academicJournals

Vol. 12(22), pp. 3466-3471, 29 May, 2013
DOI: 10.5897/AJB12.2192
ISSN 1684-5315 ©2013 Academic Journals
http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Physicochemical characterization of organic matter during co-composting of shea-nut cake with goat manure

Sanonka Tchegueni[1]*, Moursalou Koriko[1], Edem Koledzi[1], Magnoudéwa B. Bodjona[1], Koffi A. Kili[1], Gado Tchangbedji[1], Gnon Baba[1] and Mohamed Hafidi[2]

[1]Laboratoire Gestion, Traitement et valorisation des Déchets (GTVD), Faculté des Sciences, Université de Lomé, B.P.1515 Lomé-Togo.
[2]Laboratoire Ecologie et Environnement (Unité associée au CNRST, URAC 32, Unité associée au CNERS), Faculté des Sciences Semlalia, Université Cadi Ayyad, B.P.2390 Marrakech-Maroc.

Accepted 29 May, 2013

Wastes constitute a source of pollution for the environment. By composting, the value of organic matter (OM) can be improved in agriculture. From this perspective, the aim of this our work was to study the biodegradation of shea-nut cake, which is a food industry waste. The shea-nut cake was composted with caprine manure for six months. Chemical parameters were followed during composting. The compost obtained had a pH of 6.5, an OM-loss of 52.1% and a C/N ratio of 9.2. Total lipid content was reduced by 84%. The parameters for humifying the organic matter C_{HA}/C_{FA} and E_4/E_6 were stabilized at 1.33 and 2.68, respectively. The sum of the three principal fertilizing elements ($N+P_2O_5+K_2O$) represents 7.4% of the compost dry weight. These chemical characteristics show that shea-nut cake can be successfully composted. Stable and mature compost obtained can contribute to the maintenance and increase of the organic matter stock of soils. It can also bring fertilizing elements to the plant.

Key words: Shea-nut cake, composting, organic matter, goat manure.

INTRODUCTION

Current techniques and farming methods (intensive cropping) contribute to the reduction of organic matter of soils, causing a decline in their fertility. Organic matter is important for soil fertility. It plays an essential role in various soil properties: holding water, buffering pH, binding ions with varying degrees of reversibility, complexing ions and structuring the soil. It is the combination of all these properties that finally determines the fertility of the soil. Moreover, adding organic matter in the form of compost residues to soil poor in organic matter can help stabilize its structure and limit the risks of erosion. Compost also enhances soil fertility owing to the presence of humic substances (Ait Baddi et al., 2003; Senesi et al., 1996), and adding humus to soils stimulates plant growth and improves yields. Chen et al. (1994) reported that adding humic substances and mineral elements simultaneously leads to much greater increases in yield than adding mineral elements alone. Organic matter contributes to recycling, storage and availability of the nutrient for the benefit of plants and also intervenes as a source of nutrient and energy for the micro-organisms and macrofauna of the soils (Ait Baddi et al., 2001; Sellami et al., 2008).

Composting is a technique that gives values to organic

*Corresponding author: E-mail: tchegsani@gmail.com.

Table 1. Initial characteristics of materials to be composted.

Parameter	Shea-nut cake	Caprine manure
Moisture (%)	13.67±1.21	20.00±1.00
OM (%)	90.50±2.30	75.50±1.90
TOC (%)	55.48±1.20	37.64±1.02
TKN (%)	2.76±0.16	2.35±0.12
C/N	20.10	16.00

OM, Organic matter; TOC, total organic carbon; TKN, total Kjeldahl nitrogen.

waste which can be recycled in the form of humus.

During composting, readily degradable organic matter is utilized by microorganisms. The final product of compost consists of transformed, but hard-to-degrade compounds, intermediate breakdown products and dead microorganism cell walls. In other words, composting transforms fermentable waste into organic matter, similar to the organic matter of the soil. The effects of compost in the soil are durable when its organic matter is highly humified (stable).

