COMPOST QUALITY FROM BIOWASTE TREATMENT IN WEST AFRICA

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ABSTRACT

Composting is generally considered as a cost effective waste management option for stabilising waste and produce a soil improver/organic fertilizer. Passive aerated open windrows is a typical low cost option feasible in in São Tomé and Principe (pop. 197 900), a small island state in West Africa. Here the European Union, in partnership with Instituto Camões, UCCLA and the local authority, invested in the waste management system upgrade. A composting plant integrated with biowaste collection has been working since 2013. In order to assess the composting process efficiency, a novelty in São Tomé on this scale, temperature was regularly measured and registered. The matured compost was analysed in Portuguese Laboratories, targeting parameters such as: humidity, pH, electrical conductivity, organic matter, macronutrients and heavy metals. The results are encouraging suggesting that composting is a good option for treating biowaste collected separately at households, central markets, supermarkets, rest homes, restaurants, municipal gardens…etc. Compost output has high C/N ratio and concentration of organic matter, thus evidencing agronomic value. However, some heavy metals (Cr, Ni) content are a matter of concern, and require further assessment in order to prevent their presence.

Besides the financial benefits, composting allows saving natural resources by transforming biowaste into a product, reducing harmful impact of chemical fertilizers to soil. This article paves the way to further research and should encourage more experiences in this field, transforming waste into ready available compost.

Keywords: compost, composting, São Tomé e Principe, biowaste, nutrients, waste management in Africa

INTRODUCTION

São Tomé and Principe located in the Gulf of Guinea, West Africa, is a Small Island Developing State (SIDS) facing acute waste management problems due to the lack of suitable resources and knowledge (Agamuthu, 2014). The typical weather at the São Tomé International Airport is tropical with a dry season between June and September – the annual average temperature is 26ºC and 75% humidity (Instituto Nacional de Estatística de São Tomé e Principe, 2015).

Since 2009 UCCLA, a Portuguese Non Profit Municipal Association, with the financial support of the European Union, Portugal Aid (Camões), and in partnership with Local Authority – Câmara Distrital de Água Grande - has been implementing infrastructures and providing expertise in different areas of waste management. Considering the waste composition in São Tomé e Principe, with over 70% of biowaste (TESE, 2011) it is assumed that composting should play a role in sustainable waste management.

The present work aims to carry out an analysis of the composting process, using the temperature evolution and an assessment of the quality of the compost produced from separately collected biowaste in São Tome, namely percentage of organic matter, C/N ratio and presence of heavy metals.

MATERIALS AND METHODS

MATERIAL

Biowaste was separately collected with 120 litre bins and 15 litre buckets from municipal markets, local restaurants, institutions (rest home) and other different sources (Vaz & Dias-Ferreira, 2015). Its composition varied, but was essentially made by fruits, such as banana peels; fresh and rotten vegetables; dry hay and grass; coffee grounds (from a Café); sawdust, paper cardboard and other organic matter (Figure 1). The organic waste collection was not fully successful: biowaste from municipal markets was often impaired by plastic bags, cans, batteries, mobile phone parts and unwanted or other non-biodegradable fragments (Vaz & Dias-Ferreira, 2015).

Figure 1 - Composting Plant: biowaste unloading

Figure 2 - Composting site in Água Grande District, São Tomé

COMPOSTING SITE

A total of 16 passively aerated windrow piles were monitored in detail, during 2014. The piles were on average 0.6 to 1.2 meter high, 0.6 to 1.8 meter wide and 3 to 7 metres long. The average capacity of composting piles was estimated at 2.24 m^3, with an average 1345 kilograms input of organic materials per pile. The piles were set on a porous foundation gravel with raw materials blended to achieve a balance between high nitrogen “Greens” (fruits, vegetables, leaves, peels, food scraps,…etc.) and “Browns” (saw dust; woodchips, branches, wet cardboard). Improving the formulation for the recipe was a key factor in reducing the composting period, maximizing the operation by enhancing conditions for microbial activity.

All tasks regarding the piles composting process were performed manually without the help of machines. Temperature in each pile was carefully measured, by local workers, in five sections across the pile (T1 to T5 – see Table 2), close to the centre of pile, every 3-4 days, in average, always using the same procedure. The analogical thermometer (manufacturer: TFA) was found to be accurate, user-friendly and reliable. Composting piles were revolved periodically, at least three times during the entire composting process.

In Figure 3 the Composting Plant layout is represented in a 3D drawing. A water tank was built to harvest rainwater, ensuring that water would be available to keep the piles with a minimum moisture content, during the dry season. The characteristics of the composting site in São Tomé are compiled in Table 1.

