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Valorization of Urban Sewage Sludge: Aerobic composting with Banana peel, Rice straw and Eucalyptus leaves

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Abstract

The disposal of urban wastes and sludge from wastewater treatment plants (WWTPs) is an issue of growing importance; which hinders urban development in developing countries like it is the case in Africans' countries. Here we have investigated the composting of sewage sludge with i. banana peel (BP) and ii. mixture of rice straw-eucalyptus leaves (RS-EL) as bulking materials. Results shown good performance of both materials, and very good humification of organic matter and decomposition rates were estimated for about 41.4% and 50.3%, respectively in the compost with BP and with RS-EL. Physicochemical properties [pH (7.4 - 7.8) and electrical conductivity (EC, 3.29 – 3.58 mS cm^{-1})] of the produced composts favored its utilization in agricultural soil as fertilizer. However, further investigation on the degradation of organic micro pollutants and the mobility of heavy metals is still needed to fully appreciate the safety of such compost.

Keywords: Sewage sludge, composting, valorization, banana peel, Rice straw.

Introduction

Solid waste predominantly, is any garbage, refuse or rubbish which include- domestic, commercial and industrial wastes especially common for disposal[1]. In the past two decades, the rapid increase of urban population led to the drastic increase of solid wastes including sewage sludge in urban area across the world. In the United State, approximately yearly produced 6 x 10^6 metric tons of biosolids, of which about 60% is applied to land[2]; while in China, an annual production of 11.2 million tons of dry sludge was reported[3]. It is noteworthy that wastes and particularly sewage sludge constitute threat for human health and the environment[4,5]. This is justified by the high concentration of organic pollutants and inorganic pollutants, mainly heavy metals[6] in these matters. Environmental pollution caused by both urban waste and sewage sludge has become an issue of great concern which favors not urban development in poorest countries. It is therefore urgent to find ways for recycling and reuse such wastes in order to reduce their negative impact on the ecosystem and environment[7].

Composting is an effective and economical, simple and environmentally-friendly method for the stabilization of solid organic wastes. It is a biochemical degradation of organic materials and produced nuisance-free bio-amendment material to maintain soil fertility[8-12]. Composting is a spontaneous biological decomposition process of organic materials in a predominantly aerobic environment which under optimum conditions taken place within a month[7]. Its process passes through several steps, each of which is characterized by the activity of different microbial groups. In advanced countries such as USA, Europeans countries, China, etc., composting technology has been widely adopted and applied to co-digest and stabilize sewage sludge with various bulking materials for the benefit of agricultural use[13-16]; while in developing countries like it is the case in Africa, the technology it is not yet well know and adopted.

In the republic of Benin (West Africa), the management of urban wastes still remains a great challenge to the decision makers and the institutions in charge of environmental protection and human health security. The existing WWTPs do really not follow the international norm of a well build WWTP. They are very small comparatively to the challenge (huge amount of wastewater) before it. As a consequence, the treatment quality is compromised and the sewage sludge is not well stabilized. Although the main byproduct (sludge) is not well stabilized, it is already being used in the agricultural land as soil amendment for the benefit of plants. Such situation might lead to a secondary pollution mainly spreading of pathogens and micro pollutants in the environment. In a previous study (under review) it has been pointed out the risk of heavy metals contamination and spreading when such sludge is used in agricultural soil. In this regard, it is critical to find a way for better stabilization of the sludge.

The present work aims to valorize the sewage sludge via it stabilization via composting. Bulking materials including:

banana peel, eucalyptus and rice straw were co-composted together with sludge. The performance of the composting was evaluated based on the changes of different physicochemical parameters including: Temperature, pH, electrical conductivity (EC), total organic matter (OM), total organic carbon (TOC), nitrogen (N) and quality of the final compost, from the point of view of organic matter degradation and humiliation.

Material and Methods

Composting materials: Sewage sludge was collected from municipal wastewater treatment plant was the material of interest in this study. It was co-digested with i. prepared banana peel (BP) and ii. the mixture (RS-EL) of eucalyptus leaves (EL) and rice straw (RS) [RS (25%) and EL (75%)]. Rice straw was collected from rice farm and Eucalyptus leaves were collected from the university garden.

