ISSN 2347-6893

Evaluation of Two Drying Systems in Municipal Organic Solid Waste Composting

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ABSTRACT

An experimental study design with laboratory analysis was used to evaluate effects of natural and artificial drying on the quality of organic fertilizers. Organic waste was subjected to windrow composting and the matured compost was dried using two different methods: Sun Drying (SD) and an Electric Rotary Dryer (ERD). Part of the fertilizer was spiked with chemical fortifiers (phosphate and urea). Organic and organo-mineral fertilizers were analysed for nutrient and heavy metal contents. The nutrient levels: %N (1.88±0.02; 1.37±0.01), %P (2.86±0.01; 2.05±0.01), %K (8.62±.01; 5.47±.01), %O.C (4.57±.01; 6.48±.01) and heavy metal contents: Pb (2.49±0.01mg/kg; 1.57±0.01mg/kg), Cd (1.97±0.01 mg/kg; 1.24±0.01 mg/kg), Zn (96.86±0.01 mg/kg; 89.47±.01mg/kg), Cr (0.68±0.00; 0.62±0.01mg/kg) were significant higher in SD than ERD samples respectively. Hence, both methods were effective as the guidelines were maintained in both samples. It is recommended that the use of electric dryer should be complemented with chemical fortification to boost the fertilizer nutrient levels.

Keywords:-Electric rotary dryer; Artificial drying; Chemical fortifiers; Organo-mineral fertilizer

Academic Discipline And Sub-Disciplines

Environmental Science

SUBJECT CLASSIFICATION

Environmental Technology

TYPE (METHOD/APPROACH)

Laboratory-based experimental studies

Council for Innovative Research

Peer Review Research Publishing System

Journal of Advances in Biology

Vol. 7, No. 3

www.cirjab.com

editorsjab@gmail.com , editor@cirjab.com

INTRODUCTION

The quality of compost depends on its original constituents and the condition it undergoes.While compost which is too dry can be dusty and irritating to work with, wet compost can become heavy and clumpy, making its application more difficult and delivery more expensive. Within the last 20 years, bio drying has been investigated, tested, and promoted for waste management [1, 2], however electromechanical drying remains a relatively new technology and published research in this area is limited.Wu and Ma [3], in a related study, compared evolutionof CO_2, seed germination rate, and water-soluble organic carbon between fresh samples with short storage at 4^oC for less than 1 week and air-dried compost samples stored for one year. They concluded that the effects of storage and air-dry on the measured parameters depended on compost stability and maturity and on the compost material source.

The general benefits of dry compost have related to pathogen destruction and stabilization of biodegradable volatile solids. Also, drying eases the transportation and handling expenses, and can minimize potential odour even if the composting process is incomplete. In contrary, the problem of high moisture content in compost is more critical in many countries like Nigeria where the environment is relatively humid and during the rainy season.Besides organic waste composting, a situational review on biogas technology byAnthony and Wilson [4] showed that biogas production was gaining ground in Sub-Saharan Africa, though Nigeria has not been able to develop plant with big capacities. All types of biogas plants generate spent slurry (also known as liquid fertilizer). The slurry needs to be applied directly on the farms because it cannot be stored due to high moisture content.This situation normally leads to over fertilization and condition known as 'soil sickness'.Furthermore, both compost and biogas slurry requirelargespace of land for natural drying by sun which may not be easily available in the face of other developmental projects.

The optimal moisture content for successful composting varies depending on the physical state and size of the particles and on the composting system used. Less moisture in the pile will result in dehydration, which slows biological processes. Excess water interferes with aeration by clogging pores. If the moisture content of the mass is so high as to displace most of the air from the interstices, anaerobic conditions develop within the mass. Therefore, the maximum acceptable moisture content is a level at which no nuisance conditions (e.g., anaerobiosis) will develop and at which the process will proceed satisfactorily. Moisture content of the pile can be measured in the field using a range of analytical equipment ranging from gypsum blocks to tensiometers. Alternatively, a sample can be taken to the laboratory and measured field-moist and oven-dry (i.e., after 48 h in an oven at 105°C). These data are used to calculate the gravimetric moisture content. Moisture is rapidly depleted from an active compost pile and must be replaced by regular additions of water. The optimum amount of water to be applied to a compost pile can be

calculated from a mass balance equation [5].

Hammed [6] determined effect of moisture content on bio-mineralization of nutrients, release of heavy metals and microbial characteristics of liquid, solid and semi-solid fertilizers was investigated. Three identical compost chambers were maintained at 10%, 50%, and 80% ofmoisture content in a windrow composting process. He concluded that there were variations in the levels of nutrients, heavy metals and types of microorganism in the samples maintained at different levels of MC. More nutrients and lower pathogenic organisms were characterized from compost with 10% MC. However, Akanbi et al. [7] demonstrated that instead of in bulky heavy form, compost could be formulated into liquid form. This reduces quantity required per unit area of land, makes handling and application easier and improved the chances of adoption of composting technology by the peasant farmers in Nigeria.