Unlike many types of oil-seed cake, shea-nut cake has a poor value as a fodder because it has saponin and theobromine (Atuahene et al., 1998). In Togo, the new industry of oilseeds (NIOTO) annually generates more than 7 500 tons of shea-nut cake. Part of these residues is incinerated with other wastes in a power station. Recycling the shea-nut cake by composting could be an advantageous alternative to incineration which generates toxic compounds like dioxanes (Prashant et al., 2008) and aromatic polycyclic hydrocarbons. Due to reduction of environmental problems caused by waste (water, soil and air pollution) is a major concern, our work aims to study the biodegradation of shea-nut cake and to encourage its use in agriculture. Shea-nut cake contains tanins (Chamkha et al., 2002), stable chemical structures which have a direct or indirect antimicrobial action (Roger et al., 1999). They can thus negatively influence the degradation of organic matter. In this study, we carried out composting with goat manure that facilitates degradation of organic matter and improves the fertilizing value. The process of transformation and stabilization of the organic matter was followed for six months, through the determination of chemical parameters.

MATERIALS AND METHODS

Composting process

A pile made by mixing 36 kg of shea-nut cake and 30 kg of caprine manure was composted for 180 days. During composting the moisture of the pile was maintained at about 70%. The pile was turned fortnightly to aerate and homogenize the mixture. The microbial activity was measured by monitoring the temperature of the pile. Temperature was monitored daily at the different places in the pile. The samples were taken by mixing five sub-samples from five sites of the pile, from the whole profile (from the top to the bottom of the pile). Samples were immediately frozen and kept for analysis. All analyses were performed on samples taken at the beginning, after 30, 90 and 180 days of composting. The main characteristics of the raw materials are reported in Table 1.

Chemical analyses

The pH was taken in a suspension of compost in water (1:5 w:v) after stirring the sample for 60 min using Crison pH 25 electrode pH-meter. The organic matter content was determined by ignition of samples (1 g) at 550°C for 6 h. Organic matter loss percent (OM-Loss) was calculated according to the following formula (Jouraiphy et al., 2005; Som et al., 2009):

$$\text{OM-Loss (\%)} = 100 - 100 \times A_i(100 - A_f)/A_f(100 - A_i)$$

Where, A_i and A_f are the initial and final ash contents.

Total organic carbon (TOC) was analyzed by dichromate oxidation and total nitrogen, by the method of Kjeldahl (Mathieu, 2003). Ammonium ion content was assessed by alkaline distillation and nitrate was also assessed by alkaline distillation after reduction by Dewarda alloying (Mathieu, 2003). The humification of the compost was evaluated by the ratio of humic acid carbon to fulvic acid carbon (C_{HA}/C_{FA}) and the E_4/E_6 ratio of the humic acids (Amir et al., 2003; Sellami et al., 2008) at various stages of composting. The humic substances were extracted by 0.1 M NaOH. The humic acids (HA) were separated from the fulvic acids (FA) by precipitation at pH=2 for 24 H at 4°C (Ait Baddi et al., 2001). The carbon of the humic substances of the extracts was determined by oxidation with bichromate and the ratio of C_{HA}/C_{FA} was then calculated (Jouraiphy et al., 2005).

The precipitated humic acids are washed with acidified water (pH=2) several times and then taken up again in 0.025 M bicarbonate solution (Zbytniewski and Buszewski, 2005). On the basis of the E_4/E_6 absorbance ratio, the degree of maturation (humification) may be determined. The humic acid E_4/E_6 absorbance ratio is determined by measuring its optical density at 465 nm and 665 nm. Absorbance at 460 to 480 nm is an indication of the presence of organic material at the beginning of humification (rich in oxygen and poor in carbon) and absorbance at 600 to 670 nm is indicative of strongly humified material (rich in carbon and poor in oxygen) with a high proportion of aromatic condensed groups (Zbytniewski and Buszewski, 2005). Total lipids were extracted by hexane with the Soxhlet according to NF V 03-905, and then quantified by weighing after evaporation in a Rotavapor. Statistical treatment (Tukey Test) is carried out using Assistat 7.6 Beta.