Experimental design and Setup: Four sets of experiments were setup (table-1). Mixtures were made to achieve a total weight of 10 kg. The mixture was subjected to aerobic digestion for 35 days. The compost was manually thoroughly returned periodically followed by sampling on the days: 0, 7, 14, 21, 28 and 35). Collected samples were used for physicochemical parameters determination.

Reactor configuration: Bioreactor was made of cylindrical plastic container (r = 30.6 cm, h = 45 cm). Holes were perforated on the body of the digester to allow external oxygen exchange (aeration). Materials were mixed in another separated plastic box covered in the bottom with a steel sieve before being transferred into the digester; as showed in the figure (figure-1).

Table-1
Experimental design

Materials	Sludge (kg)	BP (kg)	RS-EL (kg)
C1	8	2	0
C2	8	0	2

Physiochemical analysis: Physicochemical characterization the sludge and mixtures prior the digestion process is shown in the table-2. During the composting, temperature was daily measured using a digital temperature sensor. Moisture content (Mc) was determined by drying sludge samples under an oven at 105 ^{o}C. pH and EC were measured in a water suspension of the sludge or compost samples ratio 1:10 (w: v) as recommended by He et al[17]; and their values were measured using a multi-parameter (HACH, HQ40d). The total organic matter (OM) content was determined by loss of weight using the ignition method at 600^{o}C. Total organic carbon was calculated according to Iglesias-Jimenez and Perez-Garcia[18] following the equation (equation-1) below. Nitrogen was determined via Micro-Kjedahl Method. And the C/N ratio was calculated as the ratio of the percentage of TOC on the percentage of nitrogen (equation- 2).

$$\mathrm{TOC}\ (\%) = \frac{\mathrm{OM}\ (\%)}{1.8} \quad (1)$$

$$\mathrm{C/N} = \frac{\mathrm{OM}\ (\%)}{\mathrm{N}\ (\%)} \quad (2)$$

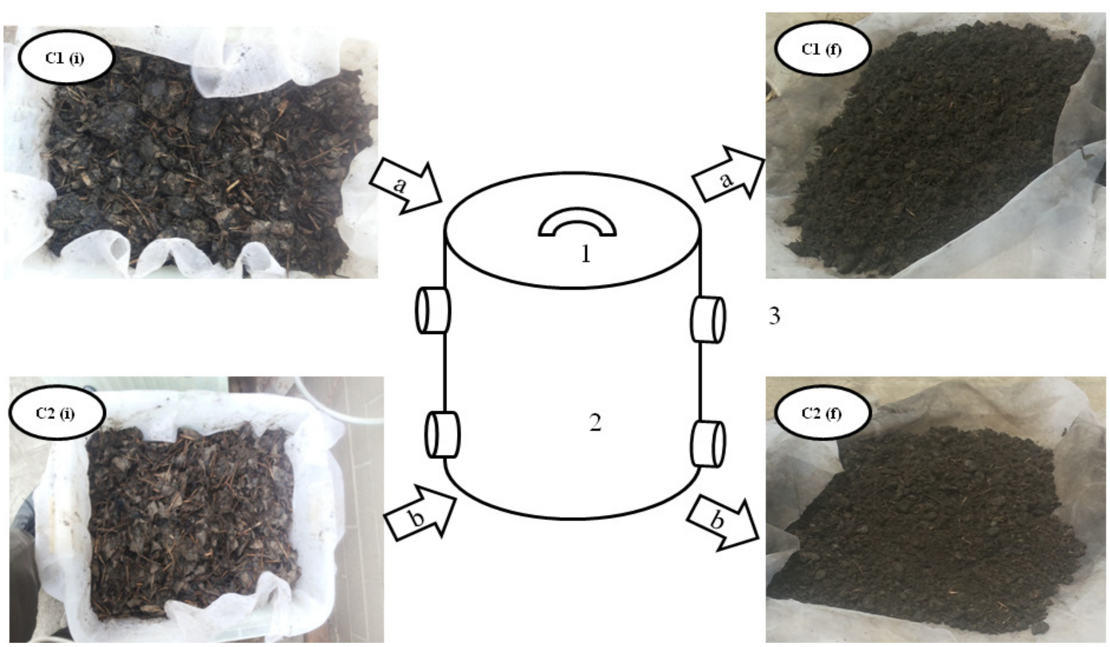

Figure-1
Experimental setup (1)-Cover, (2)-Digester, (3)-Perforated holes for aeration C1 (i) and C1 (f) respectively represent the compost before and after aerobic digestion with banana peel (BP). C2 (i) and C2 (f) respectively represent the compost before and after aerobic digestion with rice straw and eucalyptus leaves (RS-EL)