PHYSICOCHEMICAL PARAMETERS

Eight mature compost samples were collected from São Tomé composting plant and analyzed at the laboratories of Coimbra School of Agriculture (ESAC) and Castelo Branco School of Agriculture (ESCB), in Portugal. Physical and chemical properties were determined using standard analytical procedures for the following parameters: humidity, pH, electrical conductivity, organic matter (OM), apparent density, C/N ratio and content of chemical elements (N, B, C, N, P, K, Mg, Cu, Zn, Fe, Pb).

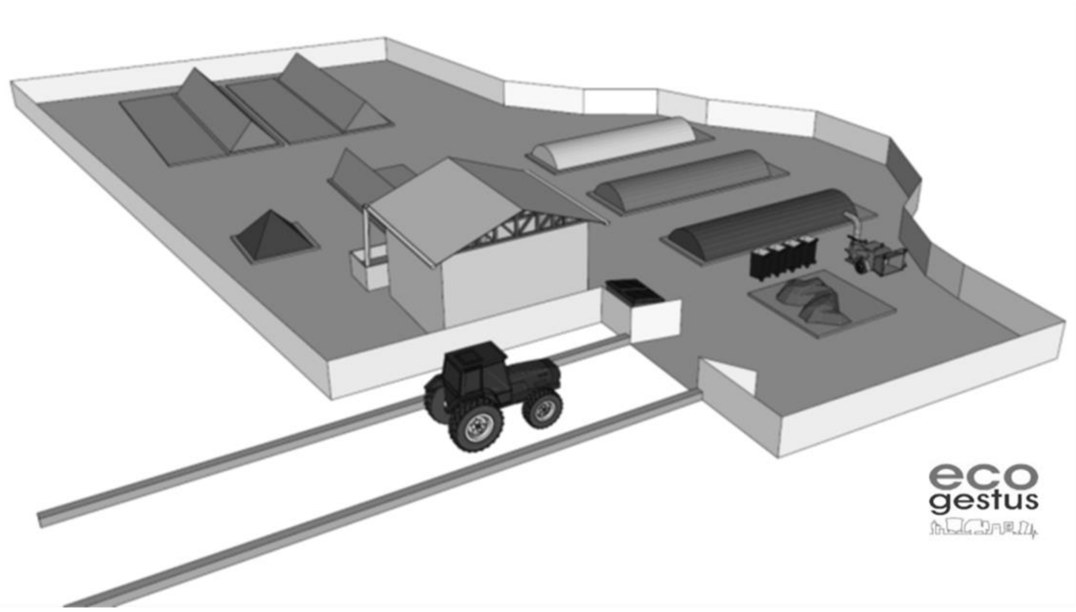

Figure 3 Scheme of Composting Site in Sao Tome

Table 1 - Summary of the São Tomé Composting Site

Parameter	Composting site in São Tomé
Form of organisation:	Municipal
Type of waste:	Biowaste
Collection:	Separate biowaste collection specific producers e.g. markets, supermarkets, rest homes,…etc.
Waste treated (capacity) (t/year):	350 to 500
Compost production capacity (t/year):	50 to 100
Number of employees:	4 (1 full time and 3 part time)
External funding/subsidiaries:	Yes: European Union (>70%); Camões - Instituto da Cooperação e da Língua; UCCLA, Local Authority
Main market for the compost	Municipal gardens, Hotels and Resorts; Agriculture
Pre-processing:	No
Type of process:	Turned - Windrows ; Green waste is shredded
Turning equipment:	Manually by workers
Process time (weeks):	Min 5 to 14 weeks
Additives:	None
Process control parameters measured:	Temperature (regularly)
Quality control:	pH, organic matter content, C/N ratio, heavy metals

RESULTS

COMPOSTING PROCESS DESCRIPTION ACCORDING TO TEMPERATURE PROFILES

The most important monitoring parameter for composting piles is temperature - an indicator of microbial activity (Mohee, 2007). From the technical point of view only Piles 10 to 21, formed from July to September 2014, present valid data, and completed the composting cycle without major impairments (e.g. mixed with other piles; infrequently monitoring). So, earlier piles (No. 1 to 9) were not considered in this work due to inconsistent monitoring and incomplete data.

Mature compost was considered as such when recorded temperature at the end of process was similar to air temperature, ~ 30°C. Figure 4 shows the temperature measured in composting piles No 10 to 15. It can be seen that the evolution went according the standard composting profile. All monitored piles exceeded the temperature of 55 ºC during at least 10 consecutive days. Higher temperatures are required to kill pathogens, weed seeds, and fly larvae within the compost. According to Martinho (2000) the conditions achieved allow us to be sure that pile hygienization occurred successfully and that pathogenic organism were eliminated.

