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Experimental Study of Urban Waste Composting and Evaluation of its Agricultural Valorization in Lomé (Togo)

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ABSTRACT

This study concerns waste processing by composting in Lomé (Togo). It presents the composition of this waste, the treatment by composting of this waste recovered in the centers of transit and collected within individual households, an evaluation of its use as a fertilizer and finally a market research to determine its economic value. The composition of the Municipal Solid Waste showed that even though mineral components like sand and gravel represent the most important part of the waste arriving at the final dump location, organic material makes up a large part of households wastes. In order to determine the optimal conditions for composting biodegradable materials and for the overall process, a study was launched at a transfer site within a district of Lomé. Four types of compost were investigated, two with organics collected directly in households and two with raw waste stored at transfer sites that had been collected by a non-governmental organization in charge of primary collection. Amendment of the compost with natural fertilizer, natural phosphate and chicken manure was also tested. It was found that the quality of the types of compost was quite similar except for the one in which natural phosphate and manure had been added. Studies on the toxicity of the types of compost on their agricultural effectiveness and their economic value were also carried out. The market research demonstrated that the production costs of the compost were low enough to make it an attractive and potentially profitable alternative to existing fertilizers such as manure.

Key words: Waste, composting, agricultural, economic, fertilizers

INTRODUCTION

Twenty years ago, Lomé, the capital of Togo, was a pleasant city that was considered to be an attractive destination for international tourists. Unfortunately, recent political and socio-economic turmoil within the country have affected Lomé negatively. Rural depopulation has occurred at a rate that is among the highest in African countries (Parrot *et al.*, 2009). In addition, over the past twenty years Togo has experienced a reduced economic growth and a decline in the Gross Domestic Product (GDP) per capita (IMF, 2003). There is an interest, therefore, in activities that might contribute to the economic development of newly urbanized areas within Togo. The creation of solid waste is unavoidable consequence of production and consumption activities of society. In developing

countries the waste generation ratio of households varies between 0.4-0.7 kg/cap/day, but seasonal variations can influence the amount of waste generation and its physical and chemical characteristics. For instance, high humidity during the rainy season or the consumption of vegetables and fruits can influence the moisture content and organic content of Municipal Solid Waste (MSW) (De Guardia *et al.*, 2010; Lin, 2008). Variations in these characteristics can in turn affect whether treatment processes such as recycling or composting can be effective (Tinoco *et al.*, 2009). At the present time, recycling of materials collected door-by-door by either municipal or non-governmental organizations (NGOs) is not done on an organized basis but is instead done by individual scavengers and waste pickers. In Lomé issues related to Solid Waste Management (SWM) have been neglected for decades and the economical stagnation of the country, with resulting low investment in the SWM sector is seen as a serious problem. As a result the inhabitants of Lomé are faced with the problem of uncontrolled disposal of solid wastes close to their households. Faced with similar problems in other developing nations, NGO members, gardeners and scientists in India (Zurbrugg *et al.*, 2004) or Bangladesh (Zurbrugg *et al.*, 2005) have investigated the possibility that composting of MSW that can improve the functioning of the solid waste management system while producing a marketable product.

Here we investigate the efficacy of composting in Lomé, Togo. The idea to be investigated is whether compost can be produced in Lomé in a sustainable and economical manner and whether the compost produced could be of a quality that allows it to be used as an alternative fertilizer to animal manure. If so, then this compost produced in the urban zone could be transferred to agricultural areas adjoining Lomé. It is expected, based on local conditions, that composting would best be carried out in decentralized systems. If done properly, the use of compost could result in a variety of environmental benefits. Composting organic materials that have been diverted from landfills avoids the eventual production of methane (Domingo and Nadal, 2009; Rudrum *et al.*, 2002) and leachate (Kjeldsen *et al.*, 2002) in the landfills while producing a product with economic value. Furthermore, using compost can reduce the agricultural demands for water, fertilizers and pesticides (Hoitink *et al.*, 1997; Weltzien, 1989; Sahin and Bolukbasi, 2009). Composting also extends the life of the municipal landfill by diverting organic materials from landfills to agricultural lands.

To gather information on different parameters of the composting process, this study has been set up to control and analyse two boxes and two windrows of different compositions of compostable materials. Chemical analyses of the compost were followed during the time of the aerobic decomposition of the waste. The finished compost was then evaluated as a fertilizer by performing growth studies on carrots. In addition, the finished compost was evaluated to estimate its economic value and the potential that its production could be done profitably.

