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Manufacture of Bio Fertilizer by Composting Sawdust and Other Organic Waste

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Abstract: **Bio fertilizer was produced in this research by composting mixtures of sawdust and urine, sawdust and sewage sludge and sawdust and cow dung respectively. Pilot scale study was performed with containers made of polyethylene (PET) as the composter sequel to selection of a mixture with high yield of Nitrogen. In this study, the mixtures of organic waste were composted at different weight ratios (2:1, 4:1, 6:1 and 8:1). 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 a mixture of sawdust and sewage at a ratio of 6:1 gave a higher percentage of Nitrogen. Organic matter and fixed carbon decreased due to increasing the temperature. Highest temperature obtained was 59.5^{o}C after 25 days. Also the temperature of some of the compost decreased slightly at day 30 due to maturity of the compost. The heavy metal content of all the composts decreased to world health organisation acceptable standards established by United State environmental protection agency 2004 (2800mg/l for Zn, 300mg/l for Pb, 1500mg/l for Cu, 1200mg/l for Cr and 39mg/l for Cd). The optimization results gave a mixture of sawdust and sewage at a weight ratio of 5:1 for 22.5 days at moisture of 45% as the optimum condition for the manufacture of bio fertilizer. The results indicated that co-composting of sewage and sawdust is a reliable and simple method for the production of bio fertilizer.**

Keywords: **Bio-fertilizer, Composting, Sawdust, Sewage sludge, Urine, Cow dung.**

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 [14].

The fertility of soils is central to the sustainability of both natural and managed ecosystems [6]. 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 [1]. 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 [2].

The decline of Soil Organic Matter with cropping is a major factor affecting sustainability of many cropping systems in sub Saharan Africa [7],[13]. Nutrients have been depleted by crop harvest removals, leaching, volatilization and soil erosion to the extent to which 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, [3],[17]. This can be done through practices like mulching and addition of organic fertilizers [14]. 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 [12]. 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

1.1 Research Aim and Objectives:

The aim of this study was to manufacture fertilizer by composting using sawdust, cow dung, sewage and urine as our raw materials.

In achieving the aim of this research, specific objectives included:

1. To determine the process variables that affect the yield of fertilizer from mixtures of sawdust and urine, sawdust and cow dung and sawdust and sewage sludge respectively;
2. To compare fertilizers produced from sawdust and urine, sawdust and cow dung and sawdust and sewage sludge respectively;
3. To optimize the fertilizer production process using the response surface methodology.

2. EXPERIMENTAL

2.1 Raw materials and their sourcing:

The main raw material used in this research work included: sawdust, cow dung, human urine, and sewage sludge. Others are distilled water, sulphuric acid, Nitric acid, hydrochloric acid, zinc metal, cupric sulphate, and boric acid. The sawdust was sourced from wood processing industry at Kenyatta Uwani Enugu Nigeria, Other organic wastes used in this research was also sourced locally from Enugu state Nigeria,

2.2 Method of composting:

The samples:

A = sawdust +urine.

B = sawdust +sewage sludge

C = sawdust +cow dung.

D = sawdust only.

Each of the mixtures were submitted on a separate containers of 50litre 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. The aeration process was made by manual mixing, at least once daily. The maturity of the composts was determined by monitoring of compost temperature and pH

The varied parameters in this work are:

1. Fermentation days (15, 2 0, 25 and 30)

2. Dosage ratio (w: w), (2:1, 4:1, 6:1 and 8:1).

3. Moisture content (%), (30-40, 40-50, 50-60, 60-70)

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4. Type of components, A, B, C and D

The F-test and the variance statistical analysis were used to determine the mixture with highest percentage of Nitrogen. The independent variables included fermentation days, dosage ratio, moisture content and type of component [3]. The confidence level used in the F-test was 95%.

During the composting process, temperature were measured daily, Also during the composting process, the properties of the compost were monitored, including total nitrogen content, total fixed carbon, organic matter content, pH, volatile matter, heavy metal content, phosphorous and potassium. The composting and all analysis were performed at Eastern farm and animal science laboratory Federal university of Agriculture Umudike Abia state Nigeria.

2.3 Digestion of Sample A, B, C and D:

5g of sample A, B, C and D were 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.