Table-2
Raw materials and compost mixtures physicochemical characterization

Raw materials				
Parameters	**Sludge**	**BP**	**EL**	**RS**
Mc (%)	73.6	65	57.8	0
pH	7.6	5.9	4.7	7.3
EC (mS cm^{-1})	3.6	2,8	3.4	4.6
OM (%)	62	94.3	94	93
TOC (%)	34.4	52.2	51.6	52.3
N (%)	3.41	0.84	1.91	1.43
C/N	10.0	62.4	27.1	36.2

Composts mixtures characterization on day 0		
Parameters	**C1**	**C2**
Mc (%)	67.5	69.4
pH	7.4	6.3
EC (mS cm^{-1})	3.6	3.1
OM (%)	70.0	73.0
TOC (%)	38.8	40.5
N (%)	2.9	2.7
C/N	13.8	14.6

The use of bulking materials slightly upgraded C/N ratio: C1 (13.8) and C2 (14.6) compared to 10.0 in the raw sludge.

Results and Discussion

Temperature and moisture content: Temperature is one of the main parameter to monitor composting process. The increase of temperature during the course of the composting denotes microbial activity[19]. According to Boniecki et al[20], it is the key parameter with second (after pH) importance for ammonia emission. A temperature profile during the composting process is shown in figure-2a. Temperature ranged from 29°C to 60°C in digester C1 and 32°C to 63 °C in the digester C2 during the composting process. The highest temperature C1 (59.8°C) and C2 (62.5°C) were achieved respectively on the day 12 and 7. According to Ruggieri et al[21], temperature > 45°C is considered thermophilic range. Accordingly, in our case, thermophilic temperature was achieved in both digesters C1 and C2. Moreover, the temperature lasted 7 consecutive days at thermophilic range in C1 and 8 in C3; donating intense microbial activity. Lower (50°C, 55°C) [15] and higher temperatures up to 70°C[22] have been reported during composting. Beside, for bacteria to start exercising intense activity, 7 days for C1 and 6 days for C2 were necessary required. This might be explained by the high moisture content in both C1 and C2; which did not favor earlier bacteria activity. Otherwise, bacteria activity in C2 was relatively better compared to C1 as higher temperature was achieved in C2. This could be due to the fact that RS-EL in C2 provided better structural support to prevent the physical compaction of the pile and increasing air voids allowing the aeration of the pile compared to BP in C1 (figure-1). The diminution of moisture content during the composting process is also an indicator of microbial activity. By the end of the composting, water content dropped from 69.4 % to 42.3% in C1 and 67.5% to 40.3% in C2 (figure-2b).

