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Follow-up of Physico-chemical parameters of the compost manufacturing tests according to the different constituents

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ABSTRACT: The presence of a high level of organic matter in solid household waste is a positive criterion for considering waste recovery through composting.

This research aimed at studying of the impact of the fermentable fraction of municipal solid waste during composting. Five (5) mixtures have been developed and in each of the treatments, the added fermentable fraction represents 25 or 50% of the removed fraction. The temperature, Total Organic Carbon, nitrogen and pH values of each treatment were determined during the maturation process of the compost manufacturing trials according to the different constituents.

Results revealed a strong positive correlation (r^2= 0.8566) between the total organic carbon and the fraction of total organic matter in the mixtures submitted to composting. From the analysis of the compost treatments carried out, it appears that the inputs of the T50v treatment (treatment obtained by substituting 50% of vegetable matter with the fermentable fraction of the MSW) are well degraded at the end of composting. Consequently, they would bring a substantial quantity of organic matter as a soil amendment, despite a slightly high C/N ratio that could be compensated by an input of nitrogen compounds. This mixture could enrich the soil with a substantial quantity of humic substances.

KEYWORDS: household solid waste, composting, fermentable matter, vegetable matter, temperature, Carbon/Nitrogen (C/N).

1 INTRODUCTION

The choice of a material recovery method such as composting, a low-cost treatment, generally appears to be the most suitable solution for both developing and IP cities because of the high proportion of fermentable materials contained in several categories of waste (green waste, fermentable fractions, paper, cardboard). Composting is a biological process of conversion and valorisation of organic matter present in animal and vegetable forms which allows, under the action of aerobic bacteria with the presence of oxygen, their transformation into humic substances (Cenkseven et al., 2017 and Lehmann et al., 2015). This is one of the options, the most adopted in the countries south of the Sahara. This technic of recovery of fermentable matter is very widespread and adopted, according to the work of Muliele et al. (2017) and Mosler et al. (2006), for waste treatment in several countries. Indeed, this process benefits a high acceptance degree by the public both in the IPs and in those under development according to the work of Parrot et al. (2009) and Féniel et al. (2009). The problem with composting is the quality of the incoming products, and therefore the selective collection of the fermentable fraction from household waste (FFOM).

The success of this sector is linked to obtaining a quality product that ensures a good image of the compost and therefore stable outlets. Consequently, it is necessary to control the composting process in each of its stages in order to ensure the good quality of the final product with a good price.

Our previous work indicates that the waste of Abomey - Calavi city is characterized by a C/N ratio of 15.81 and comprising 52.41% compostable materials and recommends recovery by composting preceded by sorting (Topanou et al., 2011).

It is in this order that the present study aim to determine the best treatments for obtaining mature compost, taking in account physicochemical and empirical parameters.

2 Materials And Methods

2.1 Materials

During the composting process, the following constituents are collected, the plant fraction (azadirata indica and chromolena odorata), fermentable matter obtained after sorting of solid household waste collected exclusively to make compost, cow dung collected on the farm of the Faculty of Agronomic Sciences (FSA) of Abomey-Calavi University, poultry droppings obtained from a laying hen rearing site located in Akassato.

For each pit, 100 kg is divided in 10 alternative layers of 10 kg each. A layer is composed of a fraction of each component in the calculated proportions (Table 1). According to the literature, which recommends 70% vegetable matter for 30% animal matter per pit, different mixtures are made (Alidadi, et al., 2016). The control mixture consists exclusively of green waste and animal waste. The objective being to study the impact of the fermentable fraction of municipal household waste during composting, this fraction has been gradually introduced as a substitute for animal dejecta (mix a) in one hand, and plant debris (mix v) in other hand. A total of 5 mixtures were produced and, in each case, the added fermentable fraction represents 25 or 50% of the removed fraction. (Table 1)

Table 1. Composition of the constituents of each mixture

Mixtures	Fermentable Matter (MF)	Plant debris (DV)	Animal dung (cow dung and animal droppings) (DA)
T_0	0 %	70 %	30 %
T_{25a}	7,5 %	70%	22,5 %
T_{50a}	15 %	70%	15 %
T_{25v}	17,5 %	52,5 %	30 %
T_{50v}	35 %	35 %	30 %

Legend: Tij = Treatment of compost obtained with i % substitution of fraction j (with j=a= animal or j= v= vegetable).