2.4 Analytical methods (characterisation):

ASTM D2974 standard test method for moisture, volatile matter, ash content, fixed carbon and organic matter of peat and organic soil were used (onwu, 1999). The heavy metal, phosphorous and potassium contents of different materials were analysed using Atomic absorption spectrophotometer, model 2010.VGP manufacturer USA. The total nitrogen content analysis was performed by kjldahl method.

3. RESULTS AND DISCUSSION

3.1 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 3.1 shows that component B maintained higher percentage carbon after composting and are considered a better option, though the entire component maintained a reasonable percentage of carbon and hence is a good source of humus and energy to microorganisms. The organic carbon disappearance is due to its biotransformation into carbon dioxide

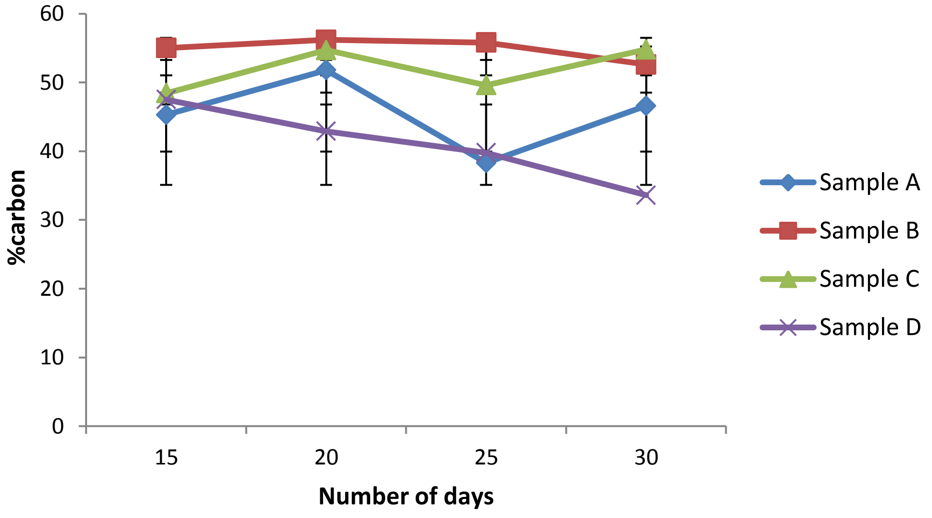

Fig 3.1 Carbon content variation during composting

3.2 Nitrogen content variation during composting:

Nitrogen been the most important parameter in this research was analysed by kjeldahl method (http://blog.pharmaphysic.fr/eviter-distillation-methode-kjeldahl/#more-83).Fig 3.2 below shows that component B has the highest concentration of nitrogen(11.45%).this is in agreement with the literature that sewage sludge contains a very high concentration of nitrogen. Fig 3.2 shows clearly that the percentage of component D decreases with increases in number of days, 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] .

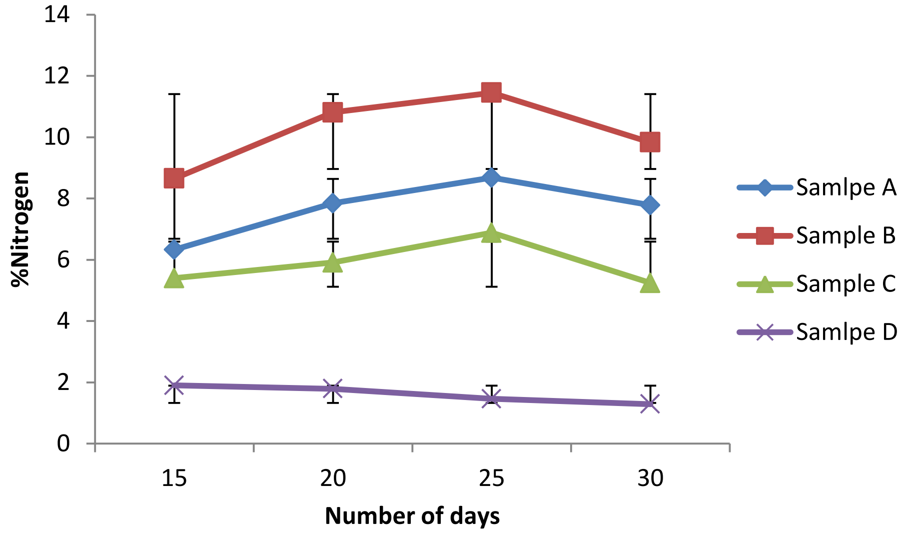

Fig 3.2 Nitrogen content variation during composting

At 0.05 level of significance, This F-test analysis suggested that the ideal condition for the process is a mixture of sawdust and sewage at a ratio of 6:1 composted for 25days maintain the moisture between 40-50%