MATERIALS AND METHODS

Origin of waste and sampling: Domestic waste samples were collected from 33 houses randomly identified in the middle District of Lomé after an investigation conducted by the NGO in charge of waste collection in the District. The 33 houses were selected in order to sample wastes from households having a range of economic standing. Two collection methods were utilized. In the first, only compostable wastes were collected from the household. In the second, raw waste was collected and then sorted to eliminate materials not suitable for composting (papers-cardboards, textiles, plastics, glasses, metals, miscellaneous, hazardous, etc.). The samples for physical characterization were obtained in both the dry season and in the wet season; For the selective collection, a mass of

250 kg waste was characterized; for the raw waste, a mass of 500 kg was collected and characterized. One of the samples obtained by selective collection was amended with chicken manure and organic phosphate. Sorted wastes were obtained from two different districts within Lomé. The four types of composts to be evaluated were prepared according to the following combinations of raw materials (Table 1).

Goal of this study was to compare the effect of manure, compost made from waste, manure and compost made from household waste alone. Very often, farmers use this kind of manure as organic fertilizer in agriculture without any preliminary treatment. Consequently, a considerable emission of harmful gases is released into atmosphere (greenhouse gases), nitrogen losses from manure are large and contamination of soil with pathogens is possible. Manure handling, storage and disposal continue to present major problems for poultry producers throughout the world (Petric *et al.*, 2009).

Compost C and D are drawn because of the waste composition of various neighborhoods in terms of quality of fermentable matter.

Waste of compost A and B are from the collection of neighborhood Agbalépédogan. The compost activation process is performed by micro natural organisms.

Windrow and box preparation: After the sorting of the waste to remove unsuitable materials (metals, glass, miscellaneous and hazardous), the remaining organic waste was poured into buckets to build the compost pile. Two composting methods (box and windrow) were utilized. These two methods are described below.

Box composting method (or reactor composting method): In this method all the operations were conducted under a roof to protect the compost from excessive rain and sun (Zurbrugg, 2003). Compostable materials were placed in boxes that were 1.2 m long, 1.2 m wide and 0.5 m high. The boxes were made of cement and were constructed to allow air penetration on their sides. The bottom of the reactor was designed with a slope to facilitate leachate drainage.

Windrow composting method: The organic wastes were piled on the ground after sorting and were protected from excessive sun and rain by a composting fleece, permeable to air but not to rain water (Zurbrugg *et al.*, 2005). A drainage system collected leachate and rainwater, which was used

Table 1: Composition of different biodegradable materials

Box or windrow	Composition of compostable materials (kg)					Size	
	MSW Organic fraction	MSW raw	Chicken manure	Natural phosphate	Covered	Volume (m ³)	(L×W×H)
Box A	120	0	0	0	Yes	0.72	1.2×1.2×0.5
Box B	120	0	24	8	Yes	0.72	1.2×1.2×0.5
Windrow C	0	1650	0	0	No	4.25	1×2.5×1.7
Windrow D	0	1420	0	0	No	4.25	1×2.5×1.7

Compost A = Organic fraction of the waste collected directly from houses, Compost B = Organic fraction+Chicken manure+natural phosphate, in the proportion of 15/3/1, Compost C = Domestic raw waste after sorting undesirable (unwanted waste) from Bè Avéto District, Compost D = Domestic raw waste after sorting undesirable from Agbalépédogan District

for watering of the windrows. The dimensions of the windrow were 1 m long, 2.5 m wide and 1.7 m high. These methods are less costly than other composting technologies, such as in-vessel composting (Van Haaren, 2009).

Turning frequency: The boxes and windrows were turned every 2 weeks to allow the aeration of the pile, the homogenization and also the cooling of the waste during aerobic degradation. In normal windrow composting practice, oxygen may not penetrate throughout the body of the windrow. Therefore, some anaerobic reaction may take place, resulting in methane formation. However, with adequate turning, the amount of methane generated in windrows is very small (Van Haaren *et al.*, 2010).

Compost control parameters

Temperature: The temperature was determined every day with an alcohol thermometer at different points of the pile (deep, middle and bottom) (Waste Concern, 2006; Unmar and Mohee, 2008).

