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Production of Biofertlizer by Composting Sawdust, Sewage Sludge and Succulent Tissue of Green Plants Using an Accelerator

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Abstract: **With the increasing demand in agricultural produce, it has become important to increase productivity by using various fertilizers. Bio fertilizer was produced in this research by composting mixtures of sawdust, sewage sludge and succulent tissue of green leaves respectively using Effective Microorganisms (EM) as the accelerator. Pilot scale study was performed with containers made of polyethylene as the composter sequel to selection of right proportion of mixtures with the best Carbon to Nitrogen ratio (C/N). In this study, the mixtures of organic waste were composted at different weight ratios (1:1:2, 1:2:1, 2:2:2 and 2:1:1). Turning over was done once every week for aeration. Temperature was monitored at different depths daily. Other parameters such as N, C, organic matter, pH and heavy metals were determined at the end of the composting. The results of the study showed that dosage ratios of 1:1:2 and 1:2:1 gave the right proportion of carbon to nitrogen ratio. Organic matter and organic carbon decreased due to increase in temperature owing to the multiplication and activities of different communities of microorganisms. Highest temperature obtained was 59.82^{o}C after 20 days. Also the temperature of some of the compost decreased slightly from day 25 due to maturity. The heavy metal content of all the composts decreased in accordance with World Health Organization (WHO) Acceptable Standards Established by United State Environmental Protection Agency 2004 [1] (2800mg/l for Zn, 300mg/l for Pb, 1500mg/l for Cu, 1200mg/l for Cr and 39mg/l for Cd).F-test analysis showed that the independent variables; dosage ratio, Time and type of materials are significant at 99% confidence level ($p < 0.01$)**

Keywords: **Biofertlizer, heavy metals, sewage sludge, succulent tissue, sawdust.**

1. INTRODUCTION

Agriculture as the main source of livelihood and food security in Nigeria is facing a challenge of matching food, fodder, fuel, and fibre production with population growth. Nigeria is blessed with a lot of natural endowment which if properly harnessed will make it compete favourably with other industrialized nations of the world technology and development. Although endowed with all these gifts, little or no efforts are being made to put them to optimum conversion for the enhancement of the living standard of the teeming population. It is imperative therefore that resource productivity be increased in order to bridge the gap between per capita food production and population growth. This calls for increased use of inputs such as clean irrigation water, organic manures fertilizers and crop protection techniques, which impact on the economics of agricultural production, environmental quality as well as soil fertility [2]. The fertility of soils is central to the sustainability of both natural and managed ecosystems [3]. This is because it is the medium from which terrestrial production emanates. Soil Organic Matter (SOM) plays an important role in maintaining soil texture, water holding capacity, the micro biomass and in nutrient cycling among others [4]. It also helps in improving the drainage and aeration properties of the root zone and acts as a great source of nutrients to the growing plants [5]. The decline of Soil Organic

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Matter with cropping is a major factor affecting sustainability of many cropping systems in sub Saharan Africa [6][7]. Nutrients have been depleted by crop harvest removals, leaching, volatilization and soil erosion to the extent that soil fertility replenishment has been recommended as a necessary investment in natural resource capital. Studies also indicate that soil physical, biological and chemical properties can sustainably be improved through the improvement of Soil Organic Matter, [8][1]. This can be done through practices like mulching and addition of organic fertilizers [9]. One of such important soil amendments is sawdust mulch. Sawdust is mainly surface applied mulch used in ginger and garlic organic gardens. According to [10], surface applied mulches serve to reduce soil water evaporation thus enhancing the potential for increased soil water conservation. This is highly important for improving crop production in tropical rain fed agriculture. The use of these inputs in agricultural production needs to be optimized in relation to economic and environmental quality considerations [11]. This necessitates thorough understanding of the system response to applications of such inputs, which can only come from long-term experiments with the inputs in the farming system for optimum plant growth; nutrients must be available in sufficient and balanced quantities [12]. The most important constraint limiting crop yield in developing nations worldwide, and especially among resource-poor farmers, is soil infertility. Unless the fertility is restored in these areas, farmers will gain little benefit from the use of improved varieties and more productive cultural practices. Soil fertility can be restored effectively through adopting the concept of Integrated Soil Fertility Management (ISFM) encompassing a strategy for nutrient management-based on natural resource conservation, biological nitrogen fixation (BNF) and increased efficiency of the inputs [13]. Bio-fertilizers are important components of integrated nutrients management. These potential biological fertilizers would play key role in productivity and sustainability of soil and also protect the environment as eco-friendly and cost effective inputs for the farmers. They are renewable source of plant nutrients to supplement chemical fertilizers in sustainable agricultural system. Bio-fertilizers are products containing living cells of different types of microorganisms which when, applied to seed, plant surface or soil, colonize the rhizosphere or the interior of the plant and promotes growth by converting nutritionally important elements (nitrogen, phosphorus) from unavailable to available form through biological process such as nitrogen fixation and solubilization of rock phosphate [14]. Beneficial microorganisms in biofertilizers accelerate and improve plant growth and protect plants from pests and diseases [15].In this work, the role of soil microorganisms in sustainable development of agriculture has been reviewed [16], Biofertilizers was produced using the effective microorganisms and the right combination ratio for subsequent composting of organic wastes such as sawdust, sewage sludge and succulent tissue was also established.