RESULTS

Composting is a microbiological and thermal phenolmenon. The increase in temperature of the composting bulk

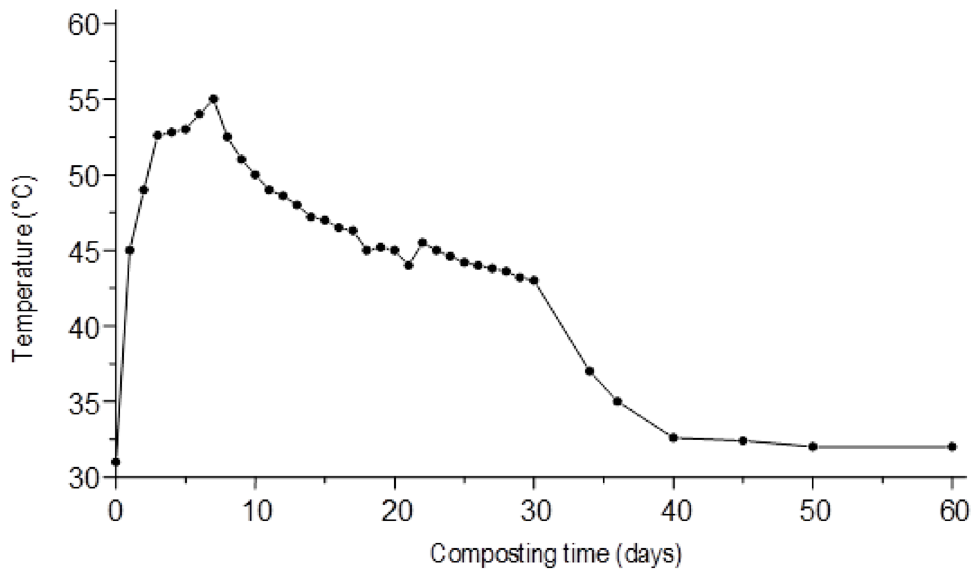

Figure 1. Temperature versus time of composting.

Table 2. Physicochemical characterization during the composting of shea-nut cake with caprine manure *(average compared to the dry mass).*

Parameter	Initial	30 days	90 days	180 days	SMD
Moisture (%)	70.65[a]	70.00[a]	69.27[a]	61.97[b]	4.57
pH	7.01[b]	7.36[a]	6.67[c]	6.52[c]	0.32
OM (%)	86.55[a]	80.00[b]	79.00[b]	75.50[b]	5.10
TOC (%)	47.75[a]	40.17[b]	39.96[b]	38.55[b]	3.31
OM-Loss (%)	0[c]	37.84[b]	49.54[a]	52.11[a]	4.50
TKN (%)	2.58[c]	3.83[b]	4.44[a]	4.20[a]	0.37
C/N	18.51	10.49	9.00	9.18	-
$N\text{-}NH_4^+$ (mg/g)	-	0.265[a]	0.197[b]	0.189[b]	0.031
$N\text{-}NO_3^-$ (mg/g)	-	0.015[c]	0.295[b]	0.847[a]	0.037
NH_4^+/NO_3^-	-	17.67	0.67	0.22	-

OM, Organic matter; TOC, total organic carbon; TKN, total Kjeldahl nitrogen; C/N, carbon-to-nitrogen ratio; SMD, = Significative minimum differenc. The Tukey Test at a level of 5% of probability was applied. The averages followed by the same letter, in the same line, do not differ statisticaly between themselves.

constitutes the most easily measurable parameter. It is due to the activity of micro-organisms, in which oxidezation of the organic matter of the substrates leads to the release of the energy of chemical bonds of the constitutive molecules (Mustin, 1989). Changes in temperature (Figure 1) indicate an intense phase of fermentation characterized by the rise of the temperature during the first week. This is the result of an intense microbiological activity and depends on the proportion in the mixture of easily biodegradable organic matter under aerobic conditions. Thereafter, the temperature decreases from 55 to 32°C and stabilizes after 40 days.

Changes of the pH, moisture, organic matter, organic carbon, total nitrogen, inorganic nitrogen, OM loss and total lipid (Figure 2) were also followed and reported in Table 2. During the process, the pH remained between 6 and 7. An increase of 0.35 pH unit was noted during the first month followed by a decrease until it stabilized around 6.52. Lipids are hydrophobic substances and most are polar. They tend to form films of molecules with specific orientations on the surface of soil aggregates. They improve the permeability of the soil but decrease its water holding capacity. The lipid content was 14.32 mg/g at the beginning of composting. Almost 70% reduction of lipid content was noted after one month and more than 84% after six months.