Moisture content (H%): The moisture content of sample ($m_0 = 100$ g) was determined at 105°C in an oven (Yobouet *et al.*, 2010). An approximate method was also used in the field in which a handful of compost was firmly squeezed. If no drops of water emerged, then the moisture content of the waste was considered to be too small. Moisture content in the field was adjusted by watering:

$$H\% = \frac{M_0 - M_1}{M_0} \times 100 \quad (1)$$

where, M_0 = weight of sample (100 g), M_1 = weight of sample after drying at 105°C

Organic matter content: To measure organic matter content, 25 g of compost were burned at 550°C in an oven for 2 h (Unmar and Mohee, 2008; Sutherland, 1998). The content in organic matter or in volatile solid was obtained by the difference of weight between the mass of the dry waste and the mass of the burned waste.

pH measurement: Composts pH was measured in a 1:5 (w/v) composts ratio to distilled water. To measure pH, 20 g of dry matter were mixed with 100 mL of distilled water. The suspension was homogenized by magnetic stirring during 15 min. The pH was measured directly by reading using a pH-meter with a combined glass electrode (Yu and Huang, 2009; Belyaeva and Haynes, 2009).

Other compost quality criteria: When collecting a sample from a decomposing pile, one has to take into account that the material is highly heterogeneous. Recognizing this, samples were collected by taking several handfuls of material from different places within the pile. These samples were then mixed again and one kilogram of material was collected from the mixture.

Nutrient and contaminant analysis: The preparation of the sample for the analysis of all parameters except nitrogen and carbon contents consisted of a wet digestion in acidic conditions (HCl/HNO₃).

- Total phosphorus was determined by color spectrometry using ammonium molybdate and ascorbic acid
- Total Kjeldahl Nitrogen (TKN) was determined by the Kjeldahl method (Barrena *et al.*, 2010).
- Cationic species (Na, K, Mg and Ca) and heavy metals (Pb, Ni, Cd) were determined by Atomic Adsorption Spectrometry AAS (Adouby *et al.*, 2007; Bustamante *et al.*, 2008; Belyaeva and Haynes, 2009; Koffi *et al.*, 2010)

Germination Index (GI) test: The biomaturity test was conducted with a fresh water extract from the compost that was dropped into a plastic petri dish with a filter paper. Ten milliliter of diluted compost extract was put on each petri dish. Twenty corn (*Zea mays*) seeds and twenty bean (*Virgna unguiculata*) seeds as basis cultures in Togo and twenty cress (*Lepidium sativum*) L. seeds were distributed on the filter paper and incubated at ambient temperature (28°C) in the dark (Pourhadian and Khajehpour, 2010) for 48 h under cover (Chikae *et al.*, 2006). The numbers of germinating seeds were counted and the lengths of the roots were measured. For the control, 10 mL of distilled water was used rather than compost extract. The GI was calculated by the formula of Zucconi (Bustamante *et al.*, 2008; Zucconi *et al.*, 1981):

$$GI = \frac{\text{Seed germination} \times \text{root length of treatment}}{\text{Seed germination} \times \text{root length of control}} \times 100$$

Two treatment levels (GI50 and GI75) were used in which the compost extract made up either either 50 or 75% of the sample. The same water used for the control was used for these dilutions. The Germination Index (GI) was defined as the arithmetic average of the 50% (GI50) and 75% (GI75) treatment levels:

$$GI = \frac{GI\ 50 + GI\ 75}{2} \quad (2)$$

Agricultural study

Field test: The composts A, B and C were tested in comparison with chicken manure and artificial fertilizer (NPK). All the trials were conducted in the same field. For each test a plot size of 2.8×1 m was used. Within the plot an area of 25×1 cm was sown with 3 or 4 carrot seeds. The following manure treatment levels were used:

- T₀: Natural soil with no application
- T₁: Natural soil with chicken manure at a dose of 20 t ha⁻¹
- T₂: Natural soil with inorganic fertilizer (N15P15K15)
- T₃: Natural soil with inorganic fertilizer (N30P30K30)
- T₄: Natural soil with inorganic fertilizer (N60P45K45)

A, B and C are natural soil with composts A, B and C at a dose of 20 t ha⁻¹.

The carrot seeds were allowed to germinate and grow for a period of 90 days in the field. The field was then harvested and the total mass of carrot tubers for each treatment level was calculated.

Statistical analysis: Standard errors for the field tests were calculated using general statistical methods like the ones described by Salant and Dillmann (1994) and Rea and Parker (1997).