2. MATERIALS AND METHOD

2.1 Raw material sourcing:

The main raw materials used in this research work were; sawdust, sewage sludge and soft succulent tissue of green plant. The sawdust was sourced from Nsukka saw mill; sewage sludge was sourced from the septic tank of Wilson Industry Nigeria limited, and the succulent tissue was from Afan Garden all in Nsukka Eastern province of Nigeria. The culturing of effective microorganisms was done at Microbiology Laboratory at University of Nigeria Nsukka.

2.1.1 Preparation of Effective microorganisms:

Seeds of maize, wheat and rice were surface-sterilized with 0.1% mercuric chloride for five minutes and then washed three times with sterile water. The sterilized seeds were germinated on water-agar (1.5% agar) plates and one-week-old contamination- free wheat seedlings were transplanted into soil samples collected from from different locations in Nsukka. The plants were harvested after three weeks and the roots were thoroughly washed with sterile water to remove adhering soil. One-gram root pieces was homogenized in 10 mL of sterile water and serial dilutions were prepared. These dilutions were used to inoculate N-free combined carbon medium and N-free malate medium [15] and incubated at 30 ± 1 °C. The vials showing bacterial growth and acetylene reduction activity were used to inoculate plates of the same solid media to obtain pure colonies. The bacterial isolates were grown in Luria Bertani broth with shaking at 30 ± 1 °C [16].

2.2 Method of Composting (Preparation of Biofertilizer):

Material composts best when it is 1.25-3.75 cm in size. Soft, succulent tissues did not need chopping into very small pieces, because they decompose rapidly. The sawdust was sieved with a 1-inch sieve mesh to get the required sizes. For the composting process to work most effectively, the material to be composted should have a C: N ratio ranging from 15:1

to 35:1. In order to get the right combination, the compost materials except the effective microorganisms (EM) were mixed at different dosage: A (1:1:2), B (1:2:1), C (2:2:2) and D (2:1:1). Four different compost piles were used for the four combinations. Each of the mixtures was submitted on separate containers of 50 litre capacity made of PET (polyethylene) with big feeding surface to allow a good contact between composting materials and atmospheric oxygen for an efficient and easy aeration [17]. The PET, which serves as the composter or reactor was inoculated with microorganisms before being piled up with the composting materials. Water was sprinkled on each pile from time to time to maintain the moisture content and to help in maintaining optimum temperature for the growth of microorganisms. The aeration process was by manual mixing, at least twice every week. The maturity of the composts shall be determined by monitoring the rise and fall of compost temperature. The compost piles were monitored between 5 and 30 days. Normally, the compost is ready after two weeks when the heap has cooled down and the height of the pile has fallen down. F-test analysis were conducted on the independent variables; Dosage ratio, types of component and number of days to ascertain the extent at which one mostly affect bio fertilizer production from the aforementioned raw materials. Other dependent variables such as temperature and presence of hydrogen ion in a solution (pH) were also monitored during the composting

2.3 Method of analysis of Bio fertilizer:

2.3. 1 Digestion of fertilizer samples:

5g of bio fertilizer samples was measured separately on a weighing balance using a Petri dish. The weighed samples were digested with aqua – regia (a mixture of nitric acid and hydrochloric acid in the ratio of 1:3) of 30ml for each sample and put on a hot plate inside the fume cupboard to be heated. The samples were removed from the fume cupboard as soon as a clear solution was seen.