The maturity of the compost is also evaluated by humification parameters (Sellami et al., 2008). The C_{HA}/C_{FA}

Table 3. The agronomic value of composts of shea-nut cake and urban wastes from Togo.

Parameter	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)
Compost of shea-nut cake	4.2 ± 0.2	1.2 ± 0.1	2.0 ± 0.2	2.0 ± 0.3	0.5 ± 0.1
Composts of urban waste*	0.7 - 0.8	0.8 - 1.4	1.5 - 2.0	1.6 - 3.9	0.3 - 0.4

*Composts of urban waste of the town of Lome (Togo) (Koledzi et al., 2011).

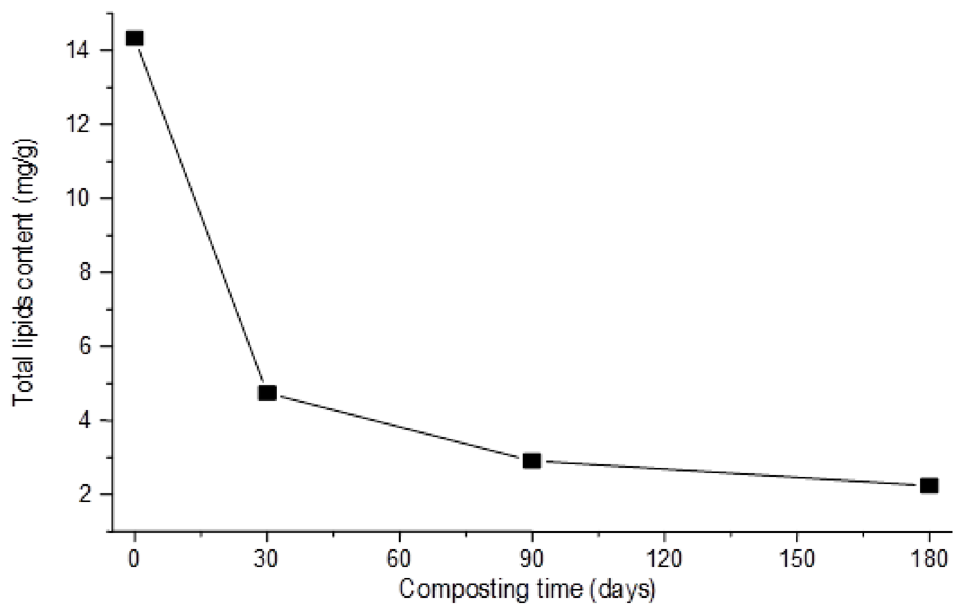

Figure 2. Total lipid content during the composting.