The temperature measurements in the composting piles No. 16-21 (Figure 5) showed that stabilised composting was obtained after a minimum time of 45 days (pile 17).

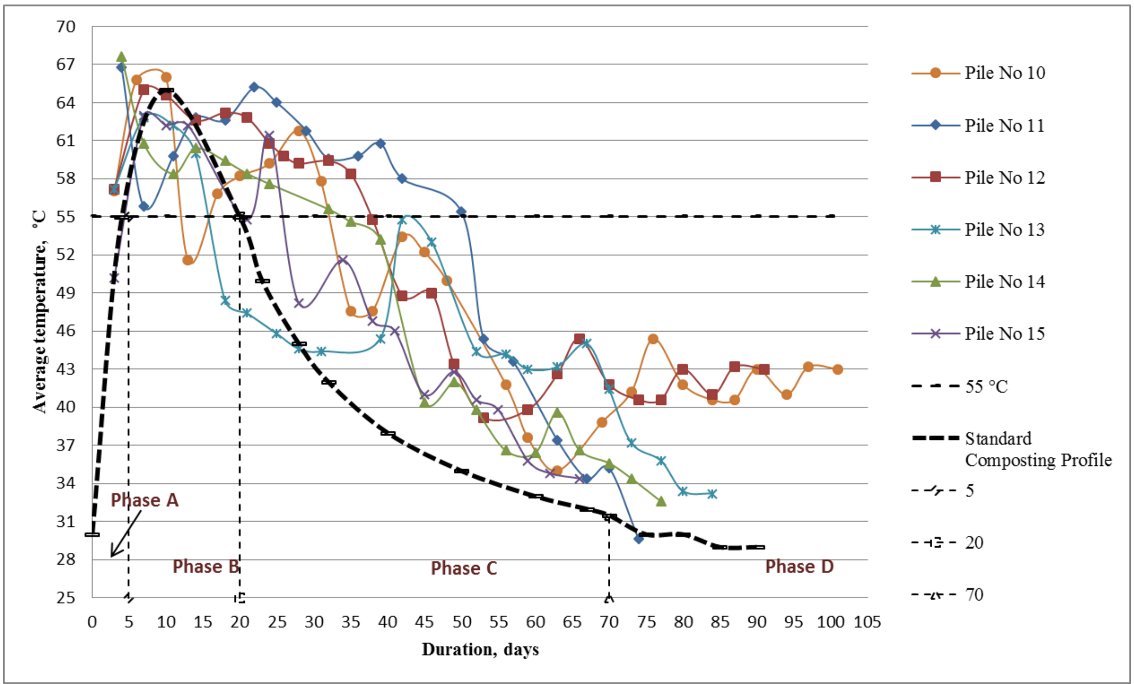

Figure 4 - Temperature Profiles Piles No 10-15 and Standard Temperature Profile

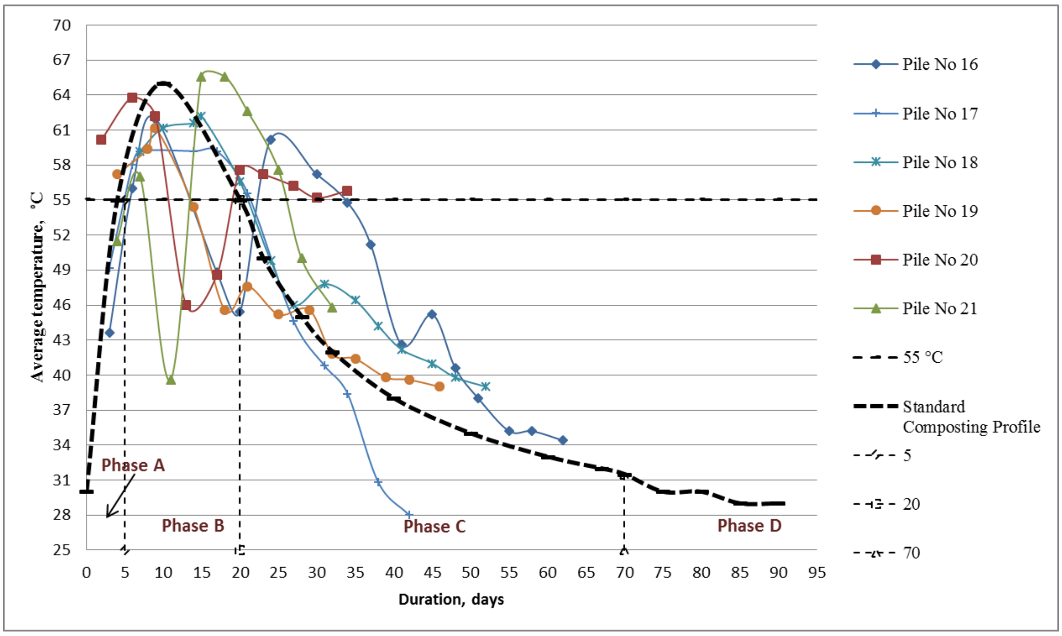

Figure 5 - Temperature Profiles Piles No. 16-21 and Standard Temperature Profile

Pile No. 15 behaved exactly according to theoretical models, suggesting three different phases: mesophilic, thermophilic and maturation – see Table 2 and Figure 6. The temperature increased in phase A, reached the maximum at phase B and started to decrease, when temperature was less than 55°C – it is defined as phase C phase A is clearly visible, during 5 days as temperature rises to 50°C rapidly within 3 days and then to phase B (after 7 days temperature increases to 63.°C). After 25 days, temperature decreases, the pile is then into maturation phase. And, after 66 days, the temperature reached 34°C and it is then assumed that composting process was entering maturation, however not yet stabilized.