2.3.2 Determination of heavy metals:

The presence of high amount of heavy metals in sewage sludge and other organic waste is one of the most significant reasons that restricted its application in agricultural land 18]. The digested Samples of the fertilizer were made up to 250ml with distilled water, the metals were analysed using AAS (Atomic Absorption Spectrophotometer) based on their different wave-length

2.3.3 Determination of pH:

All the analyses were performed in a compost extract made with distilled water. The extract was obtained by mixing 10g of fertilizer sample transformed into a puree with a mortar with 100ml hot distilled water. The content was filtered and for each determination, 10ml filtrate was used. The pH was measured in the filtrate solution using pH-meter 340I/SET.

2.3.4 Determination of moisture content:

ASTM D2974 (2010)[19] standard test methods for moisture, volatile matter, Ash content and organic matter of peat and organic soil were used. Moisture content is the loss in weight of a solid sample when heated at a certain temperature in a Petri dish [20].

A Petri dish was washed, dried in an oven and weighed. 5g of the undigested samples of fertilizer was added in the Petri dish and weighed using a weighing balance. The weighed sample was inserted in an electric oven and dried at a temperature of 100^{o}C for two hours after which the Petri dish containing the sample was taken out from the oven with the help of tongs, cooled in desiccators and re-weighed. The process of oven-drying, cooling and re-weighing was done several times until the weight of the sample became constant .The percentage moisture was determined on the basis of dry gravimetric moisture content (M_d)

Mathematically,

$$\%moisture = \frac{loss\ in\ weight\ of\ the\ sample}{weight\ of\ the\ sample} \times \frac{100}{1} \quad (1)$$

2.3.5 Measurement of Electrical conductivity:

Fresh sample of biofertlizer was passed through a 2-4 mm sieve.20gm of the sample is added to 100ml of distilled water to give a ratio of 1:5.Stirring is done for about an hour at regular intervals. The conductivity meter was calibrated using 0.01moles of potassium chloride .Using conductivity meter (SVG Electronics Ltd) conductivity of the unfilled organic fertilizer suspension was measured.

2.3.6 Determination of organic matter:

The organic matter content is the ratio expressed as the percentage of the mass of the organic matter in a given mass of sample to the mass of the dry solid.

The masses of empty, clean and dry porcelain dishes (mp) were determined and recorded for the four samples. A part of the oven-dried contents from moisture contents experiment were placed in the porcelain dishes and the mass of the dishes and samples (MpDs) were determined and recorded. The dishes were placed in a muffle furnace. Gradually, the temperature in the furnace is increased to 440^0C and the samples were left to attain a constant weight. The porcelain dishes were carefully removed using tongs as the dishes were very hot. The porcelain dishes were allowed to cool to room temperature. The masses of the dishes containing the ash (burned samples) (MpA) were determined and recorded. The dishes were emptied and cleaned.

Mathematically,

I. Determine the mass of the dry samples

$$MD = MPD - Mp \qquad (2)$$

II. Determine the mass of the ash (burned) samples

$$MA = MPA - Mp \qquad (3)$$

III. Determine the mass of the organic matter

$$MO = MD - MA \qquad (4)$$

IV. Determine the organic matter content

$$OM = \frac{MO}{MD} \times \frac{100}{1} \qquad (5)$$

2.3.7 Determination of Nitrogen:

The nitrogen content of the samples was determined through the procedure explained below.

Digestion of Samples:

0.5g of the samples were measured and put into kjeldal flask together with sulphuric acid. 10g of sodium sulphate anhydrous (potassium sulphate is also applicable) was added to the four samples. Also 1g of copper sulphate ($CuSO_4$) was added into the flasks as a catalyst. The solutions were heated inside a fume chamber using Bunsen burner. The heating lasted for about 3hours at the end of which the nitrogen digestion was completed. The completion of the digestion was confirmed by the forming of the solution in the flask into bluish-green colour. The flasks were removed and allowed to cool down over night during which the bluish-green solution solidified into white or milk colour substance.

