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Improvement of the agronomic value of faecal sludge by co-composting with *Typha domingensis* leaves in Cambérène wastewater treatment plant (Dakar/Senegal)

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ABSTRACT

Objectives: The aims to monitor the agronomic and sanitary stability of mixtures of faecal sludge and *Typha domingensis* (Cattailbiomass).

Methodology and Results: Four treatments (T) of different mixtures by volume of faecal sludge and *Typha domingensis* leaves were tested with 3 replicates for each. Analyses of physico-chemical, microbiological and parasitic parameters were carried out in order to evaluate the maturity, the agronomic value and the content of faecal coliforms and helminth eggs. Results show that temperatures vary between 36 and 48 °C in the thermophilic phase. The pH is about 7 in all windrows and the conductivity and humidity vary between 1500 and 1800 µs/cm and, 34 and 64% respectively. C/N ratios are below 12. Nitrogen contents vary between 17 kg/t and 14 kg/t, phosphorus from 2.5 to 2.7 kg/t and potassium from 0.79 to 1.45 kg/t. Composting eliminated a large part of the faecal coliforms (FC). However, only the T0 met the WHO standards for FC ($2.5x10^2$ CFU/g of compost). With regard to helminth eggs, only T0 and T1 comply with the WHO recommendation.

Conclusions and application of findings: The composts obtained are agronomically mature even if they have to be kept a little longer (for at least 6 months) in dry conditions to completely eliminate biological pollutants. They have a significant agronomic value that allows them to be used as fertilizer or organic amendment.

Key words: agronomic value, co-composting, compost maturity, faecal sludge, hygienic quality, *Typha domingensis*.

INTRODUCTION

Agriculture remains an essential sector of the Senegalese economy. It employs 60% of the population but contributes only to 7.5% of GDP (USAID, 2011). Because of its importance, Senegal has taken the option, through the *Loi d'Orientation Agro Sylvo Pastorale* (Agro Sylvo Pastoral Orientation Law), to make agriculture as driving force of economic growth. For this to happen, the development of the sector must be accompanied by adequate resources to match the stated ambitions (equipment, rural infrastructures, fertilisers, phytosanitary products, certified seeds financing.) in order to boost and optimise production. The State of Senegal has translated this political will into several programmes such as the *Programme de Relance et d'Accélération de la Cadence de l'Agriculture au Sénégal* (PRACAS) (Agricultural Reactivation and Acceleration Program in Senegal), the *Grande Offensive Agricole pour la Nourriture et l'Abondance* (GOANA) (Great Agricultural Offensive for Food and Abundance). These programmes are planned to achieve, among other things, the objectives of food self-sufficiency, an increase in the area farmed and the increased use of inputs (CNCR, 2009). The USAID report (2011) estimated that Senegalese farmers used about 49,612 tons of chemical fertiliser between 2002 and 2008, which is too low compared to other countries such as Malawi (229,307 tons), Zambia (187,044 tons), Mali (175,052 tons), Cameroon (112,396 tons), Burkina Faso (100,115 tons) and Ghana (87,770 tons) cited in the report. As a response of these weaknesses, the State of Senegal has implemented a new policy in order to increase utilisation levels to 52,500 tons per year. Paradoxically, the transfer price of chemical fertilisers has increased over the years. Between 2003 and 2011, the price rose from 0.24 to 0.66 USD/kg (USAID, 2011); i.e. an increase of more than 100%. The high cost of agricultural inputs can limit their use by most rural households, which are often among the poorest in the population. Given the high cost of chemical fertilisers, the use of organic fertilisers is an urgent alternative that could enable farmers to increase their yields. The use of organic matter to improve agricultural production is tantamount to giving agriculture a new function and integrating the environmental issue into the farming profession (CIRAD, 2006). It can mitigate the decrease in organic matter and thus the impoverishment of cultivated soils, which, according to Bresson *et al.* (2001), can be due to the excessive use of soluble mineral fertilisers. The primary interest of organic amendments is therefore a reduction in the proportion of these leachable fertilisers and their replacement by recovered organic waste (Albrecht, 2007).Organic matter is used either as an amendment to provide humus to the soil in order to improve its properties (physical, chemical and biological), or as a fertiliser to provide plant nutrients, or both (mixed agronomic profile product) (Wong *et al.*, 1999). It improves the physical properties of the soil by increasing water conductivity and decreasing soil density (Wong *et al.*, 1999), improves soil porosity and structure (Pagliai *et al.*, 2004), reduces soil surface degradation (Bresson *et al.*, 2001), and reduces soil acidity, thus decreasing the risk of metal export to the plant (Bolan *et al.*, 2003). In addition, stable organic matter amendments increase the buffering capacity and exchange capacity of soils, two parameters that influence the mineral nutrition of plants (Mustin, 1987).However, the use of organic substances of animal or plant origin can be dangerous in some cases. The use of compost can be a source of disenchantment because the carbon input, which is too stabilised by the composting process, not only does not increase the intensity of microbial activity, but can also create a nitrogen deficiency, which can have adverse effects on plants (Jiménez & García, 1989). The negative effects of using humus are most noticeable when it is immature or unstable. Indeed, according to Jiménez & García (1989), the rapid decomposition of immature compost can cause a decrease in the oxygen concentration and redox potential of the soil and, as a consequence, the creation of a strongly reducing anaerobic environment in the root system. This causes an increase in the solubility of heavy metals in the soil and an inhibition of plant germination through the production of phytotoxic substances, mainly ammonia, ethylene oxide and organic acids (Jiménez and García, 1989). Furthermore, unstable organic matter such as sewage sludge or faecal sludge can pose health risks to consumers, farmers, and people living near facilities where this type of humus is used. In fact, sludge contains several pathogens such as bacteria, viruses and parasites (Capizzi-Banas *et al.*, 2004). Faecal sludge has low carbon content, which results in very low C/N ratios which is not favourable to a good composting process. Moreover, it is very liquid to be composted alone. Therefore, co-composting with a bulking agent becomes crucial to correct the carbon deficiencies but also to counteract the high moisture content. As a bulking agent, plant organic matters are often indicated. This study aims to monitor the composting process of a mixture of faecal sludge and *Typha domingensis* biomass at different association doses.