RESULTS AND DISCUSSION

Physical characterization of collected waste: Not surprisingly, the composition of the wastes collected directly from the households was found to be significantly different from that of the non-sorted raw waste (Fig. 1a, b). There were also some differences in composition observed between the dry and rainy seasons. For the waste collected directly from the homes, 66-75% was compostable, 20-30% was non-compostable and less than 10% were fine grain (<20 mm) material (Fig. 1a). For the waste collected directly from the households, a high organic matter of 70 to 80% was found. Relative moistures of 50 to 70% were also observed. For the raw waste collected at the final discharge site, the results of the characterization of two seasons (wet and dry) revealed a rate of 15-22% of compostable fraction, 30-32% of non-compostable waste and a high proportion of fine fraction 46-56% (Fig. 1b). The average humidity ranged from 15% in the dry season to 44% in the wet season. Organic matter represented an average of 24-25% of municipal waste with a rate of 8-9% organic matter in the fine fraction. This is not advantageous for composting of raw waste as it indicates a high percentage of non-compostable mineral materials (e.g., sand and gravel).

The results revealed that the waste composting closer to the households or in the neighborhoods could be more effective than on the centralized final disposal as a higher percentage of the material was compostable.

Follow-up of process parameters

Moisture content (H%): All the substrates in boxes or in windrows were always controlled and the moisture content was maintained at 40-50% during the process. Less watering was needed during the rainy season to maintain the optimal water content. The Table 2 show water requirement in different seasons.

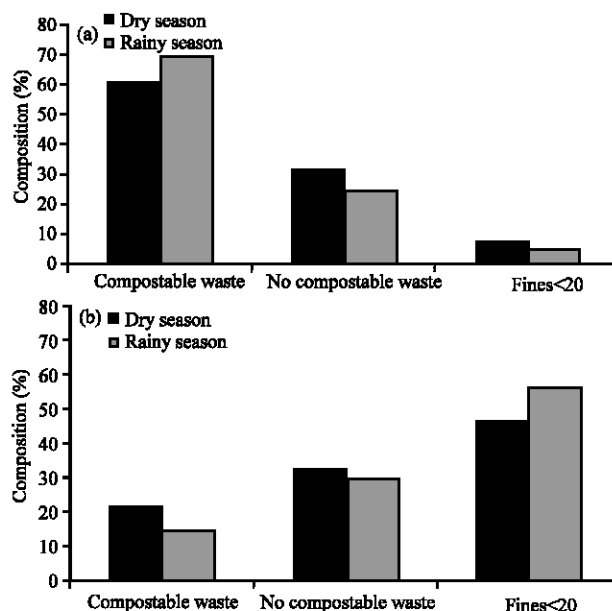


Fig. 1: Composition of waste after (a) collection directly from household and (b) final discharge

Temperature: Daily temperature recorded during the composting process clearly showed the two commonly-seen composting phases: the thermophilic phase ($T > 50^{\circ}\text{C}$) for the boxes (Fig. 2a, b) and $T > 60^{\circ}\text{C}$ for the windrows (Fig. 2c, d) and the mesophilic phase ($T < 40^{\circ}\text{C}$) for the boxes (Fig. 2a, b) and $T = 40\text{-}50^{\circ}\text{C}$ for the windrows (Fig. 2c, d). As expected, turning the compost generally had the effect of beginning a phase of temperature increase as fresh organic material and oxygen was mixed into the pile the pile temperature with occasional turning (Hassen *et al.*, 2001). The maximum temperature seen in the boxes was $50\text{-}60^{\circ}\text{C}$ (Fig. 2a, b). A maximal temperature of $60\text{-}70^{\circ}\text{C}$ was observed in the windrows (Fig. 2c, d). Present results are similar to those reported by Chikae *et al.* (2006). Composts C and D reached the temperature of the environment after 65 days (Fig. 2c, d).

Evolution of pH according to the organic matter content: The pH values ranged from 8 to 9.6, waste collected from the households (A, B Table 3) contained a quantity of ashes from basic wood or coal representing almost all the sources of energy in households. Three of the four composts recorded a pH above 9 which can induce the volatilization loss of ammonia as the acid/base equilibrium shifts from NH_4^+ to NH_3 ($\text{pK}_a = 9.2$) (Fadran and Dube, 2009). Compost B was the only one in which the pH was below the ammonia pK_a , with a pH at 8.7 (Table 3). Changes in the pH through time are a function of the fluctuating alkalinity during the composting process (Sawyer and McCarty, 1978; Komilis and Ham, 2006). A possible reason for this effect may be that a quantity of ashes from basic wood or coal increased the pH level in the composting, thus partly counteracting the toxic effect of low pH. Organic acids have been shown to be more toxic at an initial lower pH value (Yu and Huang, 2009; Beck-Friis *et al.*, 2003).

