calculated below:

$$\text{Relative seed germintation } (\%) = \frac{8}{10} \text{ x } 100 = 80\%$$

$$\text{Relative } rootgrowth(\%) = \frac{0.89}{\sqrt{1}} \text{ x } 100 = 89\ \%$$

$$GI\ (\%) = \frac{(80)x(89)}{100} = 71.2\%$$

h. **Maturity assessment**

Compost is assigned a maturity rating of immature, mature, or very mature, pending the outcome of up to three parameters analyses. The compost C: N ratio is first evaluated: compost with a C: N ratio greater than 25:1 would be classified as immature compost; no further testing would be necessary needed for the maturity classification. If the C:N ratio is equal to or less than 25:1, then the compost must be evaluated for both stability and maturity using one of the indicators presented in **Table 9**, **TMECC, 2002.**

According to **Table 9** above M2 compost may be classified as mature compost.

4. CONCLUSIONS AND RECOMMENDATIONS.

4.1. Conclusions

1. Incineration proved to be a good cellulosic waste treatment. It can be noticed that combustion reduces the original volume and weight of cellulosic waste by 97.4% and 85% respectively.
2. Three different blend were suggested according to three C/N standard ratios to evaluate the feasibility of co-composting organic food waste with the cellulosic bottom ash [(M1) 95/5,(M2) 75/25,(M3) 50/50].
3. Results showed that the blend of M2 [OFMSW: BCA] [75:25] was most beneficial to composting. It maintained the highest temperature for the longest duration for 9 hrs. at (53) ºC, achieved the highest nitrogen content (1.65%) , a C/N ratio of (14.18 %), nitrification index (N-NH4/N-NO3) of (0.29), nitrogen, phosphorous and potassium (NPK)(1.65, 1.22, 1.73) %, Seed Germination 80 % indicating that the achieved compost is mature and stable according to regulations.
4. Heavy metal contents (Cd, Cr, Cu, Mn, Ni, Pb and Zn) were detected in the above compost and all were lower than the regulation limits of the metal quality standards for compost and stabilized bio-waste.

Finally the research proved a simple way of treating food solid waste with cellulosic bottom ash by turning these waste into useful biomass as soil amendment.

4.2 Recommendations

1. Government and its Ministries of Education, Health and Environment must collectively develop a plan that is recognized by all sectors of society to ensure the concept of environmental sustainability is understood and continues to be developed throughout society,

2. Encouraging recycling efforts, by giving incentives and tax exemptions where appropriate. Encourage public-private partnerships for instance giving licenses to private waste collectors.
3. Encouraging private sector to set up more recycling industries for recycling plastic and metallic solid waste. The private sector should also come up with strategies of reusing and conversion (composting) organic waste.

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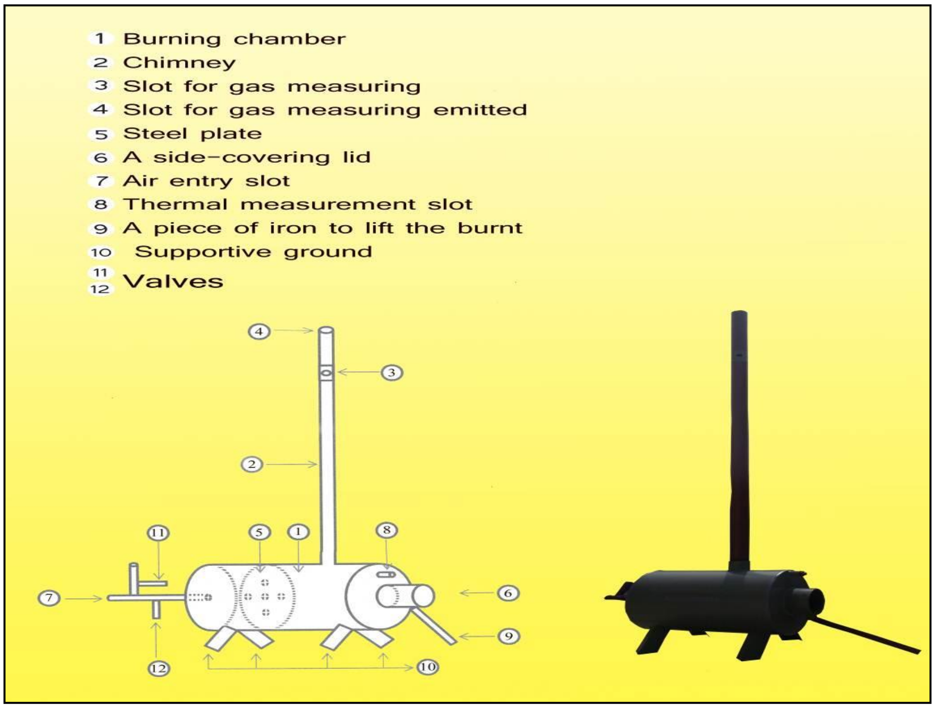


Figure 1. A schematic diagram of the incineration chamber .