Distillation:

The digested samples were dissolved with 200ml of distilled water and were transferred into 1 litre flat bottom flask. Three pieces of granules of zinc metals were introduced into the flask and was allowed to cool down. 60ml of 40% sodium hydroxide solution was added into the flask so that there was no agitation.

The flask was immediately connected to a condenser and provided with an adapted tube attached by means of a rubber stopper. The adapted tube was dipped into 250ml conical flask containing 100ml of 4% Boric acid solution. Three drops of methyl red indicator were added to the boric acid solution which turned the solution pink.

The one litre bottom flask was heated on an electric oven heating mantle and the distillation was allowed to reach 200ml in the 250ml flask. During condensing of the steam the boric acid in the 250ml flask will turn to colourless. Titrate the colourless solution with 0.1M sulphuric acid to turn back to its initial colour. The solution turned from colourless to pink.

Mathematically,

$$\%N = \frac{T.V \times 0.0014 \times 100}{weight\ of\ sample\ digested} \qquad (6)$$

Where T.V =titre value

2.3.8 Determination of phosphorous:

The digested samples were analysed for phosphorous and potassium using flame Atomic absorption spectrometer, model 2010.VGP manufacturer USA.

2.3.9 Estimation of Organic Carbon:

Reagents:-

Phosphoric acid (ortho)-85% , Sodium fluoride solution –2 %, Sulphuric acid AR-96 % containing 1.25% Ag_2SO_4, Standard $K_2Cr_2O_7$, dissolve 49.04 gm $K_2Cr_2O_7$ in water and dilute to 1litre, Standard 0.5gm Ferrous ammonium sulphate, Diphenylamine indicator and Grind air-dry compost sieved with meshes(2mm sieve). 0.5 gm sample in 500 ml conical flask is added. Later 50 ml of $K_2Cr_2O_7$ with burette and swirled a little. Then 50 ml conc. H_2SO_4 is added and swirled again 2-3 times. It is been kept standing for 30 minutes in dark place and there after 200-ml of water is added. Then the volume is made up to 500 ml in a volumetric flask. Out of this 50 ml, an aliquot (equivalent to 0.1 gm sample) was taken in another 500 ml conical flask. 15 ml of ortho phosphoric acid and 1 ml of Diphenylamine was used as an indicator. Titration is done with 0.5 ferrous ammonium sulphate till the colour flashes blue violet to green. Blank experiment was carried out without compost sample.

Mathematically,

$$Organic\ carbon(\%) = \frac{10A}{B} \times 0.003 \times \frac{100}{weight\ of\ the\ sample} \times 1.3 \qquad (7)$$

Were A = titre value with compost sample

B= titre value without compost sample

3. RESULTS AND DISCUSSION

3.1 Electrical Conductivity (soluble salt) (dS/m):

The result of Figure 1 showed that sample A has the highest electrical conductivity at day 15 which was 41.8dS/m due to salt that has dissolved in the waste. Sample B has 36.11 dS/m at day 10. Sample C has the lowest electrical conductivity of 2.3 at day 25. If only a mixture of Samples A and B is to be used as Bio fertilizer, this can cause phytotoxin to plants due to their high values of electrical conductivity. But all the compost showed a significant decrease in electrical conductivity with increase in number of days Therefore, from the results in Fig 1 it can be generally concluded that soluble salt in solid wastes could be controlled with composting, when solid wastes were mixed together which give reduction in soluble salt looking at the gradual reduction in electrical conductivity in sample D as the compost last.