The organic matter decreases with increasing composting time (Table 3), as expected. The decrease is related to the aerobic decomposition of organic matter into CO_2 and H_2O .

Table 2: Water requirement in different seasons

Box or windrow	Predominant season	Total volume of water added (m^3)	Initial tonnage of compost (T)	Water requirement ($\text{m}^3 \text{ t}^{-1}$)
Box A	Dry	0.17	0.120	1.4
Box B	Dry	0.18	0.152	1.2
Windrow C	Dry	1.84	1.148	1.6
Windrow D	Rainy	0.62	1.025	0.6

Table 3: Evolution of pH and Organic Matter (OM) in the boxes and in the windrows every two weeks

Time parameters	Week compost	Evolution								
		2	3	4	5	6	7	8	9	10
pH (u.pH)	A	nd	-	nd	-	9.10	-	9.20	-	9.20
	B	nd	-	nd	-	8.75	-	8.85	-	8.90
	C	-	nd	-	9.30		9.60		9.60	-
	D	8.00	-	9.45	-	9.45	-	9.45	-	nd
OM (%)	A	nd	-	69.6	-	42.6	-	34.5	-	34.5
	B	nd	-	38.7	-	29.9	-	27.1	-	25.1
	C		58.2	-	28.2	-	28.1	-	27.0	-
	D	45.5	-	38.5	-	31.4	-	33.6	-	nd

nd: not determined

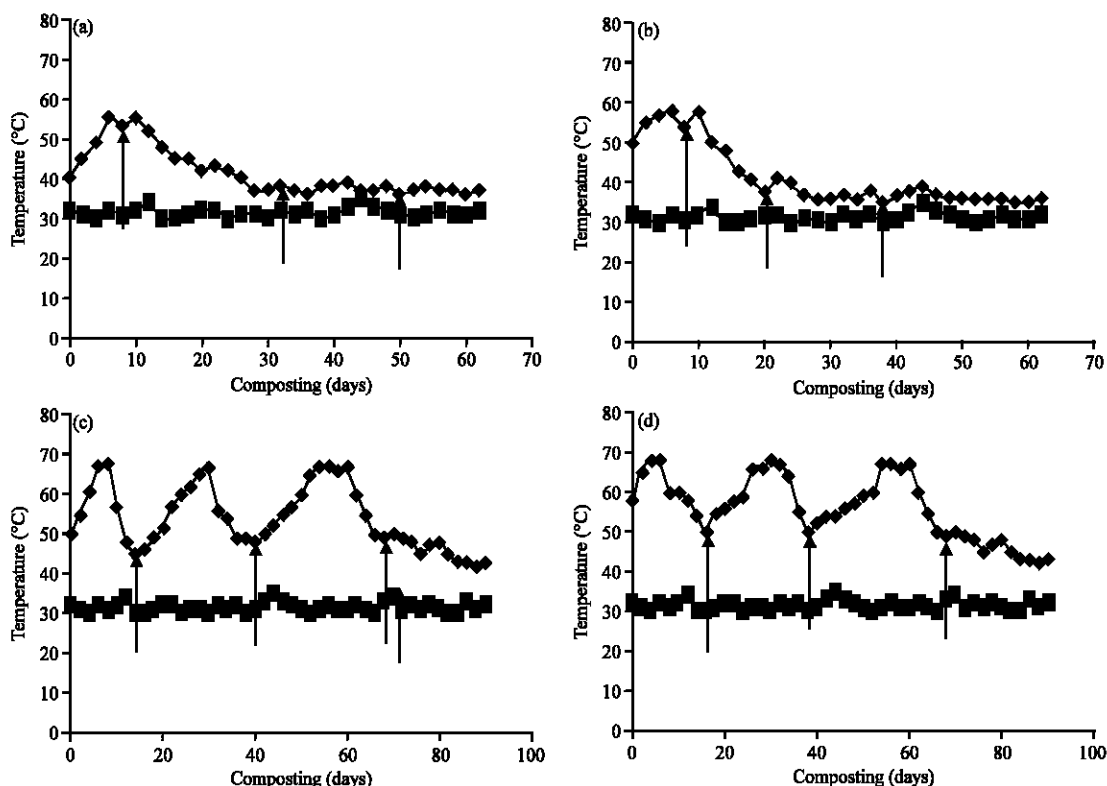


Fig. 2: Temperature versus time in boxes and windrows (arrows indicate the turning of waste).
(a) Compost A, (b) Compost B, (c) Compost C and (d) Compost D