3.3 pH variation during composting:

Fig 3.3 below shows that the pH of the components A, B and C increases as the number of days increase. 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 [17]. The pH of all composts decreased slightly during the first 10days, followed by a rise in the 14th day .The pH initially decreased due to the degradation of organic matter leading to the production of organic and inorganic acids. Further 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.

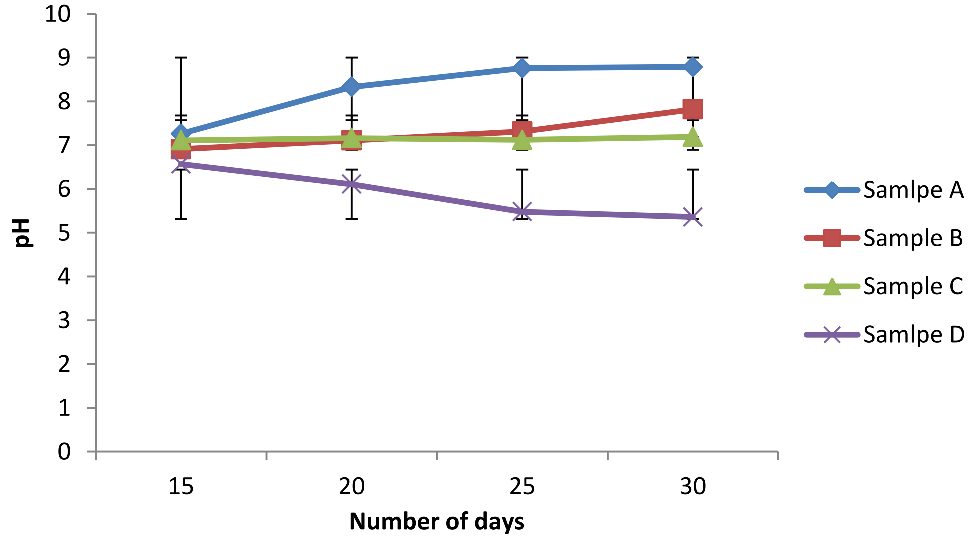

Fig 3.3 pH variation during composting

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3.4 Organic matter content variation:

Fig 3.4 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 [13] 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 3.4 shows that organic matter decomposes at various speeds at several temperature stages at which specific microorganism plays a dominant role. The mesophilic microorganism became less competitive at temperature above 40℃ and are replaced by others that are thermophilic which acts 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.

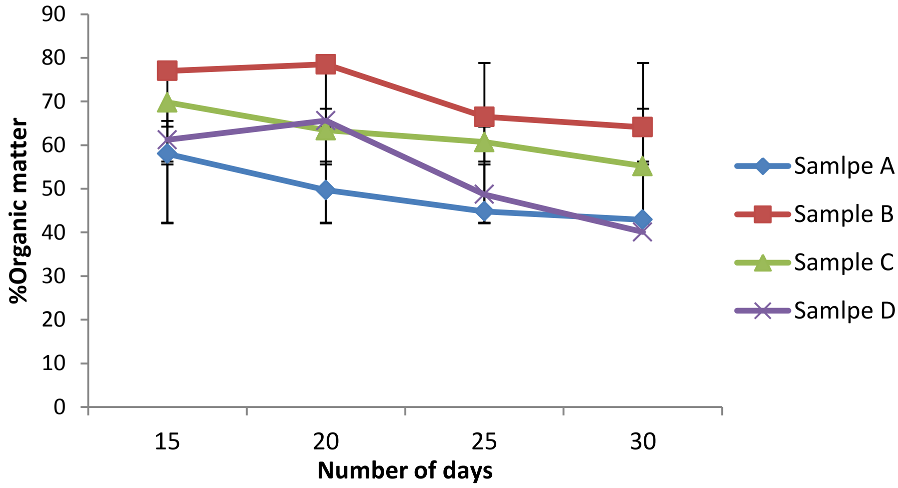

Fig 3.4 Organic matter variation during composting

3.5 Temperature Change during Composting:

The highest temperature reached during the composting process is 59.5℃ at day 25 for component B as shown in fig 3.5. 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 15 and 25 but dropped slightly from day 30.the drop 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. [13] Suggested that temperature higher than 55℃ maximize sanitation, those between 40 and 55℃ maximise biodegradation rates and between 35 and 40℃ maximised microbial diversity in composting process.