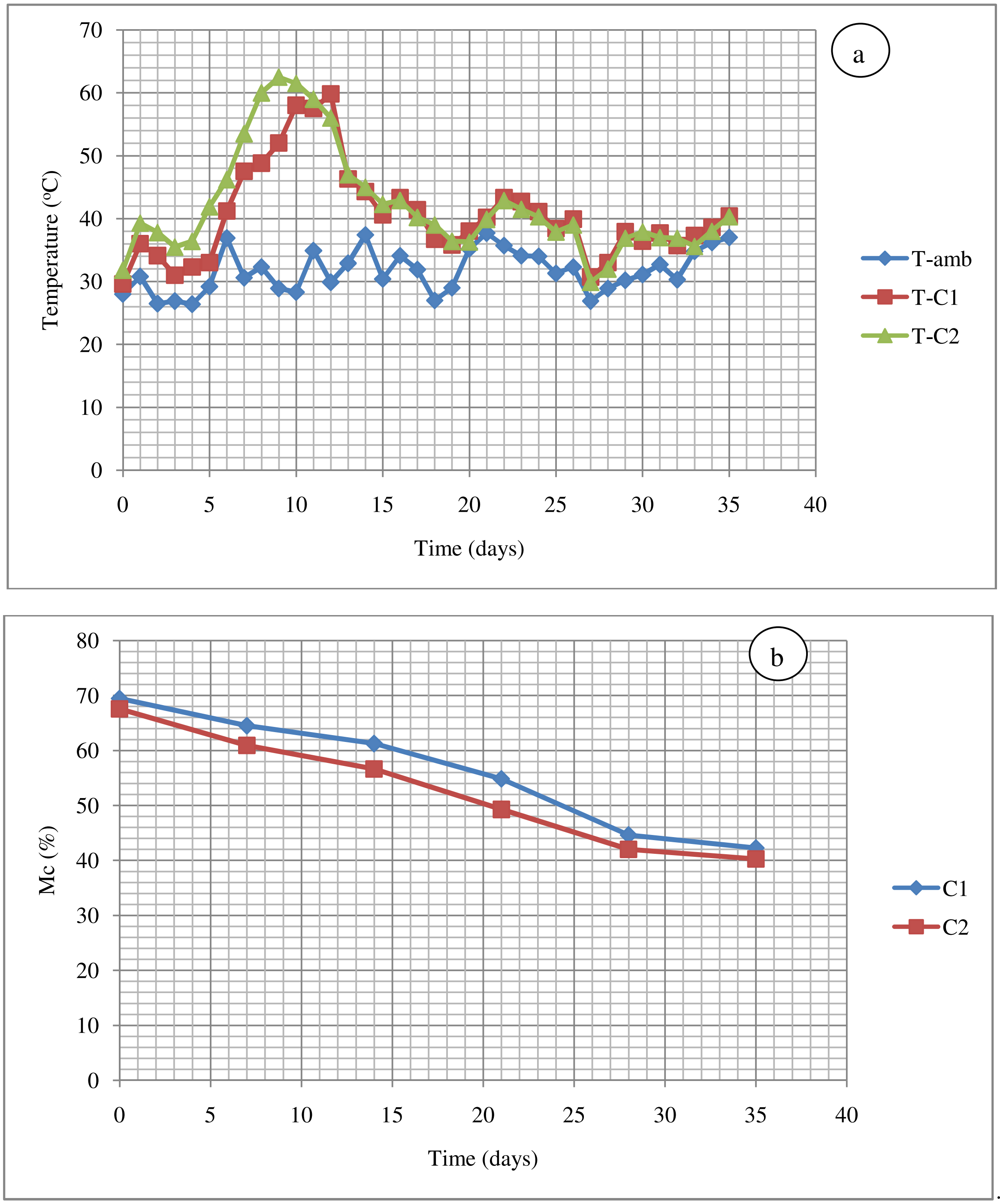

Figure-2
Variation of compost (a) temperature and (b) Moisture content during composting

pH and EC: The initial pH of the compost was 7.4 in C1 and 6.9 in C2. These are in the recommended pH range (6 – 8) for better composting process (figure-3a) [23]. Right after starting the composting, the pH dropped in both composters C1 and C2. The lower pH was 6.6 in C1 and 6.3 in C2; all achieved on the day 14. By the 21th days, the pH started to increase, till it reached 7.6 in C1 and 7.4 in C2 at the end of the process. The decrease in pH during the composting could be explained by the production of organic acids, dissolved CO_2 as result of OM degradation[24] and pH increase by the mineralization of organic nitrogen (amines) associated with protein degradation within in the medium[25]. Indeed, during composting, organic N is transformed into NH_3 or NH_4^+ during ammonification, increase the pH of the compost[26].

Electricity conductivity (EC) is a measure of total salt concentration and describes the variation in levels of organic and inorganic ions, such as Cl^-, Na^+, K^+, NH_4^+, NO_3^-, SO_4^{2-} in the composts[26]. High EC also indicates high salinity and the presence of more soluble products. Figure-3b shows the variation of EC during composting. EC increased from 3.6 mS cm^{-1} to 4.5 mS cm^{-1} in C1 and 3.1 mS cm^{-1} to 4.21 mS cm^{-1} in C2, during the first 20 days then decreased to 3.58 mS cm^{-1} and 3.29 mS cm^{-1}, respectively in C1 and C2 at the end of the process. The increase of EC is the direct consequence of the degradation or biotransformation of complex organic matter to simple compounds such as mineral ions (phosphate, ammonium and potassium etc.)[27, 28]. The decrease of EC at the end of the composting process is explained by the precipitation of some ions during sludge stabilization.