A Full Random Block Device (FBD) with three repetitions (Figure 1), in a real (not controlled) environment was used. A total of 15 pits were constructed.

The mixture was stirred with a pitchfork every 2 weeks for the first 2 months and once a month for 4 months until the compost matured.

During the first turning, 22 L of water was added to each pit to increase the moisture content during the treatments. The water used on the composting site is from the national water distribution company (Soneb). On all other occasions, when turning over, the mixture was quite wet and no water was added.

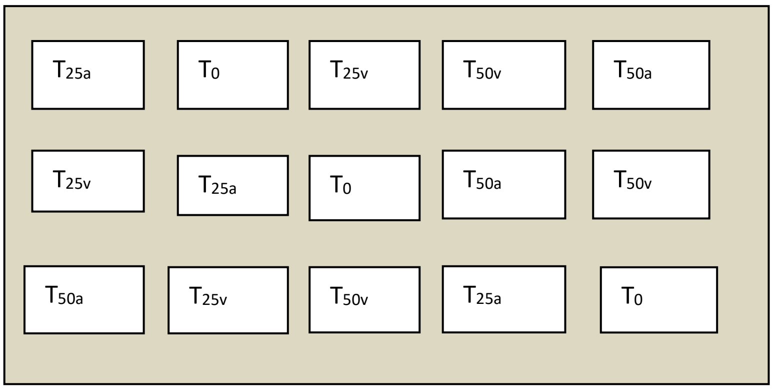

Fig. 1. Diagram of the experimental device adopted on the site for the composting trial

Legend: R1 = Repeat No. 1; R is the row of the repeat row.

2.2 Composting

The composting tests were carried out in a 250 m^2 area, isolated from any human activity and sheltered from the wind. A 0.5 m^3 pit was dug (photo 1 a).

In order to limit the impact of bad weather on the compost, each pit is delimited by four rods which are surrounded by a plastic sheet (photo 1 b). The pit is then covered with the plastic sheet at the end of the filling process (photo 1 g). In the center of each pit there is a rod (photo 1e) which will facilitate the introduction of the thermometer for daily temperature taking (photo 1i).

Photo 1 a: 0.5m3 pit delimited by four rods

Photo 1b: 0,5m3 pit delimited by a tablecloth in bags

Photo 1c: 0.5m3 pit with watering system

Photo 1d: Filling of the pit with the different components

Photo 1e: Grounding of the 5th rod in the center of the pit

Photo 1f: Pit filling process

Photo 1g: Pit covered after filling

Photo 1h: Partial view of the closed pits

Photo 1i: Introduction of the thermometer for taking a temperature

Photo 1: Different stages of the composting process (Photo Topanou, 2019)

2.3 MONITORING OF PARAMETERS

2.3.1 TAKING THE TEMPERATURE IN COMPOST WINDROWS

The temperature (T) was measured directly by a "SANDBERGER" thermometer in the compost windrows. The measurement is made every two days (photo 1i).

2.3.2 PE AND CONDUCTIVITY MEASUREMENT

The oxidation-reduction potential (ORP) and conductivity (EC) were measured with a "Toilets Proof family HANNA Instruments" multimeter on the water extracts for the various composts.

2.4 OBTAINING THE COMPOST

At the end of the process the compost obtained is sieved on the sorting table. The fine compost material (MFC) collected through the 2 mm mesh, is weighed and sent to the laboratory to determine its physico-chemical parameters. The non-fine material called reject material (RM), obtained through the 2 mm mesh, is also weighed and kept in bags at the composting site.