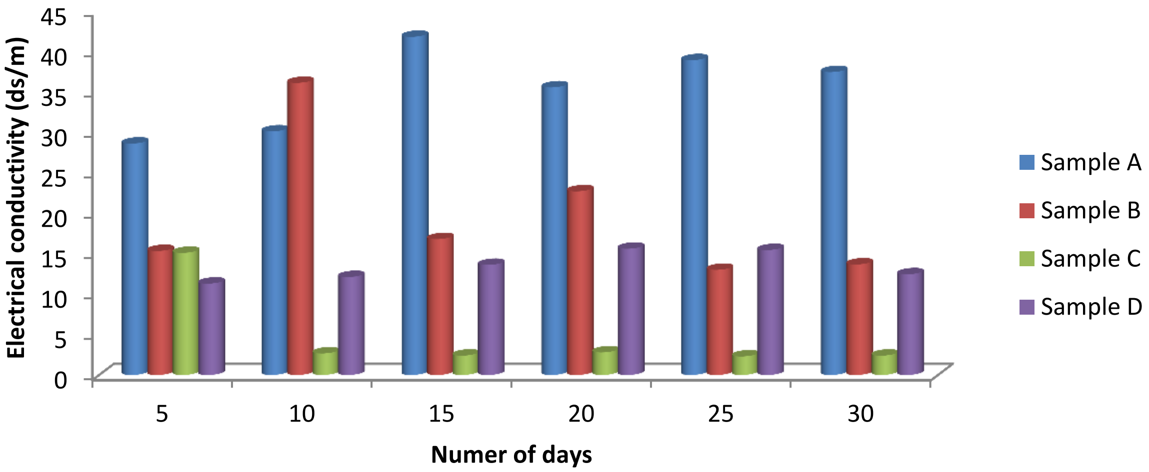

Fig.1: Variation in electrical conductivity

3.2 Changes in Temperature during Composting:

The highest temperature reached during the composting process is 59.82°C at day 20 for component B as shown in Fig 2. This is due to the activities of microorganisms and high concentration of nitrogen in the sewage sludge, Temperature of components A, B and C increased significantly between day 5 and 20 but dropped significantly from day 30.The drop

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could be attributed to the maturity of the compost. Component D did not show reasonable increase, possibly due to low percentage of nitrogen necessary for the growth and multiplication of microorganisms due to high concentration of sawdust. [23][7] suggested that temperature higher than 55°C maximize sanitation, those between 40 and 55°C maximise biodegradation rates and between 30 and 40°C maximised microbial diversity in composting process.

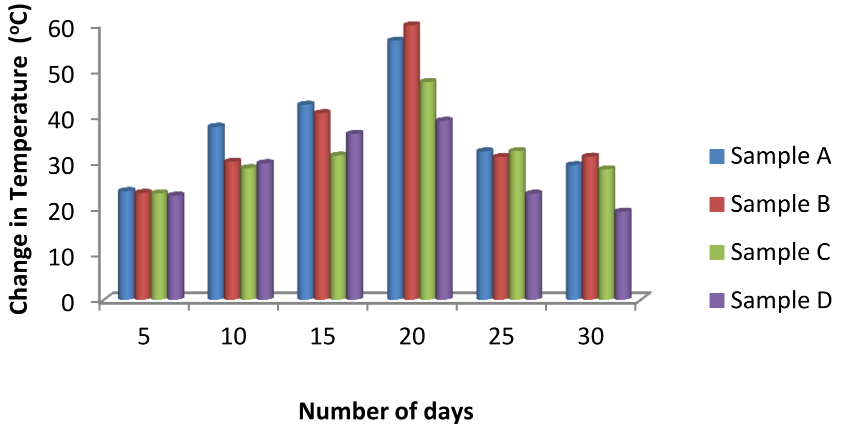

Fig.2: Variation in temperature during composting

3.3 Variation in pH during Composting:

Fig 3 below shows that the pH of the components A, B and C increased as the number of days increased but decreased from day 25. This could be due to the high concentration of proteins and ammonia in the mixture. pH of D decreases due to the decomposition of cellulose in sawdust. Microbial driving compost stabilization operates best in the range of pH between 5.5 and 9.0 [1].The pH decreased due to the degradation of organic matter leading to the production of organic acids such as methanoic acid and inorganic acids such as trioxocarbonate (IV) acid. Increasing of the pH is caused by decomposition of organic matter containing nitrogen leading to the formation of NH_3 which react with water and form NH_4OH and de-amination of amino acids released from proteins forming ammonia.