MATERIALS AND METHODS

Description of the materials used: The faecal sludge used came from the unplanted drying beds of the faecal sludge treatment plant (FSTP) of Cambérène. It is from on-site sanitation systems such as septic tanks. The sludge is deposited at the FSTP by the emptying trucks. After unloading, it remains for a week in the settling/thickening tanks. After a week of settling, the thickened sludge is pumped to unplanted drying beds where it is dried for two weeks before being collected for composting (Lo *et al.,* 2019). This dried sludge has solid content of about 40 to 70%. *Typha domingensis* is an aquatic herbaceous, rhizomatous plant that can reach 2.5 metres in height (Diarra, 2012). In this study, Typha leaves were collected in the wetland surrounding the Cambérène wastewater treatment plant. They were then cut and left to dry for 5 days. This drying time corresponds to the minimum time required to have a constant weight (GTZ, 2006).

Experimental set-up: Windrow composting is adopted and several doses are tested in this study. A total of 04 treatments are tested with 03 replicates for each treatment; making a total of 12 piles. The treatments consisted of a mixture of faecal sludge (FS), and *Typha domingensis* (Td) leaves at different doses. The 04 treatments are as follows:

- To: FS only;
- T1: 2 volumes of FS and 1 volume of Td leaves;
- T2: 1 volume of FS and 1 volume of Td leaves;
- T3: 1 volume of FS and 2 volumes of Td leaves

Each windrow had a volume of 0.31 m^3. The duration of the composting process was three months. In order to ensure optimal degradation and aeration, the windrows were turned every 21 days. In addition, the windrows were watered every 7 days in order to maintain the humidity in proportions compatible with the biological activity. This level of humidity is about 40 to 60% according to Fourti (2013). During the experiment, ambient temperatures varied between 21 and 32°C.