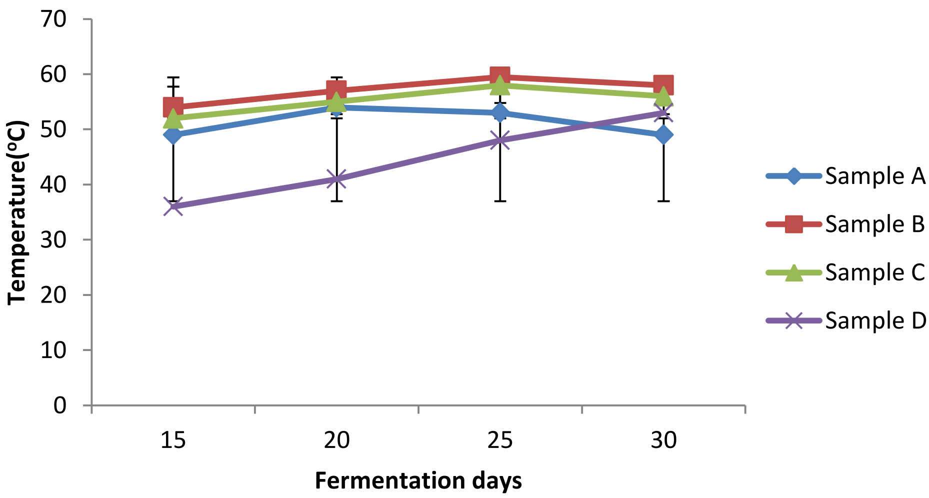

Fig 3.5 Temperature change during composting

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3.6 Phosphorous and potassium:

Concentration of phosphorous and potassium were analysed using atomic absorption spectrometer as shown in Fig 3.6 and fig 3.7. It was observed from Fig 3.6 that component B has a higher composition of phosphorous while component D has the least. Component C has the greater percentage of potassium of 11.8% at day 15 but decreases significantly as the compost last as shown in Fig 3.7. This is due to the higher concentration of green leaves in cow dung [18]. Phosphorus and potassium are among the elements needed by plant in a very high proportion. Components A, B and C gave an acceptable percentage of phosphorous while component B, C and D gave an acceptable percentage of potassium.