OM, N and C/N: During the composting process OM gradually decreased in both digesters (figure-4). OM decomposition was very active between the beginning and the day 21. This period corresponded to the active phase of composting process including the thermophilic phase; as high bio-oxidation rate of organic materials begins at 40 °C[29]. By the end of the composting, 41.4% and 50.3% OM degradation rate were achieved respectively in C1 and C2.

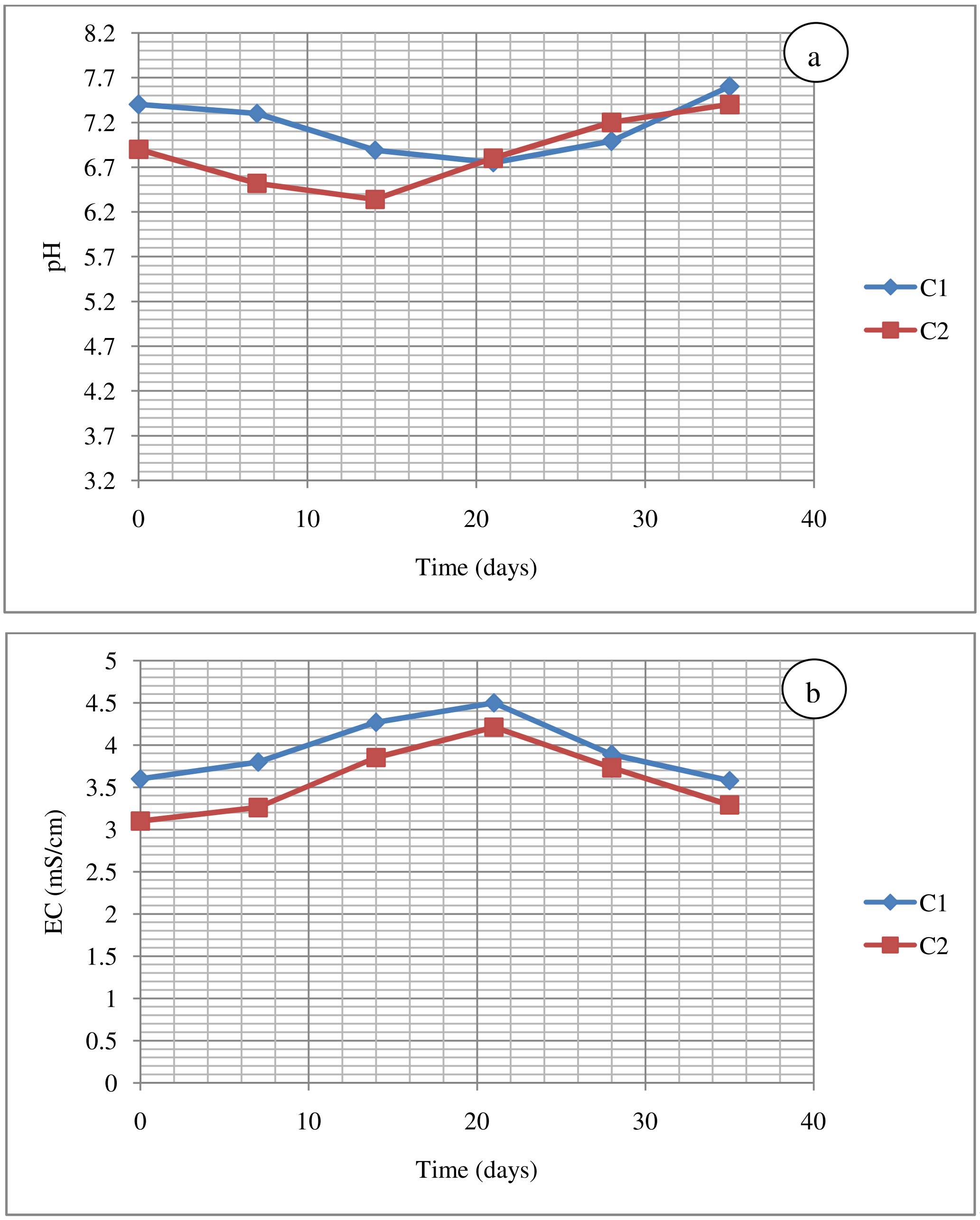

Figure-3
Variation of compost (a) pH and (b) electrical conductivity during composting