Monitoring of the composting process and compost quality

Sampling and sample preparation: Samples are taken from three different points in each pile at the periphery and the centre of the windrow. They are then mixed to form a composite. A total of 12 samples are collected. To monitor moisture and organic matter, samples are collected every 21 days before each turning. For the other parameters, samples are taken at the end of the 120-day composting process. The collected samples are dried at room temperature for one week in the laboratory, which is a ventilated area, free of humidity and protected from sunlight. After drying, the samples are sieved with a 2 mm mesh sieve. A second sieving is carried out with a 0.2 mm sieve for the samples used for carbon and nitrogen analysis. The parameters monitored are: pH, electrical conductivity (EC), C/N ratio, humic acids (HA), fulvic acids (FA), HA/FA ratio, organic matter (OM), nitrogen (N), phosphorus (P), potassium (K), calcium oxides (CaO) and magnesium oxides (MgO).

Determination of physico-chemical parameters: The temperature was measured with a BMG compost thermometer with a range of 0-80°C. Measurements were taken every day, starting the day after the windrows were made. Moisture was determined through dry matter content by oven drying at 105 °C to a constant weight. On the same sample, the organic matter content was determined via loss on ignition by burning it in an oven at 550 °C for 3 hours (APHA, 2005).

pH and conductivity were measured directly with a Crison GLP 21 pH meter fitted with a glass electrode in solutions obtained by suspending the compost in distilled water. For the pH measurement, 20 g of compost was diluted in 50 mL of distilled water (i.e. a 1:2.5 suspension) and for conductivity; the 20 g of compost was diluted in 200 mL of distilled water (i.e. a 1:10 suspension). Ca^{2+}, Mg^{2+} ions were analysed by complexiometry while Na^{+} and K^{+} were analysed by photometry. The C/N ratio was calculated from the results of separate analyses of carbon and nitrogen. Carbon was analysed using the modified Walkley and Black method and nitrogen was analysed using the Kjeldahl method. Phosphorus was determined by the colorimetric determination method (Milin, 2012). Humic acids (HA) and fulvic acids (FA) were analysed after fractionation according to the International Humic Substances Society (IHSS) method.

Determination of microbiological and parasitological parameters: The analysis of faecal coliforms was carried out using the agar enumeration method developed by AFNOR. Ascaris eggs were determined using the method developed by the Water Research Commission (Moodley *et al.*, 2008).

Data processing: The data collected were processed in Microsoft Excel 2010. The figures were produced using SigmaPlot 12.0 software.

RESULTS

Variations of physical parameters during the composting process

Temperature: Figure 1 below summarises the variation in temperature during composting. These are the average temperatures calculated from the three replicates of each treatment.