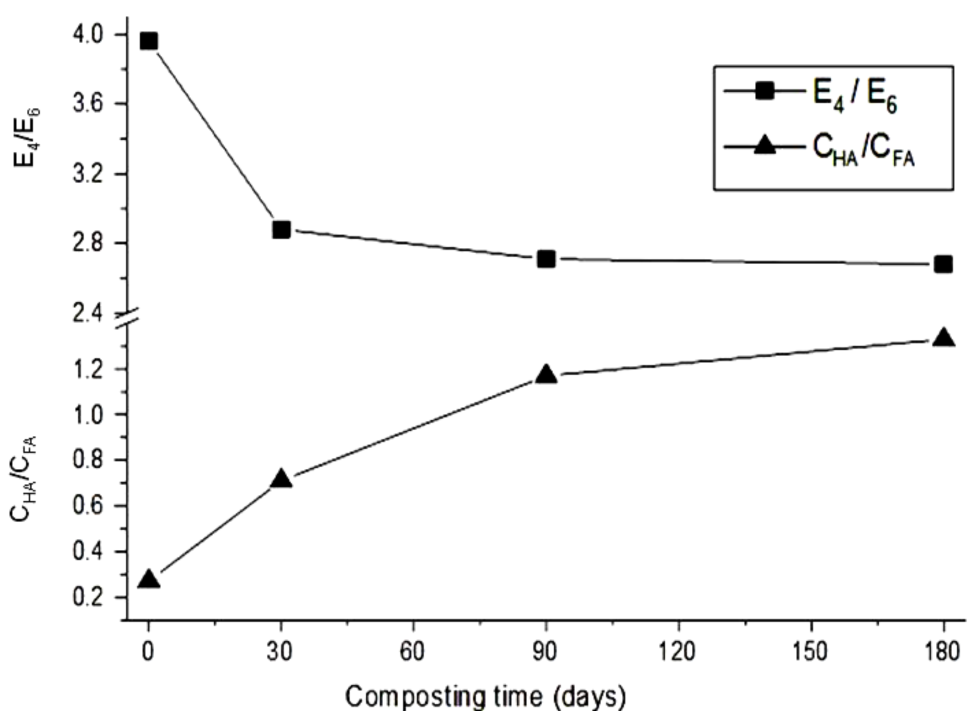

Figure 3. C_{HA}/C_{FA} ratio of humic substances and E_4/E_6 ratio of the humic acids during the composting.

ratio (humic acid carbon / fulvic acid carbon), that is, the degree of polymerization of humic substances is an extensively used indicator. The E_4/E_6 ratio of the humic acids (Amir et al., 2003; Sellami et al., 2008) extracted at various stages of composting was determined to have an idea of their molecular size. At the beginning of the composting process, the C_{HA}/C_{FA} ratio was 0.27 (Figure 3); after three months it rose to 1.17 and after six months, to 1.33. This shows that the fulvic acids, abundant in the first two months are gradually polymerized yielding humic acids during the process. C_{HA}/C_{FA} ratio, higher than 1, is a sign of maturity of the compost (Francou, 2003). E_4/E_6 ratio is given by measuring the absorbance at 465 nm (E_4) and 665 nm (E_6) of dilute humic solutions. The organic structures at the beginning of the humification (rich in oxygen and poor in carbon) absorb at 465 nm while those of higher size (rich in carbon and poor in oxygen) absorb at 665 nm. This E_4/E_6 ratio of the humic acids characterizes their molecular size. It is inversely proportional to molecular size and must be lower than five for humic acids (Amir et al., 2003; Sellami et al., 2008). The compost obtained was characterized by an organic matter level of 75.50% and can contribute to the maintenance or increase in the organic matter reserves of soil. The agronomic value of the compost (Table 3) shows that it can also contribute to the fertilization of the soil.

DISCUSSION

The variation in temperature recorded during the process (Figure 1) was typical of a two-phase composting process. The temperature rise results from intense microbial activities favoured by the high concentration of easily decomposable organic molecules. Temperature reduction signifies decrease of the microbiological activity due to scarcity of the biodegradable matter and stabilization of the temperature that characterizes the maturation phase. The maximum temperature recorded (55°C) is lower than values usually mentioned in the literature. Indeed the maximum temperature recorded by many authors is about 60 to 70°C (Ait Baddi et al., 2001). The low temperature is probably due to the small quantity of mixture composted in this work (66 kg). With a larger quantity (approximately 500 kg), temperatures of about 70°C would most likely occur and destroy the pathogenic micro-organisms.

Stabilization of the pH can be an indicator of stability of the organic matter. The pH variations recorded here are comparable with those recorded by Amir (2001) on sewage sludge composting and by Som (2009) during composting of green and bio-wastes. However, some authors found that acidification preceded alkalinisation (Bernal et al., 1998; Jouraiphy, 2007). In this work, the rise in pH at the beginning of composting can be attributed to the release of ammonia from the manure.

OM loss was higher during the first month of composting, owing to the greater activity of microorganisms that used a large quantity of easily available compounds. Later, the degradation of organic matter was restricted by the high lignin content of the composting substrate. According to Bernal (2009), labile organic compounds, such as simple carbohydrates, fats and amino acids, are degraded quickly in the first stage of composting; others, which are more resistant organic substrates such as cellulose, hemi- celluloses and lignin are partially degraded and trans-formed at a lower rate.

After six months of composting, the OM loss reached 52.11%. This is close to the levels found by Ait Baddi (2001) during the composting of olive mill waste. Indeed, during the composting of the mixture of olive pomace and wheat straw, the OM loss reached 49.60% after 6 months and 56.5% after 12 months (Ait Baddi et al., 2001). On the other hand, OM loss in this work is lower than OM loss reported during the composting of a sewage sludge and green plant waste mixture by Jouraiphy (2007). This author found that OM loss was 60% after only 135 days (less than five months) (Jouraiphy, 2007). The composting system and conditions, characteristics of the material used for composting and even the environmental conditions of the season (Parkinson et al., 2004) have a great influence on the mineralisation of the OM during composting.