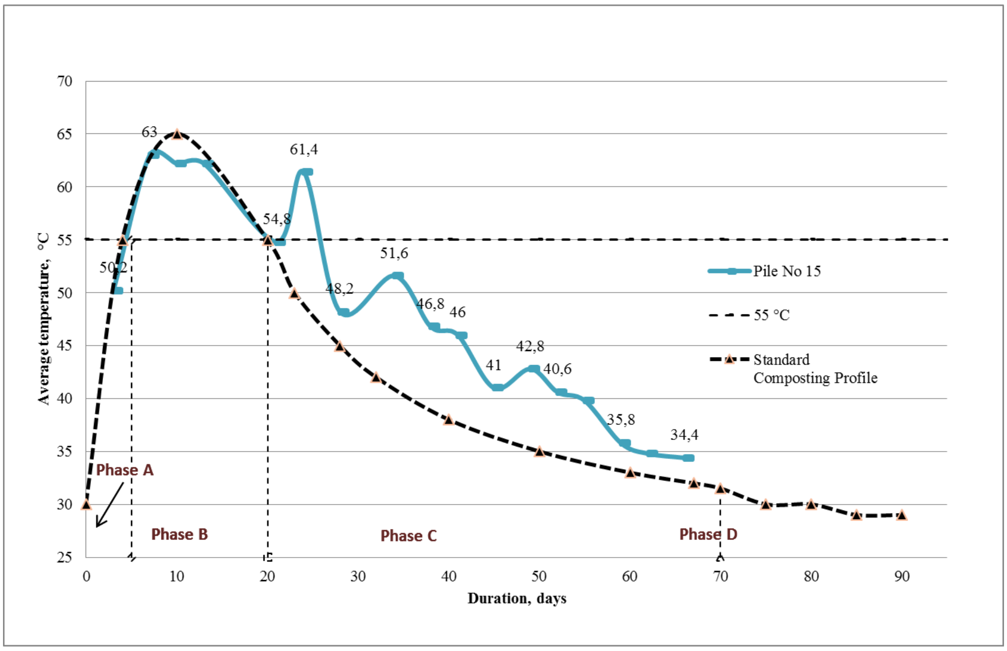

Figure 6 - Temperature Curve of the Compost Process in Pile No. 15

Table 2 - Temperature Measurements in Pile No. 15

Days	Datum	Temperature						Pile revolving
		T1	T2	T3	T4	T5	Average	
3	22.08.2014	35	58	53	53	52	50	
7	26.08.2014	63	64	63	62	63	63	x
10	29.08.2014	58	62	64	64	63	62	
13	01.09.2014	59	63	62	63	64	62	x
21	09.09.2014	52	56	57	55	54	55	
24	12.09.2014	59	64	63	62	59	61	
28	16.09.2014	48	51	50	46	46	48	x
34	22.09.2014	49	51	54	52	52	52	x
38	26.09.2014	46	46	45	49	48	47	x
41	29.09.2014	44	46	48	47	45	46	
45	03.10.2014	40	42	43	38	42	41	
49	07.10.2014	41	43	45	42	43	43	
52	10.10.2014	39	40	42	41	41	41	
55	13.10.2014	38	40	41	40	40	40	
59	17.10.2014	35	34	36	38	36	36	
62	20.10.2014	35	36	35	35	33	35	
66	24.10.2014	34	36	36	34	32	34	

PHYSICAL-CHEMICAL PROPERTIES

The physical and chemical characteristics of produced Sao Tome Compost (STC) are presented in Table 3. Typical values for a similar material from Portugal (LIPOR NUTRIMAIS compost) and the limits of Portuguese Technical Standards for Composting (DL 103/2015) are also presented in Table 3.