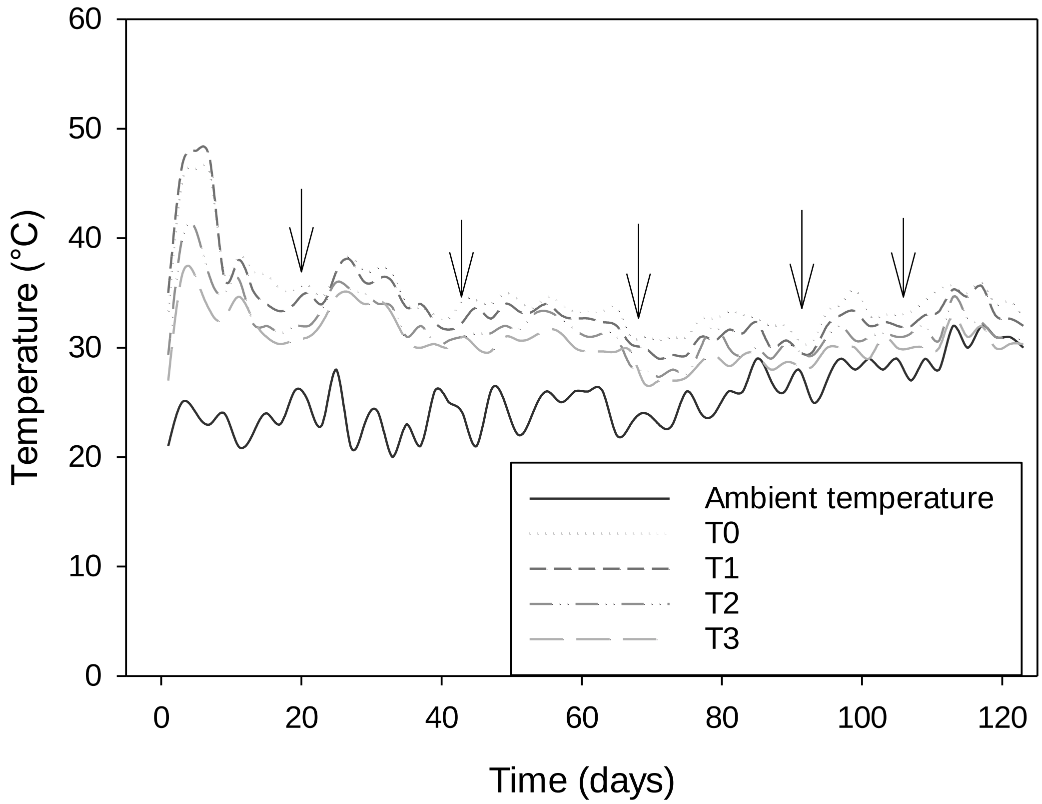

Figure 1: Temperature variations during composting
↓ **:** turning period; To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

Figure 1 shows a progressive increase in temperature from the first four days. Temperatures increased from 33° to 45°C for T0, 35° to 46°C for T1, 29° to 40°C for T2 and from 27° to 36°C for T3. This stage corresponds to the mesophilic phase. After this phase, temperatures increase rapidly from day 4 to day 8, corresponding to the maximum temperatures reached for all treatments. During this thermophilic phase, the average maximum temperatures reached were 46°C for T0, 48°C for T1, 40°C for T2 and 36°C for T3.

Moisture: Figure 2 below shows the evolution of the average moisture content of the different treatments during composting.

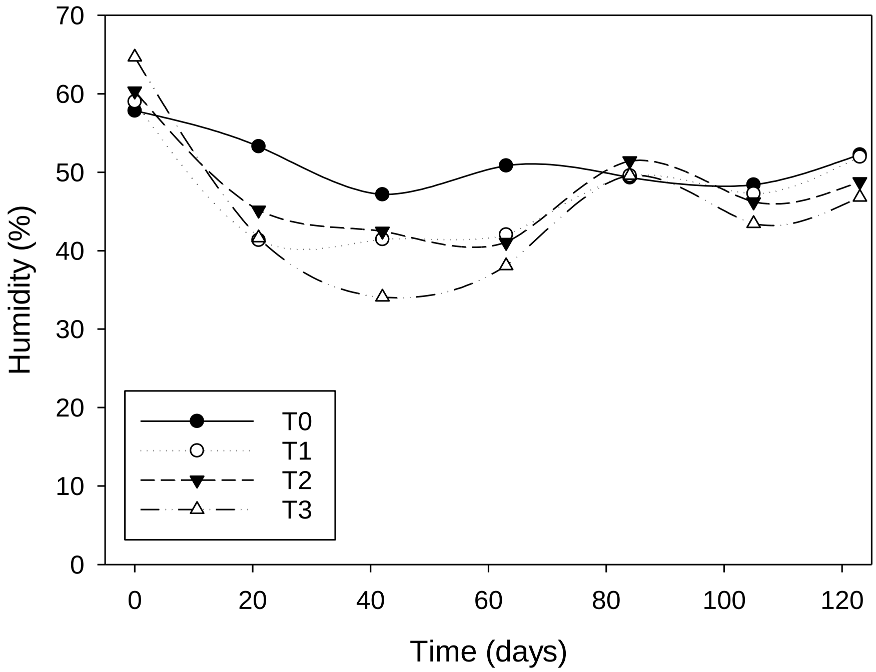

Figure 2: Moisture development during composting
To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

Figure 2 shows that moisture content varied between 34 and 64% for all treatments.

Organic matter: The average evolution of organic matter during the composting process is shown in figure 3.