The C/N ratio decreased from 18.51 to 10.49 after the first month. After six months this ratio was 9.18 (Table 2). The evolution of this ratio means the decrease of carbon (OM) and the conservation of nitrogen. This decrease, rapid during the first month, confirms the greater activity of microorganisms during the first month. The evolution of lipids shows a reduction during composting which reached 70% after the first month and 84% after six months. The changes occurring in lipid content during composting were similar to those of the C/N ratio. Consequently the stabilization of the total lipid content can be a characteristic of compost stability. At the beginning of the process E_4/E_6 was 3.96 (Figure 3) and after three months it stabilized at approximately 2.68. The decrease of the ratio shows the increase of molecular size of the humic acids during the composting, therefore the stability of the compost.

The variation of OM-loss, C/N ratio (Table 2) and total lipid content (Figure 2) shows that a phase of active degradation of organic matter takes place during the first month. After the first month, the stabilizing of these parameters means the stabilization of the organic matter of sheanut cake. This was confirmed by the nitrification index NH_4^+/NO_3^- which fell from 17.67 after the first month to 0.22 after six months of composting (Table 2). Thus the evolution of OM-loss, C/N ratio, NH_4^+/NO_3^- after 90 days (Table 2) shows the stability and maturity of the compost (Bernal et al., 1996; Bernal et al., 2009; Bernal et al., 1998; Mathur et al., 1993; Ouatmane et al., 2000; Wang et al., 2004). This stabilized organic matter added to the soil is an excellent amendment because it acts as slowrelease fertilizers for agricultural purposes.

The content of the three principal fertilizing elements ($N+P_2O_5+K_2O$) was 7.4%. Compared to urban waste composts in Togo (Koledzi et al., 2011), the shea-nut cake and caprine manure compost was the best and five times richer in nitrogen. The total nitrogen content at the end of composting was about 4.2% and that of mineral nitrogen ($N\text{-}NO_3^-$, $N\text{-}NH_4^+$) was approximately 2.5% of the total nitrogen content. The nitrogen of the compost is essentially in organic form. A progressive mineralization of the compost in the soil will release nitrogen to the plants, eliminating the risk of pollution by nitrates.

Conclusion

Our work aimed to use shea-nut cake as a soil amendment. It was composted with caprine manure. The physicochemical parameters (temperature, C/N, $N\text{-}NH_4^+/N\text{-}NO_3^-$, pH) and humification parameters (C_{HA}/C_{FA}, E_4/E_6) were used to follow maturation of the compost. After six months of composting, the total organic carbon was 38.55%; C/N ratio, 9.18; OM-loss, 52.11% and the ratio $N\text{-} NH_4^+/N\text{-} NO_3^-<1$. These parameters show that shea-nut cake organic matter can be recycled in agriculture by composting. The compost obtained can contribute to the maintenance and increase in the organic matter reserve of soils. It also constitutes a source of fertilizing elements for the plants since the sum of the three principal fertilizing elements ($N+P_2O_5+K_2O$) is 7.4%.

REFERENCES

Ait Baddi G, El Hadrami I, Hafidi M (2001). Traitement des déchets des huileries par un bio-procédé aérobie et production de substances humiques à haute valeur agronomique. Ann. Chim. Sci. Mat. 26:459-464.

Ait Baddi G, Hafidi M, Gilard V, Revel JC (2003). Characterization of humic acids produced during composting of olive mill wastes: elemental and spectroscopic analyses (FTIR and 13C NMR). Agronomie 23:661-666.

Amir S, Hafidi M, Bailly JR, Revel JC (2003). Characterization of humic acids extracted from sewage sludge during composting and their Sephadex gel fractions. Agronomie 23:269-275.

Atuahene CC, Donkoh A, Asante F (1998). Value of sheanut cake as a dietary ingredient for broiler chickens. Anim. Feed Sci. Tech. 72: 133-142.

Bernal MP, Alburquerque JA, Moral R (2009). Composting of animal manures and chemical criteria for compost maturity assessment, A review. Bioresource Technol.100:5444-5453.