Table 3 – Physical-chemical Characterisations of Sao Tome Compost, NUTRIMAIS (Maia, Portugal) and Compost from South Africa and Portuguese Technical Standards

Parameter	Compost São Tomé			LIPOR NUTRIMAIS	Technical Standards (DL103/15)				Compost from South Africa	
	n	Min.	Max.		Class I	Class II	Class IIA	Class III	Municipal	Private
Apparent density (g/L)	6	378	652	500	-				-	-
pH (1:5, v/v)	8	8.10	9.90	8±0.23	5.5-9.0				-	-
Cond. (mS/cm, 25°C)	8	1.88	4.58	-	-				-	-
Humidity (%)	6	11.91	47.35	9.23±0.33	< 40				-	-
Organic matter (%)	8	36.5	49.9	51.25±3.04	> 30				-	-
Total Carbon (%)	5	24.2	25.4	29.72±1.87					-	-
Total Nitrogen (%)	8	1.50	2.05	2.63±0.01	-				1.25	1.11
C/N	7	11.4	15.5	10.85±0.64					-	-
(Units in mg · kg^{-1})										
Total Phosphorus	8	0.13	2.03	1.26±0.02					0.23	0.17
Total Potassium	8	1.59	3.71	1.94±0.09					0.73	0.76
Total Magnesium	8	0.01	1.92	0.66±0					0.39	0.14
Total Calcium	8	1.48	14.20	12.05±0.49					2.29	0.61
Total Copper	8	48.4	81.3	-	100	200	400	600	53.0	6.2
Total Zinc	8	150	264	105.33±7.07	200	500	1000	1500	132	76.8
Total Cadmium	5	<0.04	3.30	0.56±0	0.7	1.5	3.0	5.0	-	-
Total Lead	5	11.4	51.0	22.55±0.64	100	150	300	500	-	-
Total Chromium	5	112	288	15.65±0.21	100	150	300	400	-	-
Total Nickel	5	56.7	152	9.62±0.96	50	100	200	200	-	-
Total Mercury	5	0.058	0.058	0.06±0	0.7	1.5	3.0	5.0	-	-

As a comparison, the values of compost produced from municipal green waste, municipally driven and private contractor projects implemented in South Africa (Ekelund, 2007) are also shown in Table 3. The results show that the compost made from green waste in South Africa is very similar in macro nutrients (except Potassium) to São Tomé compost.

HEAVY METALS

The results for mature compost from São Tomé Composting Plant showed that total heavy metals (Cu, Cd, Cr, Pb, Ni, Zn, Hg) were under the maximum limits advised by the Portuguese Technical Standards for Class IIA and III Compost (DL 103/2015). We assume that heavy metal presence rose due to contamination from cans, batteries, mobile phone parts and other non-biodegradable fragments. Thus, we assume that further research is required to assess the source of heavy metals and ways to lower it, especially Nickel and Chromium content. It is important to know avoid heavy metals in compost, as they accumulate in soils and enter the food chain through plant uptake.

CONCLUSIONS

The present research, conducted in São Tomé e Principe, a small Island State in West Africa, suggests that composting, passive aerated, is a feasible option for treating biowaste, collected separately at households, central markets, supermarkets, rest homes, restaurants, municipal gardens. The described experience evidences that within less than 90 days biowaste is decomposed into mature compost, assuring a reasonable time framework, even without any especial machinery, relying on manual mixing and revolving.

Mature compost samples analysed show that the compost has high C/N ratio, concentration of organic matter and therefore has agronomic value and can be economical valorised in São Tomé. However, some heavy metals (Cr, Ni) content requires further assessment in order to reduce their presence.

This article paves the way to further research and should encourage more experiences in this field, transforming waste into ready available compost, especially in developing countries where waste management is yet not established as a technical process. Besides the financial benefits composting as a waste treatment is contributing to environmental goals: saving natural recourses, transforming biowaste into a product, and reducing the use imported of chemical fertilizers in West Africa.

ACKNOWLEDGEMENTS

The present work would not be possible without the support of Câmara Distrital de Água Grande, UCCLA, European Union and by Camões - I.P. in the framework of Project "Descentralização e participação comunitária na gestão dos RSU da cidade de S. Tomé, FASE II"]. C. Dias-Ferreira gratefully acknowledges FCT – Fundação para a Ciência e para a Tecnologia (SFRH/BPD/100717/2014) for financial support.

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