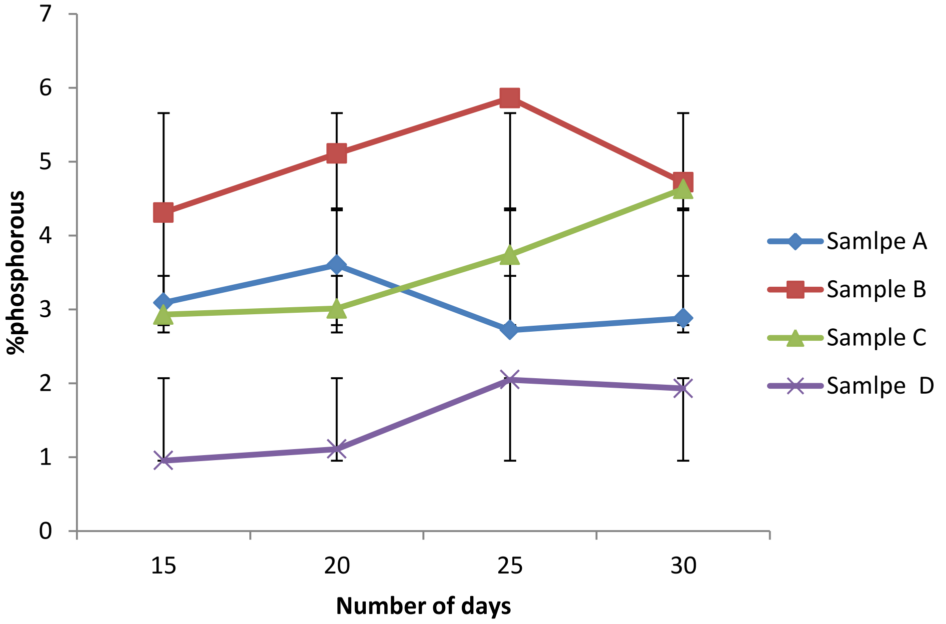

Fig 3.6 Percentage composition of phosphorous

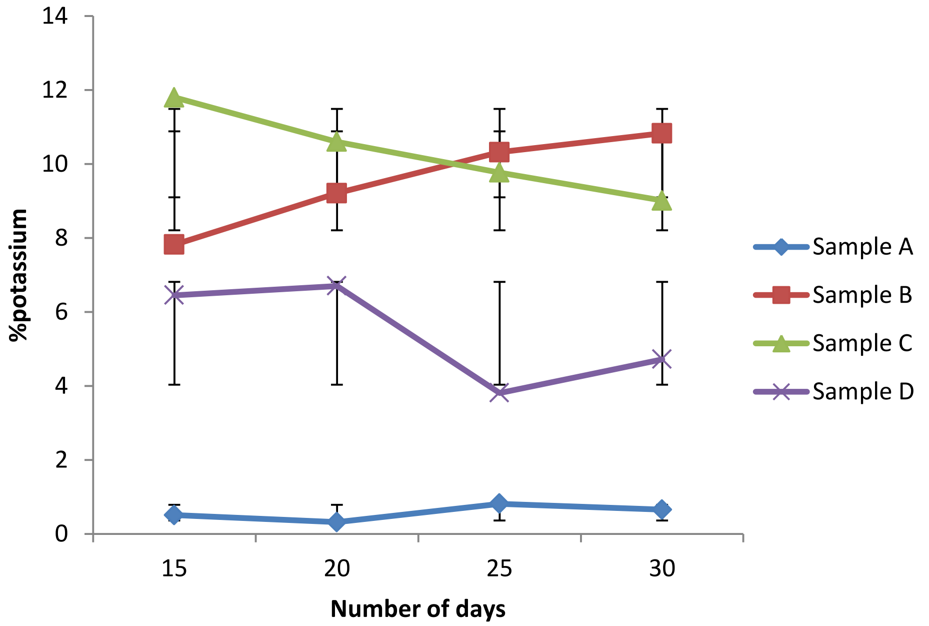

Fig 3.7 Percentage composition of potassium

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Table 3.1 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

Table3.1 shows the concentration of heavy metals detected from each fertilizer sample after composting. The heavy metals are needed by plants in a very minute quantity and hence are called the microelements [16]. The presents of high amount of it could be detrimental to the plant. Table 3.1 shows that the concentration of heavy metals on each fertilizer samples 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. Component B has a higher concentration of metals due to the high metallic content of sewage sludge [17]

3.7 FT-IR variation during composting:

The FTIR technique is an important tool to identify the characteristic functional groups, which are instrumental in decomposition of aromatic compounds. FTIR studies of this fertilizer sample (component B) helped in the identification of various forms of the minerals that are present. The FTIR of the compost sample at different stages show the location of similar peaks but the relative intensity of the absorbance are seen to change during the composting process [1]. The interpretation of the recordings is based on the data of numerous studies as shown in table 3.2

Table 3.2 Attribution of absorbance bands (cm^{-1}) for FT-IR spectra

Wave number (cm^{-1})	Attributance
3300-3500	N-H stretching vibration (amides, amines); O-H stretching vibration of OH group of alcohols, phenols, carboxylic group.
2900-3300	C-H stretching vibration of long chain aliphatic structure (fatty acid) waxes, other aliphatics
1550-1675	Stretching vibration of COO^- and C=O in amides, stretching vibration of C=O in ketones, aromatic carboxylic acids, quinones. stretching vibration of aromatic C=C.
1410-1450	Stretching vibration of C-C-, CH_2- and $-CH_3$ radicals in aliphatic structures; vibration of alkyl bond and of lignin.
1030-1180	C-O-C stretching vibration of (poly) carbohydrates and aromatics ethers.
650-850	Absorption bands of phenols aromatics carboxylic acids, bending vibration of aromatic C=O.

During composting, the initial strong absorbance around 1030-1180cm^{-1}, corresponding to the polycarbohydrates present in high levels in organic waste decreased as a result of the biodegradation of the polycarbohydrate to monocarbohydrates.