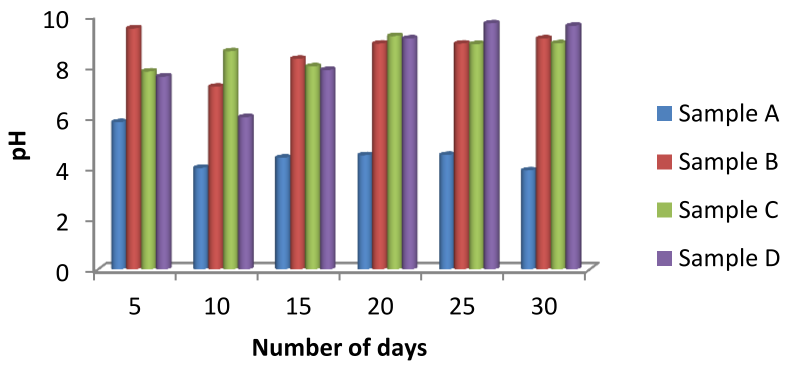

Fig.3: variation in pH

3.4 Variation in Concentration of Phosphorus:

Concentration of phosphorous was analysed using flame atomic absorption spectrometer as shown in Fig 4. It was observed from Fig 4 that sample A has a higher composition of phosphorous at day 10 though all the compost has a very close concentration of phosphorus owing to the proportion of phosphorous in the succulent tissue of green leaves [17]. Phosphorus is among the elements needed by plant in a very high proportion, therefore the higher percentage of phosphorous given by all the compost mixture is quite acceptable.

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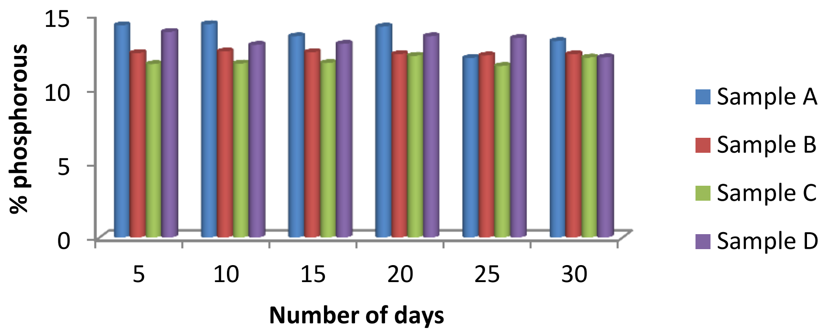

Fig.4: Variation in composition of Phosphorous

3.5 Carbon content variation during composting:

Of the many elements required for microbial decomposition, carbon is the most important because it supplies energy to the microorganism and some are humified to improve soil structure. Fig 5, shows that component D maintained higher percentage carbon after composting due to higher concentration of sawdust in the mixture while component A has the least due to higher concentration of succulent tissues, though the entire component maintained a reasonable percentage of carbon and hence is a good source of humus and energy to microorganisms. The constant decrease in organic carbon as the compost last was due to its biotransformation into carbon dioxide