3 RESULTS AND DISCUSSIONS

3.1 TEMPERATURE VARIATION DURING THE COMPOSTING PROCESS

Globally, the five (5) experiments have an identical behaviour during composting. The biological activity slowed down on day 6 and, less markedly on day 15, probably due to the oxygen lack and/or water manifested by a drop in temperature then a new increase observed after turning (Figure 2). The turnaround, carried out every two (2) weeks, results in the drop in temperature characteristic of this action as shown in Figure 2, then a restart of the biological activity results in the increase in temperature. At the end of the bio-oxidation phase, the temperature naturally drops due to the end of degradation of the easily biodegradable molecules releasing energy. The temperature begins to decrease on day 16, which may indicate that the bio-oxidation phase is almost over. During the composting process, a drop in temperature sometimes indicates an anaerobic degradation phase and therefore a low activity of aerobic micro-organisms (Tremier et al., 2005a and Béghin-Tanneau 2019). In other hand, a rise of temperature confirms the active phase of the aerobic decomposing organisms (Chen et al., 2014, Béghin-Tanneau 2019). The temperature variation observed (Figure 2) during the composting process confirms the degradation of organic matter.

The measured temperature values are relatively low for the five (5) treatments. The maximum temperature observed, not far from the ambient temperature (28°C) is not very high and corresponds to a value observed during the composting of green waste (Koledzi et al., 2012). To compare, the transformation of animal dejecta can raise the temperature to 40°C, whereas sludge from the plant can reach 70°C or more (Zhang et al., 2012).

Thus, the temperature of T25V compost is slightly higher than the temperature for the other experiments at the end of the process. Only the T50v compost seems to have a stabilisation of the temperature from day 25 onwards, while a further increase is observed for the others. The T50V compost, made up of 1/3 of each fraction (35% FFOM, 35% DV and 30% DA), behaves in a similar way to that of the control.

However, as the experiment was limited in time (4 months of composting), the main objective of the study was to see if the behaviour was different according to the mixes in terms of compostability. Thus, maturation, although an important indicator (Doublet et al., 2011), could not be measured in the laboratory. Empirical parameters were used to assess the maturity of the manufactured composts.