Mass balance: Mass balances for the waste management processes were different for composts A and B, where the compostable waste was taken from the households and samples C and D, in which waste was first sorted and then composted (shown schematically in Fig. 3). Composts A and B used the box compost method while samples C and D were composted in windrows. In samples C and D, the collected material included recyclable materials like metals and plastics which could be further sorted. After what the remaining materials could be checked for some unwanted components and could be reintroduced in the process. In general the compost mass decreased in time as the moisture and organic matter contents decreased as a result of the composting process.

Chemical compost quality: Chemical characteristics of the four compost samples were found to be similar to values available in the literature. The four compost samples (A, B, C, D Table 4) were compared to the chemical characteristics of a compost from Nan-Tzu District in Taiwan (Lin, 2008) and Bangladesh (Waste Concern, 2001). pH levels were generally higher than the pH values measured in the Guinea and Bangladesh composts (Table 4). The nitrogen content was slightly lower than the other composts, which as mentioned earlier could be the result of ammonia volatilization associated with pH values above the $\text{NH}_4^+/\text{NH}_3$ pK_a value (Fadiran and Dube, 2009; Chang and Chen, 2010). Carbon and organic matter contents were similar to the corresponding values taken from the literature. The carbon to nitrogen ratio (C/N) because of the relatively low nitrogen content, was therefore high in comparison with other domestic waste composts (Lin, 2008; Waste Concern, 2001; Chang and Hsu, 2008; Chang and Chen, 2010). The elevated phosphate rate in compost B is due to the addition of natural phosphate to the organic fraction at the beginning of the process. All the composts were found to have a high content of inorganic nutrient like

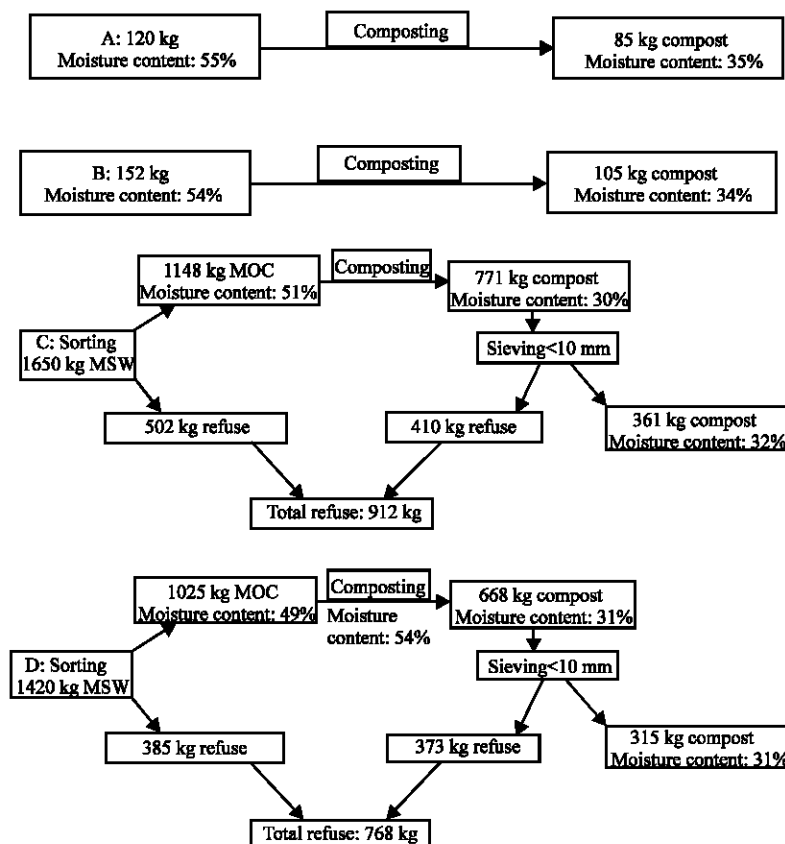


Fig. 3: Solid waste mass balance for the four compost samples. T_0 = natural soil with no application, T_1 = natural soil with chicken manure at a dose of 20 t ha^{-1} , T_2 = natural soil with inorganic fertilizer (N15P15K15), T_3 = natural soil with inorganic fertilizer (N30P30K30) and T_4 = natural soil with inorganic fertilizer (N60P45K45), A, B, C = natural soil with composts A, B, C at a dose of 20 t ha^{-1}