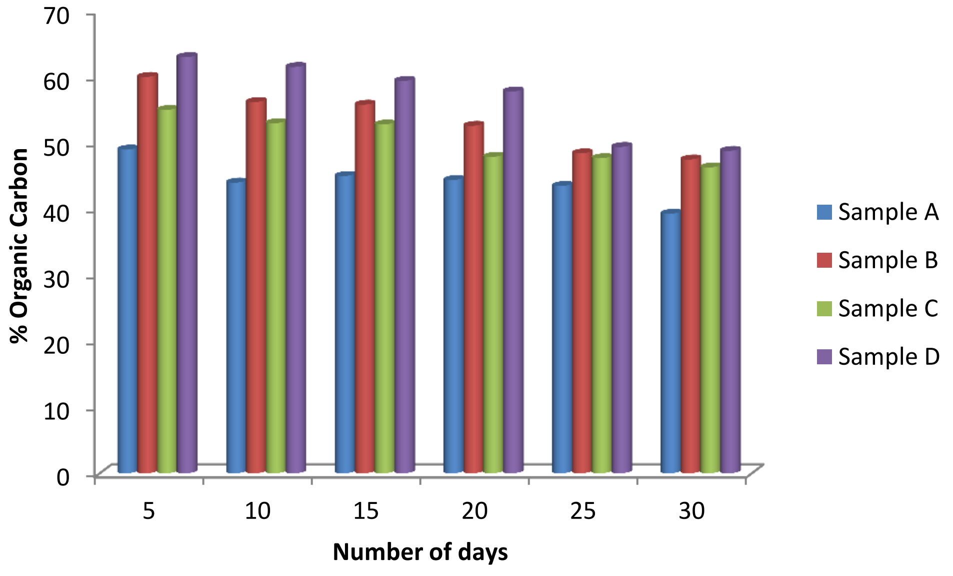

Fig.5: Variation in carbon content

3.6 Nitrogen content variation during composting:

Nitrogen being one of the most important parameter in this research was analysed by kjeldahl method. Fig 6 below shows that mixture of sample C has the highest concentration of nitrogen due to high concentration of nitrogen in succulent tissue and sewage sludge. This is in agreement with the literature that sewage sludge contains a very high concentration of nitrogen [13]. Fig 6 also shows clearly that the percentage of sample mixture D decreases with increases in number of days due to high concentration of sawdust in the mixture; this is also in agreement with the literature that sawdust ties up nutrients as it decomposes because bacteria used up the nitrogen as they digest the high carbon content of the sawdust [10]

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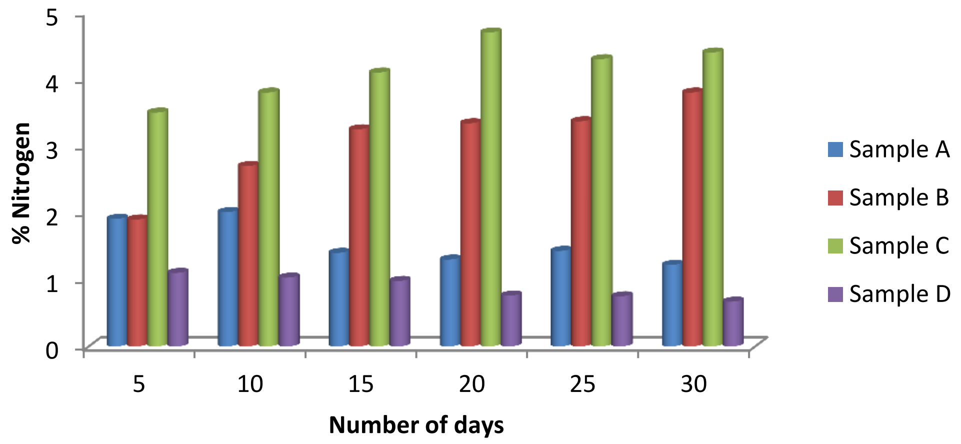

Fig.6: Variation in Nitrogen content during composting

3.7 Organic matter content variation:

Fig. 7 shows that, the organic matter content of the components decreased with increase in number of days. This is very much in agreement with the literature as suggested by [8] that the organic matters decrease as the compost last. Organic matter content improves the structure of the soil and provides energy to the microorganisms that drive compost. Fig 7 shows that organic matter decomposes at various speeds at several temperature stages at which specific microorganism plays a dominant role. The mesophilic microorganisms became less competitive at temperature above 40℃ and are replaced by thermophilic microorganisms which act on the organic matter until maturity stage of the compost. The decrease in organic matter during compost is due to the conversion of some fraction of it to volatile matters by the activities of the microorganisms [16].

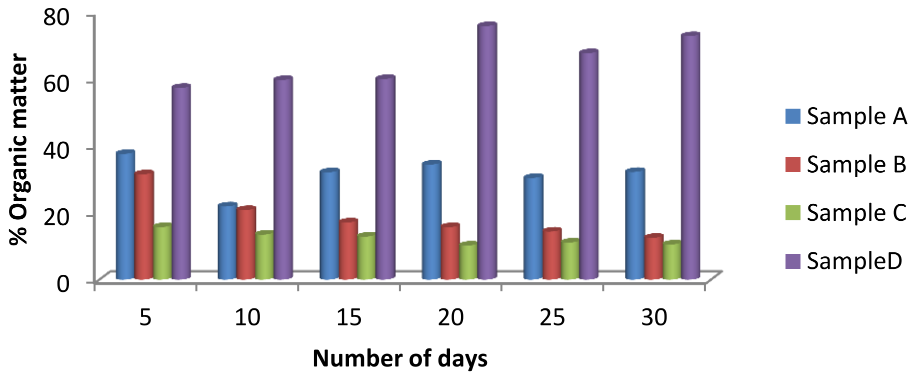

Fig.7: Variation in composition of Organic matter

3.8 Variation in Carbon to nitrogen ratio:

For the composting process to work most effectively, the material to be composted should have a C: N ratio between 15:1 to 35:1 [21][7]. From fig 8, sample mixtures A and B showed the best combination that can easly drive the compost. Sample C showed a very low carbon to nitrogen ratio due to excess nitrogen from succulent tissue and sewage sludge, while sample mixture D showed a very high carbon to nitrogen ratio due to high concentration of sawdust which ties up the nitrogen as it decomposes.