Against all thedrawbacks inherent in wet compost or organic fertilizer, there is emergent need for technical intervention on how to reduce the moisture content in cured and matured compost so as to ensure its effective application on farm. One quick intervention with a promising solution is to dry compost with electromechanically generated heat. This may have serious effects on the composition of the compost. This study therefore evaluated the potential effects of natural (sun) and artificial (electromechanical) drying on the quality of organic fertilizer.

MATERIALS AND METHODS

Organic waste was collected from the municipality in Ibadan, Oyo State. Single Superphosphate (SSP) was produced by Fertilizer and Chemical LTD in Nigeria for the Federal Fertilizer Departmentt, Federal Ministry of Agriculture and Rural Development and contained 18% P_2O_5 per 50 kg bag. Urea was a product of AFCOTT NIGERIA LMT and it contained 46% N per 50 kg bag. Organic waste was subjected to windrow composting by mixing with cow intestinal waste in ratio 3:1 (dry weigh) as described in a previous study [8]. The matured and cured compost was dried using two different methods: Sun Drying (SD) and an Electric Rotary Dryer (ERD) specially designed and fabricated for the purpose (Figures 1 and 2 respectively). Part of the dried fertilizer was fortified with chemical fortifiers (phosphate and urea) to compensate for nutrient loss. Samples were identified thus:

- Sun Dry 1- Ordinary Compost Dried by the Sun
- Sun Dry 2- Fortified Compost Dried by the Sun
- Mechanical Dry 1- Ordinary Compost Dried by ERD
- Mechanical Dry 2- Fortified Compost Dried by ERD

ISSN 2347-6893

Figure 1. Natural (Sun) drying

Figure 2. Artificial drying of compost by Electric Rotary Dryer(ERD) machine

DESIGN AND OPERATION OF COMPOST DRYING MACHINE (ERD)

Design of ERD

The machine was designed in the University of Ibadan by Engr. David Fadare in 2006. Through a keen supervision and technical guidance, a roadside welder carried out the fabrication. It consists of rotary drying chamber powered with 5 H.P gear electric motor, heating chamber with four 1,000 Watt coiled heater, air blower powered with a 2 H.P electric motor, pulley belt and air circulation channel.It works on the principles of evaporation and the materials used for fabrication were almost 99% metal. A stirrer was fixed inside the compost chamber to turn the compost and prevent lump formation. In order to minimize nutrient loss during the drying process hot air is replenished into the system through the channel. There are three control panels supplied with the machine. One is the thermo start for temperature control and the secondpanel controls the rotation of the chamber for easy loading and off-loading and the third controls blowing of hot air into the system.the direction of rotation of fan inside the blower is clockwise (CW).

Operationof ERD

The required moisture content of the compost to be dried in the drying machine shouldnot be higher than 45% for its optimal operation. In casethe compost moisture content is higher than 45%, it is recommended that the compost should be air dried for some days before loading into the machine. To load the compost into the chamber, cover of the loading hopper is lifted up and after the loading is complete, it is properly closed. Heater switchon the control panelis put onand set at 100^{o}C.Immediately after putting on the heaters, blower control switch is also put on. The compost is allowed to dry for 30 minuteswithout rotation of the drying chamber.After every 30 minutes, the drying chamber is set into one complete rotation by switching on the control button from the panel.After 4 hour of drying, depending on the quantity of the compost; the rotation of the drying chamber can now be continuous.Minimal period of 6 hours of drying is required to dry 50 Kg compost depending on the initial moisture content of the material.After drying to the required level of moisture content, heater, blower and dryer rotation control switches are put off.Cover of the drying chamber is opened and lifted toempty the dried compost.

PROCEDURES FOR LABORATORY ANALYSIS

Total Nitrogen (N) was determined by the micro kjeldahl method. Phosphorus (P) and potassium (K) were determined by wet digestion method [8]. The mixture of concentrated nitric, per chloric and sulphuric acid in a ratio of 5:1:1 respectively was used to digest 2 g of each sample and samples were analyzed for P by vanadomolybdate method, K and Ca were measured with flame photometry, Mg, Cu, Zn, Fe and Mn were measured with Atomic-Absorption Spectrophotometer [9].The results were subjected to student t- test statistics to compare the means at 0.05 significant level.

Fortification oforganic fertilizer

Material required for fortification included: scale, fortifiers- Single Super Phosphate (SSP) and urea, and mechanical mixer. A known amount of each SSP and urea were added to pre-measured compost to boost its level of phosphorus and nitrogen respectively. The mixture was fed into the fortifying tank and mixed for 5 minutes to ensure homogeneous mix. To determine the appropriate quantity of the fortifier, the following calculation was used:

Calculation for the fortification of compost

$\mathbf{C_1W_1 = C_2W_2}$ **--------------------------------- (1)**

Where **C** is concentration and **W** is weight of the fortifier.