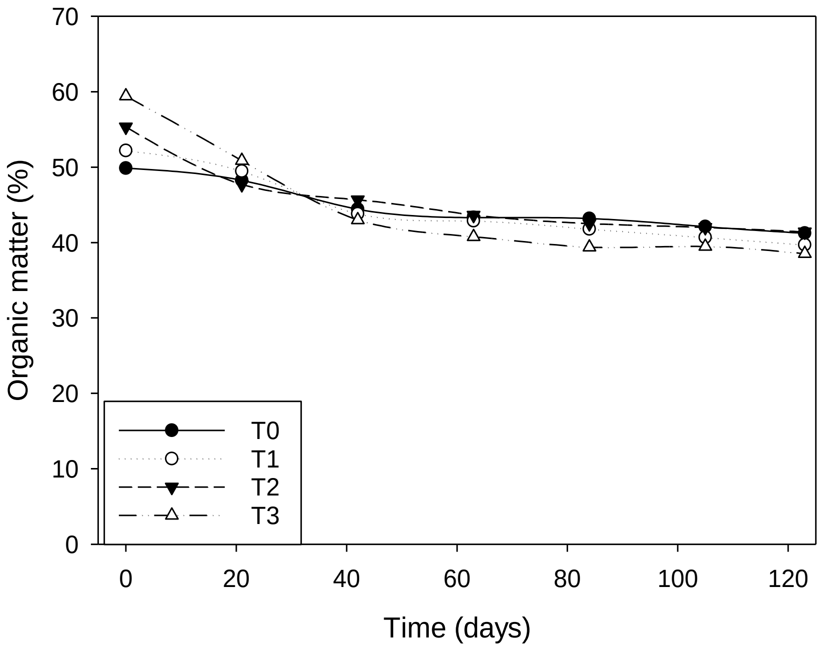

Figure 3: Dynamics of organic matter evolution
To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

Figure 3 shows a decrease in organic matter during composting for all composting rates. The organic matter content decreased from 50-60% to 38-42%.

Agronomic quality of composts: The agronomic value of a compost varies according to the nature of the material used at the beginning of the composting process. The product obtained generally has different characteristics depending on whether urban waste or green waste is composted. The average characteristics of the composts obtained in this study are reported in Table 1.

Table 1: Agronomic characteristics of composts at the end of composting

Parameters	T0	T1	T2	T3	(Ba *et al.*, 2009)	(OMS, 1993)
Physico-chemicals						
pH	6.88	6.86	6.81	6.87	7.5	6-9
CE (µS/cm)	1569.33	1863.67	1688.00	1595.33	…	….
Stability						
C/N	10	11	10	10	24	10-15
HA/FA	0.11	0.14	0.24	0.15	…	…
AH	0.1	0.1	0.1	0.10		
AF	0.72	0.68	0.68	0.74		
MO	41.23	39.7	41.41	38.53	20	20-40
Nutrients						
N (kg/t)	17	17	16	14	4.12	1-18
P (kg/t)	2.5	2.50	2.50	2.70	1.9	1-17
K (kg/t)	0.70	1.20	1.29	1.40	2.8	1-23
CaO (kg/t)	16.29	16.45	15.01	13.41	…	…
MgO (kg/t)	2.13	1.82	2.14	1.97	…	…

To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

The table shows the different treatments compared with a Typha compost (Ba *et al.*, 2009) and the WHO standard (OMS, 1993). In this study, Table 2 shows that the concentrations of Na^+ and Cl^+ are quite low compared to the other major ions. The ion balance shows a predominance of calcium (Ca^{2+}) and sulphate (SO_4^{2-}).

Table 2: Ion balance of the compost

Parameters	Units	T0	T1	T2	T3
Ca^{2+}	meq/100 g	21.03	22.00	20.90	17.93
Mg^{2+}	meq/100 g	4.80	5.10	4.33	4.10
Na^+	meq/100 g	0.35	0.41	0.38	0.36
K^+	meq/100 g	1.23	2.03	2.16	2.46
CO_3^-	meq/100 g	0.00	0.00	0.00	0.00
HCO_3^-	meq/100 g	1.08	1.50	1.33	1.25
Cl^-	meq/100 g	11.67	11.33	13.67	13.00
SO_4^{2-}	meq/100 g	12.77	16.70	15.76	8.54

To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

The compost produced can be considered unsalted and can be used to amend and fertilise the soil.