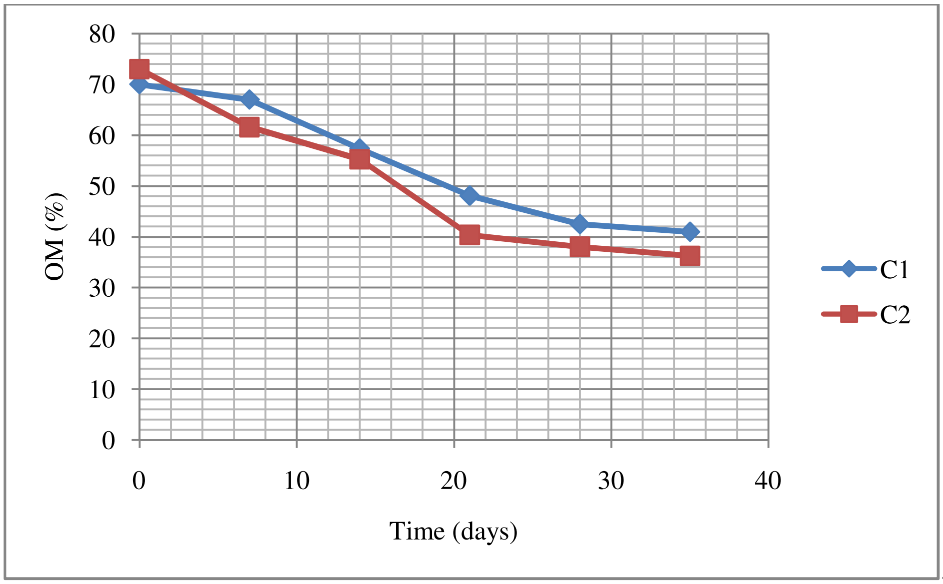

Figure-4
Variation of compost organic matter content during composting

Nitrogen contents also decreased in both composters C1 and C2 during the active phase of the composting (figure-5a). This was in accordance with Tognetti et al[30] who claimed nitrogen N decrease overtime. A decrease in nitrogen was expected due to mineralization of nitrogen and its conversion to ammonia and further in nitrate; and the usage of N by microorganisms to renew their cells. Beside, nitrogen increase noted at the end of the process could be attributed to stored source of N from some organisms that will eventually die during the composting process. This N is then recycled and uploads nitrogen concentration[31].

C/N ratio is an important factor to appreciate the decomposition rate of organic materials during composting and asses the quality of the produced compost. Figure-5b shows the pattern of C/N ratio profile during the digestion process. All through the digestion process, C/N dropped from 13.8 in C1 and 14.6 in C2, to 8.4 and 7.5 respectively. Indeed, during the degradation process of organic matters, microorganisms use carbon as energy source to renew their cells[13]. As a consequence, carbon is absorbed by microorganisms leading to the oxidation of organic carbon in aerobic condition in to CO_2 which will be released into the atmosphere during the metabolism of the cells; and thus lowering C/N ratio.

Quality of the composts: To the point of view of OM decomposition, OM was very well degraded. As showed it in the figure-1, the produced compost was physically well stabilized. Otherwise, it has been reported that the final pH of compost for agricultural use should range 6 - 8.5. In our case, pH values in both composts (from C1 and C2) were within this range and can thus be applied to agricultural soil. However, C/N ratio C1 (8.4) and C2 (7.5) of the produced composts were below the recommended limit (10 to 20)[32]. This could be explained by the low C/N of the compost at the beginning of the composting. In addition, EC values [C1 (3.58 mS cm^{-1}) and C2 (3.29 mS cm^{-1})] of the produced compost were within the recommended range for suitable land application (< 4 mS cm^{-1}) according to Wong et al[26]. As a consequence the produced compost could serve as soil amendment.