In the same way, the absorbance at 2900-3300cm^{-1} attributable to long chain aliphatic structure (lipids, proteins) decreased during composting process as a result of biodegradation of proteins and long chain fatty acids from lipids.

In contrast, other structures which absorb at about 1550-1675cm^{-1},(aromatic compounds such as carboxylic acids, aldehyde, ketones, amides) and aromatic components released from lignin biodegradation absorbing in the 650-850cm^{-1} region are formed. These results show that during treatment, the microbial population benefit from compounds that are easily assailable and freely available in the medium. i.e mainly carbohydeates and lipids.

At the end of the composting , a decrease in aliphatic carbon , such as polycarbohydrate, an increase in the concentration of aromatic compounds ,richer in functional group such as the aromatic carboxyl ions, the C=O of aromatic amides, ketones, quinones and phenols was recorded [12].

Table 3.5 Analysis of variance

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	**Remark**
Model	26.74	9	2.97	62.25	< 0.0001	Significant
X_1-No of Days	*0.21*	*1*	*0.21*	*4.48*	*0.0603*	
X_2-Dosage Ratio	*5.625E-005*	*1*	*5.625E-005*	*1.179E-003*	*0.9733*	
X_3-Moisture Content	*3.05*	*1*	*3.05*	*63.99*	*<0.0001*	
X_1X_2	*1.51*	*1*	*1.51*	*31.54*	*0.0002*	
X_1X_3	*1.06*	*1*	*1.06*	*22.18*	*0.0008*	
X_2X_3	*4.79*	*1*	*4.79*	*100.36*	*<0.0001*	
X_1^2	*12.63*	*1*	*12.63*	*264.73*	*< 0.0001*	
X_2^2	*2.457E-003*	*1*	*2.457E-003*	*0.051*	*0.8251*	
X_3^2	*4.95*	*1*	*4.95*	*103.80*	*< 0.0001*	
Residual	0.48	10	0.048			
Lack of Fit	*0.48*	*5*	*0.095*	*222.71*	*<0.0001*	*Significant*
Pure Error	*2.133E-003*	*5*	*4.267E-004*			
Cor Total	27.22	19				

Std.Dev.	0.22	R-Squared	0.9825
Mean	13.02	Adj R-Squared	0.9667
C.V. %	1.68	Pred R-Squared	0.8589
PRESS	3.84	Adeq Precision	20.599

Regression model in terms of coded significant terms:

$$Yeild\ of\ Nitrogen, Y = 13.93 - 0.44X_3 + 0.43X_1X_2 - 0.36X_1X_3 + 0.77X_2X_3 - 0.71X_1^2 - 0.44X_3^2$$

The Model F-value of 62.25 implies the model is significant. F-model and F-lack of fit having a low p-value less than 0.005 simply means that the factors have a meaningful effect on the response. A small P-value is an indication that the model is useful for explaining variations in responses. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case X_3, X_1X_2, X_2X_3, X_1^2, X_1X_3, X_3^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 222.71 implies the Lack of Fit is significant. R-Squared of 0.9825 implied that the statistical model accounted for 98.25% of the data in the experiment

Table 3.6 Numerical Optimization for the manufacture of bio fertilizer

Solution Number	Number of Days*	Dosage Ratio*	Moisture content*	Desirability	Remark
1	*22.50*	*5:1*	*45.00*	1.000	Selected

A system that utilizes more quantity of sawdust as a raw material and give a desired quality of a product should be encouraged for it will reduce the environmental challenge posed by indiscriminate dumping of sawdust in our environs. From the result of this research, a dosage ratio of 5kg of sawdust to 1kg of sewage sludge has been selected to be ideal combination.

4. CONCLUSIONS

The objectives of composting wastes are to reduce waste quantity, elimination of pathogens, and destruction of 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, cow dung and human urine in order to produce bio fertilizer compost with high nutritive value for plants and good amendments of soil physical and chemical properties. Also from the FT-IR analysis, it can be seen that sawdust (having an extra source of sugars and lignin component) and sewage sludge (having lipids and microorganisms forming enzymes) improves the biodegradation process.

Finally sawdust is a good source of organic fertilizer when mixed with the right proportion of nitrogen rich source and this research singled out sewage sludge as the best additive sequel to conversion of sawdust to bio fertilizer by composting.

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