Hygiene and health aspects of compost

Faecal coliforms (FC): FC are indicators of microbiological pollution. They are not pathogenic. However, their abundance indicates the possible presence of pathogens. Table 3 shows the faecal coliform content in biosolids from the different windrows.

Table 3: Faecal coliform concentrations before and after composting

		Before composting	End of composting				WHO standards (2012)
			T0	T1	T2	T3	
CF (UFC/g)		$5.8x10^4$	$2.5x10^2$	$1x10^3$	$6.2x10^3$	$2.7x10^3$	$<10^3$ (*E. coli)*

To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

Table 2 shows that the concentrations FC are in the range of 10^2 to 10^3. Only T0 has concentrations in accordance with the WHO standards.

Ascaris eggs: The concentration of Ascaris eggs in the composts at the end of the composting period is shown in Table 4.

Table 4: Helminth concentrations in the different composts

Samples	Number of Ascaris eggs/g of compost		
	Living	Inactive	Total
T0	06	4.7	5.4
T1	0.8	3.9	4.7
T2	1.3	5.8	7.1
T3	1	1.7	2.7

To: FS only; T1: 2 volumes of FS and 1 volume of Td leaves; T2: 1 volume of FS and 1 volume of Td leaves; T3: 1 volume of FS and 2 volumes of Td leaves

The concentrations of viable Ascaris eggs are within the WHO guidelines in T0 and T1. However, in T2 and T3 these concentrations are higher than the WHO guidelines.

DISCUSSION

Temperature variations: Figure 1 shows that the temperature increases in the windrows. This increase is due to a high activity of thermophilic micro-organisms. Temperatures are higher in the windrows with the lowest dose of Typha leaves (T1) and in the windrow (T0) that has no Typha leaves. The low temperatures measured in the treatments containing half or most of the Typha leaves (T2 and T3) may be due to the fact that these windrows are very porous because of the bulking agent particle size (Typha leaves) or to the high quantity of the bulking agent added. Indeed, Komilis *et al.* (2011) stated that less than 30% of the bulking agent must be supplied to achieve high thermophilic temperatures. The temperatures recorded in this study during the thermophilic phase are lower than those found in the literature in the order of 60 °C (Albrecht, 2007; Cofie *et al.*, 2009; Temgoua *et al.*, 2014). The low temperatures recorded in this study may be related to the small size of the windrows (0.31 m^3). However, according to Temgoua *et al.* (2014), windrows should be 5 to 6 tons in size for the temperature to reach 65 to 70 °C after one week of composting. After the thermophilic phase, the temperature in the windrows gradually decreased to the level of the ambient temperature. This phase of compost cooling has been described by several authors (Alburquerque *et al.*, 2005; Albrecht, 2007). However, the temperature drop during this phase is not uniform. Indeed, more or less significant temperature increases have been recorded after each turning. This may be related to the fact that, according to Cofie *et al.* (2009), periodic turning allows to bring back the external organic matter, not yet decomposed, inside the windrow and, increases the oxygen supply for microbial activity. The weekly supply of moisture also helps to maintain the activity of the microorganisms.

Moisture variations: The moisture contents are comparable to those described by several authors as compatible with good composting. According to Albrecht (2007) who composted sewage sludge with green waste, the optimal moisture content should be between 10 and 53%. Gobat *et al.* (2010) recommend that the humidity in the windrow should be maintained between 45 and 65%, while the WHO (1993) suggests values between 30 and 50%. This shows that this composting experience took place under optimal moisture conditions, as all windrows had a moisture content between 34 and 64% (Figure 2).