Moisture Content (MC) was corrected before fortification to established standard of12% and this was done on dry weight basis.

$\mathbf{\Delta P = P_2 - P_1}$ **----------------------------------- (2)**

Where$\mathbf{\Delta P = C_2}$. That is, concentration of fortifier one intends to achieve.

To calculate new W,

$C_1W_1 = C_2W_2$,

Therefore, $W_1 = \frac{\Delta P \, x W_2}{C_1}$

Then, W_1 which is the quantity of the fortifier was diluted to W_2 with compost.

RESULTS AND DISCUSSION

The nutrient and heavy metal values of compost dried by both methods and the compost that was fortified after drying are shown in Table 1 and 2 respectively. All the nutrient levels and heavy metal contents were significant higher in SD than ERD samples.When compared to national compost guide line all the samples from both drying methods were higher in values in terms of %N, %P and %K. Previous studies have revealed that organic waste from the country was rich in nutrient required for plant growth [8, 9, 10]. The %C was lower than the standard probably because drying denatured organic carbon content of the compost.The results are also in consonance with standards from other country [11].

The results of heavy metal contents were far below the standards obtainable from different countries. Various studies have shown reduction in heavy metal levels during composting [9, 12]. The reduction has been attributed to the metal ions becoming bound to organic molecules thereby reducing their solubility [13]. It might also be partly due to waste separation before composting [14] or effect of high temperature as shown earlier by Soyingbe et al. [12].

Table 1. Chemical composition of compost dried sun drying and electric rotary dryer

Parameter	Sundry 1	Mechanical Dry 1	Nigerian Guide line	CanadianGuide line (15)	German Guide line (14)
% N	1.88±0.02a	1.37±0.01b	1.0 to 4.0%	-	-
% P	2.86±0.01a	2.05±0.01b	1.5 to 3.0%	-	-
% K	8.62±0.01a	5.47±0.01b	1.0 to 1.5%	-	-
% O.C	6.48±0.01a	4.57±0.01b	At least 20%	-	-
Pb (Mg/Kg)	2.49±0.01a	1.57±0.01b	-	150	150
Cd (Mg/Kg)	1.97±0.01a	1.24±0.01b	-	3	3
Zn (Mg/Kg)	96.86±0.01a	89.47±0.01b	-	700	500
Cr (Mg/Kg)	0.68±0.00a	0.62±0.01b	-	210	150

Table 2. Chemical composition of dried and fortified compost

Parameter	Sundry 2	Mechanical Dry 2	Nigerian Guide line	CanadianGuide line (15)	German Guide line (14)
% N	1.97±0.02a	1.42±0.01b	1.0 to 4.0%	-	-
% P	3.03±0.02a	2.28±0.02b	1.5 to 3.0%	-	-
% K	9.16±0.03a	6.05±0.01b	1.0 to 1.5%	-	-
% O.C	7.24±0.01a	5.03±0.02b	At least 20%	-	-
Pb (Mg/Kg)	3.14±0.23a	1.99±0.01b	-	150	150
Cd (Mg/Kg)	2.02±0.01a	1.36±0.00b	-	3	3
Zn (Mg/Kg)	100.52±0.01a	90.41±0.01b	-	700	500
Cr (Mg/Kg)	0.88±0.00a	0.55±0.01b	-	210	150

Immature and poorly stabilized composts may pose a number of problems during storage,marketing and use. During storage these materials may develop anaerobic ‘pockets’ whichcan lead to odors, fire, and/or the development of toxic compounds. Continued activedecomposition when these materials are added to soil or growth media may have negativeimpacts on plant growth due to reduced oxygen and/or available nitrogen or the presence of phytotoxic compounds. The results are also in consonance with standards from other country [11].

CONCLUSION

Although, the electric rotary dryer reduced the nutrient levels of the organic fertilizer, it as well reduced its heavy metal contents which usually constitute serious threat to the use of organic fertilizer. Also, fortification has potential to re-boost compost nutrient levels. Both methods of drying may be effective as the guidelines were maintained in both samples.It is therefore recommended that the use of electric dryer should be complemented with chemical fortification to boost the fertilizer nutrient values.

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Author' biography with Photo

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He is a lecturer in the Department of Environmental Health Sciences. He has bachelor in Environmental Management and Toxicology from the University Agriculture,Abeokuta, Ogun state and a master degree and Ph.D.in Public Health (Environmental Health)from the University of Ibadan, Nigeria. He has worked in different capacities with NGOs that deal with environmental sanitation and management since the year 2006. One notable experience is being a Project Manager of a multi-million NINAAFEH/MTN Nigeria foundation Environmental Health Project at Alesinloye market Ibadan, Nigeria. Among other things, the project compriseswater sanitation, sewage management and solid waste recycling, including composting fororganic wastes and conversion of plastic/nylon waste to pellets and resins.

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