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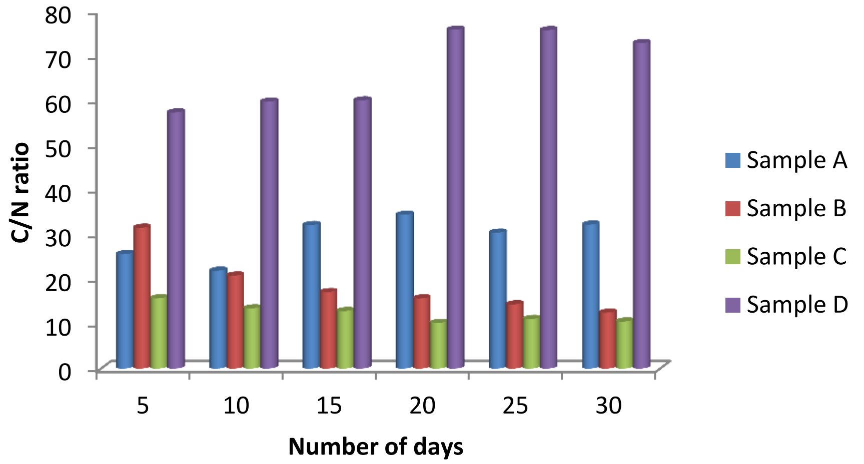

Fig.8: Variation in carbon to Nitrogen ratio

3.9 Heavy metals concentrations on the fertilizers samples during composting:

Table1 shows the concentration of heavy metals detected from each fertilizer samples from day 15 to 30.

Table 1: Summary of Heavy Metals Concentration

Type of components	Fermentation days	Zn(mgl^{-1})	Pb(mgl^{-1})	Cu(mgl^{-1})	Cr(mgl^{-1})	Cd(mgl^{-1})
A	15	6.18	-	3.672	-	-
	20	7.7	-	2.341	0.177	-
	25	5.3	-	2.711	0.186	-
	30	5.7	-	3.367	0.023	-
B	15	24.13	0.6733	10.73	5.799	-
	20	23.672	0.3746	12.76	2.644	0.027
	25	29.644	0.0433	8.894	8.867	-
	30	27.067	0.7968	9.711	3.056	0.0089
C	15	14.822	0.2734	19.721	1.233	-
	20	13.521	0.3045	16.74	1.128	-
	25	12.211	0.2642	16.02	1.345	-
	30	13.862	0.2866	15.56	1.267	-
D	15	1.73	-	0.037	0.033	-
	20	1.68	-	0.277	0.122	-
	25	1.86	-	0.486	0.097	-
	30	1.68	-	0.524	0.048	-
EPA STANDARD		2800	300	1500	1200	39

The heavy metals are needed by plants in a very minute quantity and hence are called the microelements [22][18]. The presence of high amount of it could be detrimental to the plant. The table shows that the concentration of heavy metals on each fertilizer sample produced is less than the stipulated EPA standard established by U.S.E.P.A; hence application of the fertilizer for agricultural land is safe and not detrimental. Higher concentration of metals in the compost mixtures is mainly due to the high metallic content of sewage sludge [1]

4. CONCLUSIONS

The objectives of composting wastes are to reduce waste quantity, to eliminate pathogens, to destroy odour-causing substance, and to get a final compost product that can provide farmers and gardeners with a better alternative to chemical fertilizers. Our research established the possibility of recycling biomass waste by composting sawdust with sewage sludge and succulent green tissue in a ratio of (1:1:2) or (1:2:1) in order to produce bio fertilizer compost with high nutritive value for plants and good amendments of soil physical and chemical properties using effective microorganisms as an accelerator.

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