Variation in organic matter: The amount of organic matter (OM) decreased progressively during composting in all windrows (Figure 3). Such variations in organic matter have been reported by several authors. In the study of Albrecht (2007), the organic matter rate decreased from 60 to 47% while in Temgoua *et al.* (2014) the OM concentration decreased from 46.52 to 23.5%. The decrease in OM is related to the use by micro-organisms of organic substances essential for their metabolism (Francou, 2003). Among these substances, carbon is considered as a food source and nitrogen as a digestive enzyme (Fourti, 2013). Indeed, during composting OM is subjected to different biological and physico-chemical transformation processes such as mineralisation, immobilisation of the mineral fraction, nitrification, denitrification or volatilisation of ammoniacal nitrogen (Alburquerque *et al.*, 2005). During mineralisation, carbon is transformed into CO_2 and hydrogen into H_2O. The loss of these elements leads to a progressive decrease in organic matter (Francou, 2003). However, compared to the different treatments, no significant difference was found.

Agronomic quality of the composts: At the end of composting, the four treatments have neutral pH values similar to those defined in the literature. They are therefore within the range of about 6 to 9 recommended by WHO (1993) and by Gobat *et al.* (2010) between 7-8 for mature composts. The conductivity values range from 1569 to 1863 µS/cm. Similar conductivity levels were found by Cofie *et al.* (2009). These authors found conductivities of 1400 to 1900 µs/cm in faecal sludge composted with organic solid waste. The slightly elevated conductivity levels found in this study may be due, according to Cofie *et al.* (2009), to the dissolution of sodium chloride, which is not beneficial to plants. This is particularly important for the application of compost in agriculture as high soil salinity can inhibit germination and plant growth. However, it should be noted, from the work of Cofie *et al.* (2009), that the increase in conductivity can also be explained by the decomposition of organic matter, leading to the production of nitrates. Indeed, Sánchez-Monedero *et al.* (2004) found highly significant correlations between nitrate concentrations and electrical conductivity values in different composting mixtures. The C/N ratio of all treatments is between 10 and 15. This shows that regardless of the combination rate, all composts are mature because, according to WHO (1993), the values of the C/N ratios required for mature compost are between 10 and 15. All composts have C/N ratios below 12 as stated Biekre *et al.* (2018)

for mature compost. From Bernal *et al.* (2009) who reviewed several types of composts, the C/N value of a mature compost should be below 12. The maturity of composts is also validated by the stabilisation of the organic matter during the composting process. Indeed, the organic matter decreased slightly from between 50 and 60% to between 40 and 45%. These levels of organic matter are all within the range of between 25-45% established by M'sadak *et al.* (2012) for mature composts. However, these concentrations are better than those found by Ba *et al.* (2009) of about 20% in a compost made only with Typha leaves. The HA/FA ratio is below the limit value (> 2.5) defined by Bernal *et al.* (2009). However, the FA concentrations of all composts are all within the limit value (≤ 12.5 g/kg) defined by Bernal *et al.* (2009). Nitrogen concentrations are about 17, 17, 16 and 14 kg/t for T0, T1, T2 and T3 respectively. These values are higher than those of the compost made by Typha leaves only (Ba *et al.*, 2009), which has a nitrogen content of 4 kg/t. However, the four treatments meet the criteria defined by Gobat *et al.* (2010) which is between 5 and 18kg/t. Total phosphorus levels that vary between 2.5 and 2.7 kg /t in all treatments are also quite high. They are higher than the results found by Ba *et al.* (2009) on compost made from Typha leaves only (Table 1). However, these phosphorus concentrations are in agreement with the guideline values of between 1 and 17 kg/t for mature composts established by WHO (1993). Potassium concentrations are in the order of 0.78, 1.22, 1.29 and 1.45 kg/t for T0, T1, T2 and T3 respectively. These potassium levels are slightly lower than those found by Ba *et al.* (2009) of around 2.8 kg/t in Typha leaf composts. However, the potassium concentrations in the different windrows are comparable with the values of between 1 and 23 kg/t defined by WHO (1993) for mature composts. The composts have high nutrient contents. Indeed, magnesium concentrations are in the order of 2.1, 1.8, 2.1 and 1.9 kg/t and calcium concentrations of 16.29, 16.45, 15.01 and 13 kg/t for T0, T1, T2 and T3 respectively. Similar nutrient concentrations were found by Lô *et al.* (2019) in composts made of faecal sludge and vegetable waste or fish waste.