Conclusion

Co-composting of sewage sludge with banana peel and rice straw-eucalyptus leaves was investigated. Composting has been found to be a suitable ways to deal with various domestic organic wastes and produce more stabilized biosolids which can be used as soil conditioner. Here, although both bulking agents BP and RS-EL did not significantly upgrade the C/N ratio up to the recommended range for suitable composting, very good degradation of organic matter occurred; and the degradation rate reach 50.3% with BP and 41.4% with RS-EL. The produced composts, possesses physicochemical properties that favor it land application. We then suggest and encourage the application of composting for sewage sludge stabilization and production of biological fertilizer for the double benefit of crops and environment sanitation.

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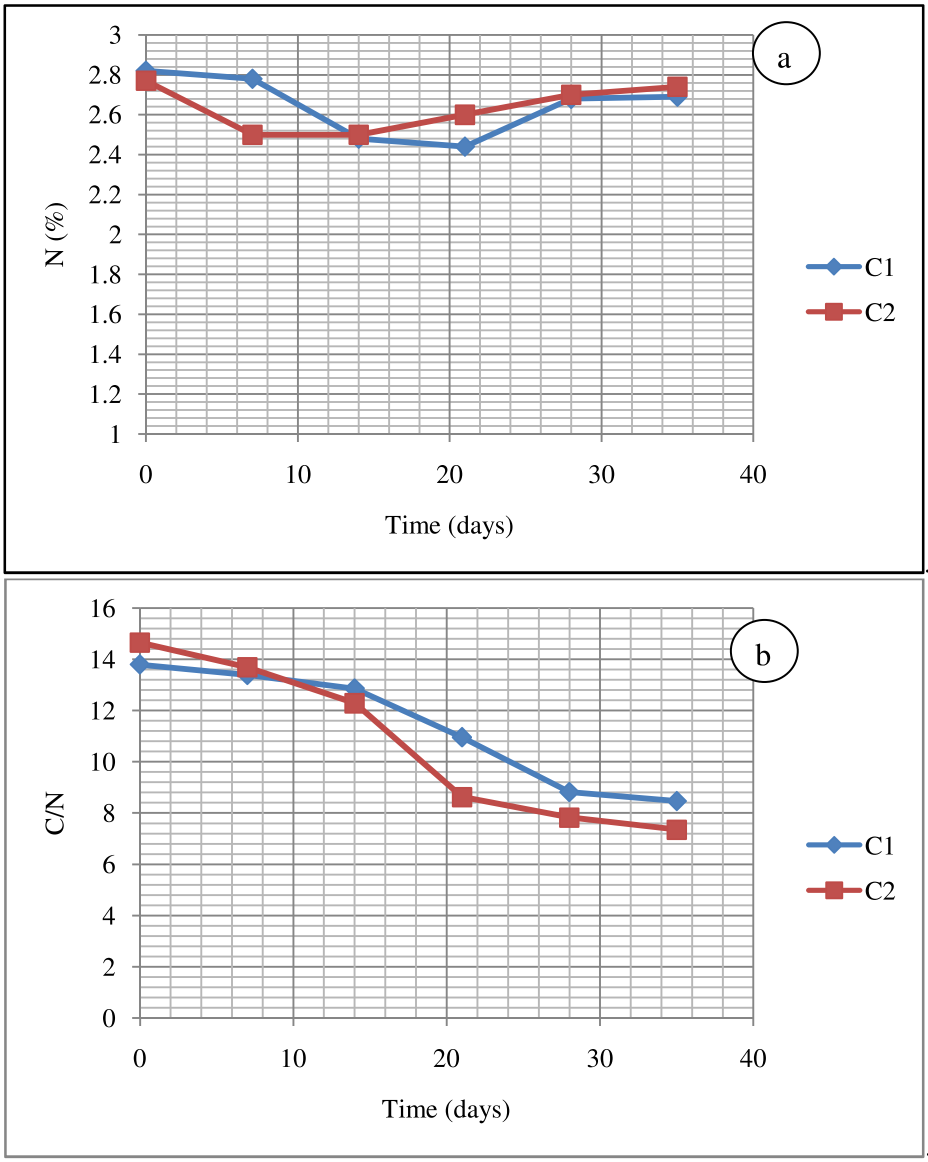

Figure-5
Variation of compost (a) nitrogen and (b) C/N ratio during composting

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