Bernal MP, Paredes C, Sanchez MA, Cegarra J (1998). Maturity and stability parameters of composts prepared with a wide range of organic wastes. Bioresour. Technol. 63:91-99.

Bernal MP, Navarro AF, Roig A, Cegarra J, Garcia D (1996). Carbon and nitrogen transformation during composting of sweet sorghum bagasse. Biol. Fertil. Soils 22:141-148.

Chamkha M, Pastel KCB, Traore A, Garcia JL, Labat M (2002). Isolation from a shea cake digester of a tannin degrading *Streptococcus gallolyticus* strain that decarboxylates protocatechuic and hydroxycinnamic acids, and emendation of the species. Int. J. Syst. Evol. Micr. 52:939-944.

Chen L, Magen H, Riov H (1994). Humic substances originating from rapidly decomposing organic matter: properties and effects on plant growth. In: Senesi N, Miano, TM (Eds.), Science and Engineering of composting: Design, Environmental, Microbiology and Utilization Aspects. The Ohio State University. pp. 551-650.

Francou C (2003). Stabilisation de la matière organique au cours du compostage de déchets urbains : influence de la nature des déchets et des procédés de compostage-Recherche d'indicateurs pertinents. PhD thesis, Institut Nationale Agronomique Paris-Grignon, France.

Jouraiphy A (2007). Compostage des boues activées-déchets verts : analyses physicochimiques, microbiologiques, toxicologiques, bilan humique et valorisation agronomique. PhD thesis, Université Cadi Ayyad, Maroc.

Jouraiphy A, Amir S, El Gharous M, Revel JC, Hafidi M (2005). Chemical and spectroscopic analysis of organic matter transformation during composting of sewage sludge and green plant waste. Int. Biodeter. Biodegr. 56:101-108.

Koledzi KE, Baba G, Tchangbedji G, Agbeko K, Matejka G, Feuillade G, Bowen J, (2011). Experimental study of urban waste composting and evaluation of its agricultural valorization in Lomé (Togo). Asian J. Appl. Sci. 4(4):378-391.

Mathieu C (2003). Analyse chimique des sols, Méthodes choisies, TEC and DOC.

Mathur SP, Owen G, Dinel H, Schnitzer M (1993). Determination of compost biomaturity. Literature review. Biol. Agric. Hortic. 10:65-85.

Ouatmane A, Provenzano MR, Hafidi M, Senesi N (2000). Compost maturity assessment using calorimetry, spectroscopy and chemical analysis. Compost Sci. Util. 8 (2):124-134.

Parkinson R, Gibbs P, Burchett S, Misselbrook T (2004). Effect of turning regime and seasonal weather conditions on nitrogen and phosphorus losses during aerobic composting of cattle manure. Bioresour. Technol. 91:171-178.

Prashant SK, João GC, Carlos AMA (2008). Dioxins sources and current remediation technologies- A review. Environ. Inter. 34:139-153.

Roger P, Alazard D, Gaime-Perraud I, Garcia J-L, Labat M, Roussos S (1999). Les recherches à l'IRD sur la dépollution et la valorisation de déchets agricoles et agro-industriels, Conference, Salon International de l'Agriculture. 1-6 Mars.

Sellami F, Hachicha S, Chtourou M, Medhioub K, Ammar E (2008). Maturity assessment of composted olive mill wastes using UV spectra and humification parameters. Bioresource Technol. 99: 6900-6907.

Senesi N, Miano TM, Brunetti G (1996). Humic-like substances in organic amendments and effects on native soil humic substances. In: Piccolo A (Ed.). Humic Substances in Terrestrial Ecosystems. pp. 531-593.

Som MP, Lemée L, Amblès A (2009). Stability and maturity of a green waste and biowaste compost assessed on the basis of a molecular study using spectroscopy, thermal analysis, thermodesorption and thermochemolysis. Bioresource Technol.100: 4404-4416.

Wang P, Changa CM, Watson ME, Dick WA, Chen Y, Hoitink HAJ 2004). Maturity indices for composted dairy and pig manures. (Soil Biol. Biochem. 36:767-776.

Zbytniewski R, Buszewski B (2005). Characterization of natural organic matter (NOM) derived from sewage sludge compost. Part 1: chemical and spectroscopic properties. Bioresour. Technol. 96: 471-478.