Sanitary quality

Faecal coliforms: Table 3 shows that in the different treatments, the faecal coliform concentrations are higher than the WHO recommendations in the different windrows, except for treatment T0 where the concentration is about $2.5x10^2$ CFU/g. In T1, the CF concentration of about 1000 CFU/g of compost is slightly higher than the WHO standard (< 1000 CFU/g). In windrows T2 and T3, CF concentrations are very high despite the large reduction compared to the CF concentration in the sludge before composting. The concentrations recorded are about $6.25x10^3$ and $2.75x10^3$ CFU/g for T2 and T3 respectively. These results are comparable with those of Lô *et al.* (2019) who found CF concentrations above the WHO standard (<1000 CFU/g) under experimental and climatic conditions similar to those in this study. In Lô *et al.* (2019) studies, the temperatures recorded in the thermophilic phases were however higher than those recorded in this study, which should have resulted in a good removal of CF. These authors linked the high CF concentrations in the windrows, despite the lethal temperatures reached, to external contamination as shown by Compaoré *et al.* (2010). Indeed, Compaoré et al. (2010) have shown that the presence of germs could have been favoured by the presence of lizards, Geckos and insects that often take refuge in the windrows. In addition, the high concentration of FC may be due to external contamination as the windrows were placed next to the desanding/de-greasing basins of the Cambérène wastewater treatment plant (Lô *et al.*, 2019). In this study, the high reduction of CF in windrows T0 and T1 may be related to the high temperatures that were recorded in these two windrows.

Ascaris eggs: Table 4 shows that composting reduced the amount of viable Ascaris eggs to a greater or lesser extent. In T2 and T3, the concentrations of viable Ascaris eggs about 1.3 and 1 egg/g of compost, respectively. These concentrations are higher than the WHO standards (< 1 viable egg/g compost) (WHO, 2006). These high concentrations of Ascaris eggs compared to the WHO standards may be related to the low temperatures that were recorded in these two windrows during the thermophilic phase. Indeed, the destruction of helminth eggs is associated with several factors such as temperature, pH, and dryness. (Kone *et al.*, 2007; Maya *et al.*, 2012). Regarding the effect of temperature, Kone *et al.* (2007) have shown that exposure to temperatures above 45°C for more than 5 days can inactivate Ascaris eggs. Studies of Maya et al. (2012) also confirmed the effect of temperature. Indeed, these authors showed that a temperature higher than 45°C leads to the inactivation of helminth eggs under conditions of pH of about 5.3 and 90% dryness. The low inactivation of Ascaris eggs in these two windrows can therefore be associated with the low temperatures that have never exceeded 45°C and the pH and dryness conditions that were not reached. The low temperature obtained in these two treatments may be related to the structure of the compost pile, specifically the porosity created by Typha leaves. These two treatments have the highest proportions of Typha leaves. T0 and T1 have Ascaris egg contents below the WHO standard (WHO, 2006). The concentrations recorded are 0.6 and 0.8 Ascaris eggs/g of compost in T0 and T1 respectively. In these treatments, the good inactivation of Ascaris eggs can be linked to the high temperatures recorded during the thermophilic phase. Indeed, the temperatures recorded during the thermophilic phase were above 45°C in these two windrows. The thermophilic temperatures recorded at T0 and T1 were respectively around 46 and 48 °C for more than 5 days.

CONCLUSION AND APPLICATION OF RESULTS

All composts have C/N ratios below 12, which proves that they are all mature. The C/N ratio, nitrogen, potassium, phosphorus and pH are in accordance with WHO requirements. Composting has resulted in a significant reduction of faecal coliforms. However, only T0 and T1 meet WHO standards for Ascaris egg concentrations. In T2 and T3, Ascaris eggs concentrations are higher than the WHO recommendations. Then, it is recommended to put them in storage for an additional time of at least 6 months to eliminate biological pollutants. Composting of sewage sludge with Typha biomass is a good option to valorise faecal sludge in agriculture. The use of this type of compost can be recommended in organic farming. However, it will be necessary to carry out acceptability studies at the level of compost users and consumers regarding the consumption of amended products from such composts.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest in this article.

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