Table 4: Chemical composition and pH of dry matter of 4 composts A, B, C, D in comparison with others MSW composts in equatorial areas

Parameters	Compost				*	**
	A	B	C	D		
pH (u.pH)	9.3	8.7	9.3	9.4	7.5	7.8
N (%)	0.8	0.9	0.8	0.7	1.6	1.0/2.0
OM (%)	32.0	31.0	34.0	30.0	-	35.0/40
C (%)	19.0	18.0	20.0	16.0	36.8	20.3/23.2
C/N	24.0	20.0	25.0	20.0	23.0	11.6/20.3
P (mg $\text{P}_2\text{O}_5 \text{ g}^{-1}$)	13.6	44.7	8.0	11.8	14.0	9.4/91.5
Na (mg $\text{Na}_2\text{O g}^{-1}$)	7.5	4.0	9.4	nd	-	-
K (mg $\text{K}_2\text{O g}^{-1}$)	17.3	19.8	15.1	nd	26.5	6.0/31.3
Mg (mg MgO g^{-1})	2.8	3.1	4.2	3.2	-	-
Ca (mg CaO g^{-1})	16.2	38.5	35.1	36.7	-	-

*Lin. (2008), **Waste Concern (2001), nd = Not determined

phosphate, Na_2O , MgO , K_2O or CaO (Table 4) which is an advantage for the use in agriculture. The content of organic matter, which was approximately 30%, would be very helpful for water retention in amended soils.

Heavy metal (Pb, Ni, Cd) concentrations were measured in all four compost samples and compared to standard values for composts (Table 5). It can be observed that the lead contents are above the standards fixed by the French Norm NFT 44051. It is troubling that lead in these concentrations was found in these composts. The heavy metal content in food products is low, especially for those heavy metals that are not essential to plant nutrients, such as Pb and Cd. The heavy metal content in the organic fraction most probably originates from the layer of humus that is found in the topsoil in the household gardens (Veeken and Bert, 2002; Nilsson, 1972; Coughtrey *et al.*, 1979). The organic fraction contains 11% of metals on dry weight of household waste with a concentration going to 154 mg kg^{-1} of Pb.

Germination test: The mean values of ten replicate germination tests were calculated for each of the four, composts for three different plants (Table 6). The results of the germination tests indicate the maturity of the composts and the lack of any compounds that would be toxic to the plants or interfere with seed germination.

A Germination Index (GI) of 50% has been used as indicator of phytotoxin-free composts (Zucconi *et al.*, 1981). For the four composts and the three plants tested, the GI varied from 75 to 87%. The lowest GI occurred for compost B, which was the household waste sample amended with chicken manure. The relatively high observed GI values indicate a very low content of the toxic substances such as the acetic acid. The acetic acid can completely inhibit the germination of cress seeds starting from a concentration of 300 mg kg^{-1} (De Vleeschauwer *et al.*, 1981). The reduction of the germination of seeds by the acetic acid was reported for cress and corn (Keeling *et al.*, 1994). The high observed GI values for these composts indicate that the composts produced are stable and mature.

Agricultural value of the compost: The produced compost brought a significant improvement to the growth of carrot tubers (Fig. 4). For instance, the field test without fertilizer produced 1500 kg ha^{-1} of carrot tubers, while composts A, B, C had carrot productions of 2699, 2998 and

Table 5: Concentration of some metallic pollutants in the different composts

Elements (mg kg^{-1})	Compost				Limited values*
	A	B	C	D	
Pb	460	380	480	290	180
Ni	40	14	20	18	60
Cd	1	1	2	2	3

*AFNOR 2005

Table 6: Mean values of germination index, GI

	GI% of compost			
	A	B	C	D
Seeds				
<i>Zea mays</i> (corn)	76	78	81	87
<i>Virgna unguiculata</i> (bean)	86	77	78	80
<i>Lepidium sativum</i> L. (cress)	79	75	86	82