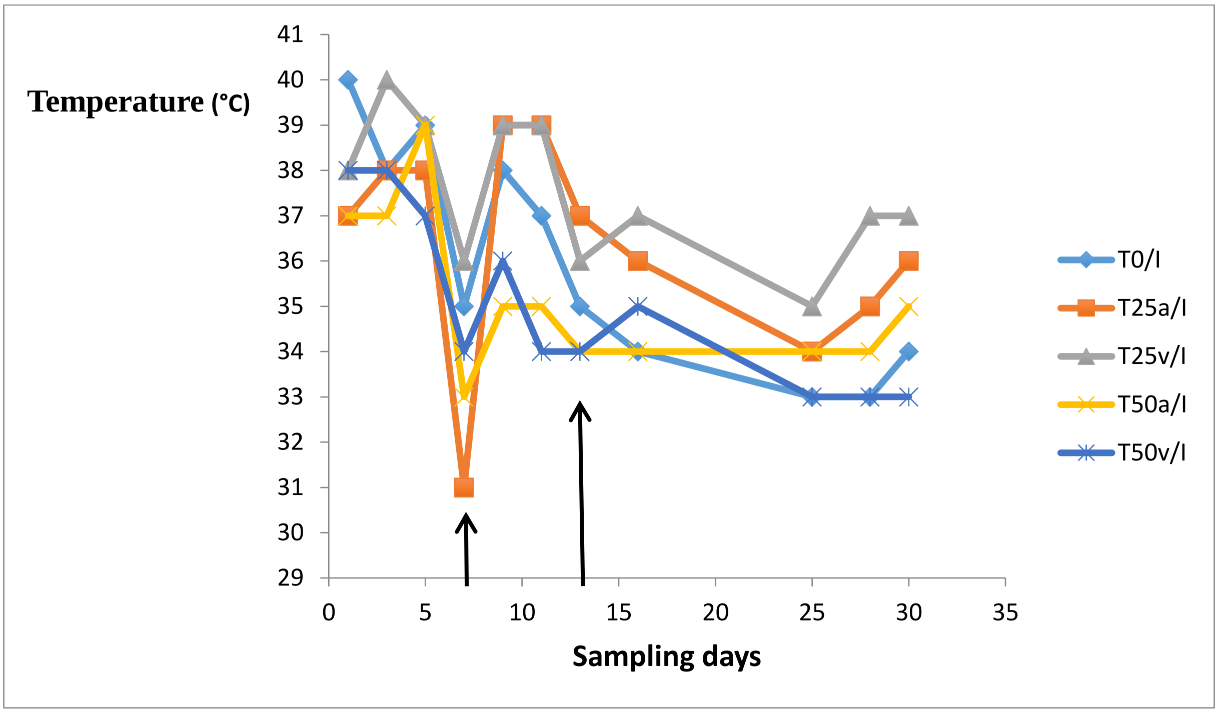

Fig. 2. Temperature variation over time per treatment

Temperature monitoring can be misleading. The temperature may be low, because aeration or moisture are deficient, without the compost being in the maturation phase (Zhang et al., 2012). For this reason, compost should be considered to have entered the maturation phase when the temperature stabilises and not when it decreases. Temperature is a good indicator of organic matter degradation that should be monitored regularly. However, the analysis of the evolution of a single parameter in isolation among several others is insufficient and can lead to misinterpretations (Doublet et al., 2011). The combination of several parameters provides additional information. For this reason, a combined analysis of several parameters was chosen.

3.2 Effects Of The Different Treatments Studied On The Chemical Parameters Of The Compost

The percentage of fine compost material collected at the end of the composting process is higher than 75% for all treatments with a value of 84.95 ± 0.44 for the T50v treatment (treatment obtained by substituting 50% of vegetable matter with the fermentable fraction of the DSM), significantly different from the other values. This treatment corresponds to a lower proportion of plant fraction, i.e. the presence of weakly and slowly biodegradable molecules (Hossain et al., (2017) and Béghin-Tanneau et al., (2017). As the presence of fine matter confirms good degradation, it would be plausible to conclude that the inputs of the T50v treatment are well degraded at the end of composting. In other hand, the T25a and T50a treatments containing, together with the T0 control, the highest rate of vegetable waste with slower degradation, have the lowest percentages of fine matter in the compost (MFC) (Table 2). The plant fractions are rich in cellulose and lignin, compounds that are poorly biodegradable (Khalil et al., 2008).

The variance analysis reveals that the treatments had a highly significant effect (at the 5% threshold) on all physical parameters of the compost, fine matter, TOM (Total Organic Matter) and, to a lesser extent, moisture (Table 2). Discriminant analysis of the averages shows that the T50v treatment has the highest MOT and fine compost material (FCM) values, while the lowest MOT and FCM values are for the T50a treatment. It is not possible to discriminate the moisture content of the different experiments on the basis of the statistical results. This information is logical, as the compost heaps remained moist during the process.

Furthermore, the variance analysis of the effect for the different treatments on the chemical parameters analysed at the end of composting (Table 2) also reveals that the treatments tested had a highly significant effect (at the 5% threshold) on total organic carbon (TOC), Kjeldahl nitrogen (KN) and consequently on the C/N ratio.

In other hand, their effect was not significant (at the 5% threshold) on the redox potential (EH) and pH. During the bio-oxidation phase, the biodegradation of easily biodegradable organic matter results in an increase in redox potential due to the mineralisation of easily biodegradable molecules and the appearance of molecules responsible for the increase in redox potential (Zhang et al., 2012 and Cottes et al., 2019). However, at the end of composting, according to the work of Cottes et al. (2019) and Khalil et al. (2008), the redox potential stabilises at a value close to 80 mV and then In the 5 experiments, all the PE values determined are close to 80 mV, thus indicating that the maturation process has started. Indeed, during the maturation phase, the molecular recombination observed is responsible for the appearance of humic substances, especially humic acids (Doublet et al., 2011). The formation of these highly polymerised, high molecular weight and antioxidant products leads to a decrease in the oxidation-reduction potential during composting and a stabilisation during maturity (Chenu et al., 2019; Kappler et al., 2004). During the ripening phase, the pH value stabilises around a value slightly above neutral.