Figure 2. Composters with three different OFMSW: BCA ratios.

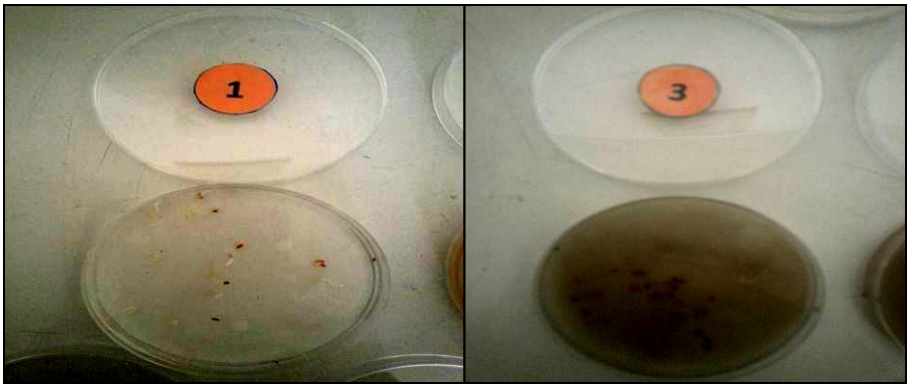
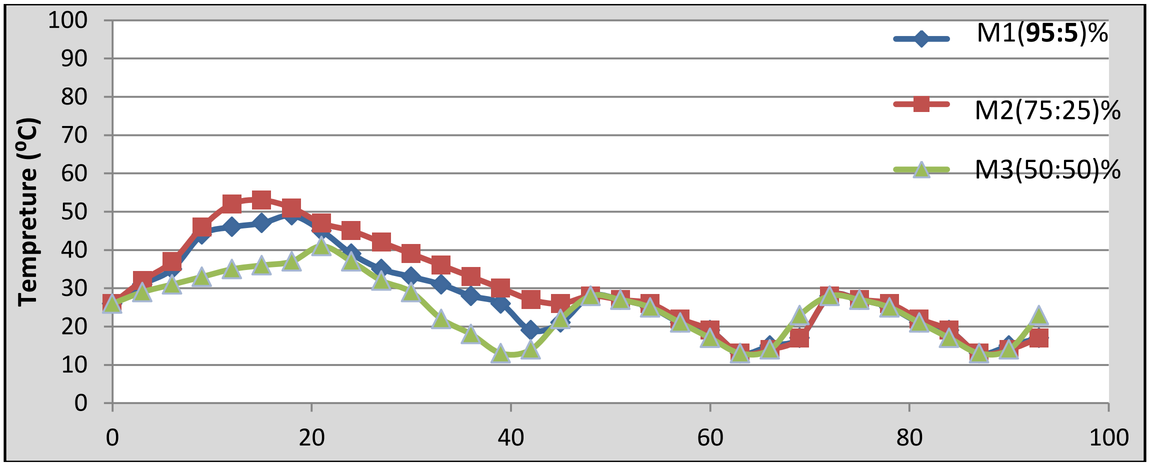


Figure 3. Germination test with de-ionized water (1) and extract of commercial compost (3).



Time (hr)

Figure 4. Temperature profile of M1, M2 and M3 as a function of time.

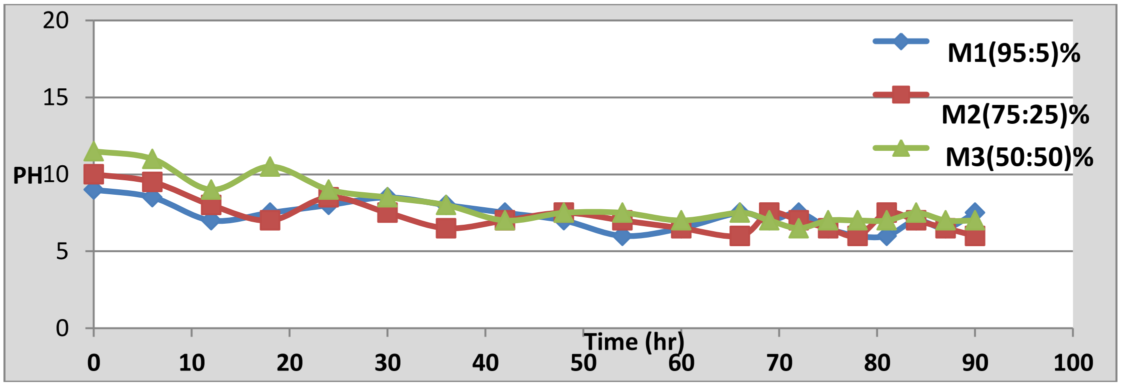


Figure 5. PH profile of M1, M2 and M3 as a function of time .