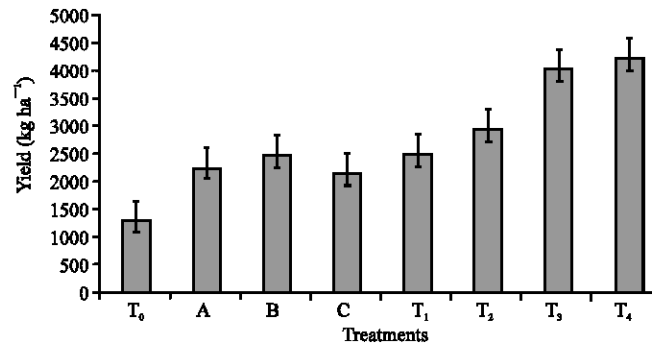


Fig. 4: Yield of carrot tubers

Table 7: Labor cost estimates for compost production

Employee designation	Number of employees	Monthly salary per person (FCFA)	Annual income per person (FCFA)	Total cost (FCFA)	Total cost (Euros)
Composting	4	30,000	360,000	1,440,000	2,198
Team leader	1	40,000	480,000	480,000	723
Extension agent	1	20,000	240,000	240,000	366
Host	1	20,000	240,000	240,000	366
Accountant (quarter-time)	1	20,000	240,000	240,000	366
Guardian	1	30,000	360,000	360,000	550
Other costs	-	-	-	50,000	76
Total	-	-	-	3,050,000	3,656

2685 kg ha⁻¹, respectively. No statistically significant difference was found between carrot tuber productions for fields treated with compost as compared with the field treated with chicken manure (Fig. 4). Fields treated with artificial fertilizer (treatments T2, T3 and T4, Fig. 4) produced higher carrot tuber production.

Compost market and its selling price : Studies conducted by Kessler (2004) and a market study showed that gardeners in Lomé and farmers in towns surrounding Lomé need fertilizer for their fields but find the cost of artificial fertilizers or natural fertilizers such as chicken manure to be too high. Given the agricultural value observed for compost, these farmers and gardeners represent a large potential market for the compost. To investigate whether compost could be produced profitably we assume that a 20 kg bag of compost could be sold for 700 CFA (1.1 euro) francs (the local currency abbreviated FCFA), which is approximately 40% less than the typical cost for 20 kg bag of chicken manure (1200 CFA (1.8 euro) francs per 20 kg bag). At this price for compost a ton of compost would fill 50 bags and produce a revenue of 35,000 FCFA/ton (53 euros/ton). We estimate the potential compost production rate and associated costs. Four composters working 6 h per day and 6 days per week can sort 52 tons of raw waste and produce 11 tons of compost per month. These 11 tons of compost would give a monthly revenue of 385,000 FCFA (588 euros). Assuming that production can occur year-round, this gives a yearly revenue for the sale of compost of 4,620,000 FCFA. Estimated labor costs (Table 7) for the composters and the associated support staff are 3,050,000 FCFA (4,656 euros) per year.

Based upon these cost and revenue estimates, four full-time composters with their support staff could produce an annual profit of 1,570,000 FCFA (2,397 euros) through the sale of compost. Other

possible revenues that might also result include the sale of recyclable materials, household participation in the collection, the grants of private vs. public, the environmental service to the community and potential carbon credits. On the other hand costs not considered in this analysis include maintenance of the site and facilities, purchase of consumables, expenses related to water and energy, wages and overhead management, taxation, marketing, sales, etc.) and costs investment, often involving the depreciation for depreciable property (site development, purchase of mobile equipment and transfer fees for feasibility studies and engineering). If these costs can be kept below 34% (1,570/4,620) of total costs, or if the additional revenues can offset some or all of these additional costs, then the compost could be produced profitably.

CONCLUSION

The physical characterization showed that a majority of wastes (70% on average) collected directly from the households was biodegradable. The composts produced using two different candidate collection and processing methods do not present risks, aside from lead concentrations which exceeded the French standard AFNOR for compost. The results of an agricultural study indicated a good opportunity for the composting of urban waste directly collected in the households in different districts of Lomé. Previous studies demonstrated that a demand exists for an economical fertilizer in the area surrounding Lomé. The compost had a benefit that was equivalent to an alternative fertilizer (chicken manure) and could be produced profitably at an assumed price that would be significantly less than the manure.

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