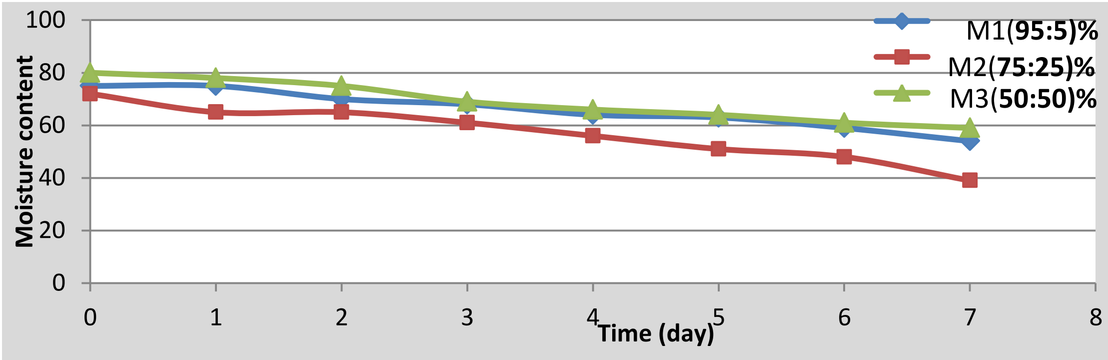


Figure 6 . Moisture profiles of M1, M2 and M3 as a function of time.

Table 1. Volume and weight reduction of cellulosic waste.

	Before combustion	After combustion	% reduction
Volume(m^3)	0.15	0.0039	97.4
Weight (kg)	10	1.5	85

Table 2. Percentage composition for food waste and ashes.

Mixture	OFMSW %	BCA%	OFMSW kg	BCA kg
M1	95	5	1.9	5
M2	75	25	1.5	0.5
M3	50	50	1	1

Table 3. Properties of initial and final compost .

	O.C.% INITIAL	O.C.% FINAL	N% INITIAL	N% FINAL	C/N INITIAL	C/N FINAL
M1 (95:5)	31.7	21.2	1.80	1.50	17.6	14.13
M2 (75:25)	35.8	23.4	1.69	1.65	21.2	14.18
M3 (50:50)	33.8	24.3	1.09	1.04	31.0	23.60

Table 4. Nitrification index for the concerned proportions .

mg/Kg	M1(95:5)	M2(75:25)	M3(50:50)
NH_4--N	267.90	312.40	399.40
NO_3+-N	848.30	1043.50	1150.80
NH_4--N/ NO_3+-N	0.31	0.29	0.34

Table 5. P and K levels in initial proportions and final composts .

	M1(95:5) Initial (final)	M2(75:25) Initial (final)	M3(50:50) Initial (final)	(TMECC, 2002)
P%	1.61 (1.03)	1.33 (1.22)	1.07 (0.87)	(0.56 -1.56)
K%	1.84 (1.91)	1.66 (1.73)	1.85 (1.89)	(0.62-1.22)

Table 6. Concentration of heavy metals in BCA and in compost end-product .

Metal mg/Kg	TMECC, 2002	BCA	M1 95:5	M2 25:75	M3 50:50
Cd	35	<LOD	<LOD	<LOD	<LOD
Cr	1200	<LOD	43	49	32
Cu	1500	114	55	12	44
Hg	7.8	<LOD	<LOD	<LOD	<LOD
Ni	420	<LOD	19	15	7
Pb	300	67	67	53	89
Zn	2800	173	188	154	96
As	41	<LOD	<LOD	<LOD	<LOD

LOD: Level of Detection

Table 7. Heavy metals concentration in M1, M2 and M3 compared to quality standards, **(Brinton, 2000)**.

Metal mg/Kg	Quality class A	M1	M2	M3
Cd	1.0	<LOD	<LOD	<LOD
Cr	50.0	43	49	32
Cu	60.0	55	12	44
Hg	0.3	<LOD	<LOD	<LOD
Ni	20.0	19	15	7
Pb	100.0	67	53	89
Zn	200.0	188	154	96
As	25.0	<LOD	<LOD	<LOD

Table 8. Outcomes of germination test.

Item/ parameter	Control test	Compost extract of M2	Compost extract of Commercial compost (beat moss)
Total seeds	10	10	10
Germinated seeds	10	8	7
Mean root length (cm)	1	0.89	0.76
Relative seed germination (%)	1	80	70
Relative root growth%	-	89	76
Germination index (%)	-	71.2	53.2

Table 9. Compost maturity indices **(TMECC, 2002) .**

Method	Units Rating		
	Very Mature	**Mature**	**Immature**
NH4- : NO3-N Ratio	< 0.5	0.5 - 3.0	> 3
Total NH3-N ppm	< 75	75 - 500	> 500
VOA ppm, dry basis	< 200	200 - 100	> 1,000
Seed Germination %	> 90	80 - 90	< 80
Plant Trials % of control	> 90	80 - 90	< 80
Nitrogen Draw-down	0	< 10%	> 25%