Table 2. Analysis of variance of compost parameters (mean values ± standard errors) according to the treatments studied after 120 days of composting

Traitements	T_0	T_{25a}	T_{25v}	T_{50a}	T_{50v}	Valeurs de Fisher	CV (%)
MOT (Total Organic Matter)	63,28 ± 1,19 b	62,46 ± 0,42 b	64,78 ± 1,73 b	57,70 ± 0,99 c	70,21 ± 0,95 a	13,42***	3,35
MFC (Fine Compost Materials)	79,68 ± 0,90 b	78,88 ± 0,53 b	80,04 ± 1,45 b	78,63 ± 1,20 b	84,95 ± 0,44 a	16,13***	1,39
RF (Rejected Materials)	20,32 ± 0,90 a	21,12 ± 0,53 a	19,96 ± 1,45 a	21,37 ± 1,20 a	15,05 ± 0,44 b	16,13***	5,71
HUM (humidity)	68,81 ± 2,93 a	68,22 ± 1,70 a	61,62 ± 2,64 ab	65,80 ± 1,11 a	56,45 ± 2,21 b	5,51**	5,94
TOC (mg C/g) (Total Organic Carbon)	26,32 ± 0,09b	23,63± 0,22 c	24,46 ± 0,51c	19,18 ± 0,29d	28,37± 0,05 a	168,52 ***	1,88
Total N (mg/g) (Kjeldahl Nitrogen)	1,05 ± 0,00 b	1,05 ± 0,02 b	0,96 ± 0,02 c	1,33 ± 0,03a	1,03 ± 0,01 b	78,65***	2,66
C/N ratio	25,04± 0,11b	23,07 ± 0,28c	25,45± 0,46b	14,36± 0,49d	27,63 ± 0,20a	328,21***	2,13
pH water	7,93 ± 0,10a	8,04 ± 0,15a	7,87 ± 0,12a	7,75 ± 0,04a	7,77 ± 0,08a	2,35ns	1,73
E_H (mV)	84,88 ± 0,83a	83,88 ± 0,26a	84,42 ± 0,33a	84,82 ± 0,66a	83,88 ± 0,29a	0,69ns	1,2

*The averages followed by the same alphabetical letters and for the same chemical parameter of the compost are not significantly different (P > 0.5) (0.05) according to the SNK test. **: Highly significant at the 5% threshold; ***: Highly significant at the 5% threshold; ns: Not significant at the 5% threshold.*

Our study indicates pH values in order of 8, which can be explained by the presence of ammonium ions and corroborate the work of Muliele et al, (2017) and Béghin-Tanneau,2019.

Thus, it seems that the mineralisation is not completely finished and/or that the presence of nitrogen groups in the inputs results in a slight ammonification.

Furthermore, discriminant analysis of the mean (Table 2) shows that at the end of the treatment, the total organic carbon content is highest (28.37 ± 0.05 mg.g-1) for the T50v treatment as opposed to the T25a treatment, for which the TOC value is lowest (23.63 ± 0.22 mg.g-1). The control (T0) nevertheless has the second TOC value, after that of the T50v compost treatment. For Kjeldahl nitrogen, the highest value is observed for the T50a treatment, while the lowest value in NTK is observed for the T25a and T0 treatments. Thus, the highest value of C/N ratio was observed by the T50v treatment while the lowest value was observed by the T25a treatment. At the end of the experiment, the T25a compost has a C/N value compatible with soil recovery, whereas the T50V compost still requires a decrease in this value, by reducing its carbon quantity. In fact, the application of a low-nitrogen amendment to the soil (C/N>20) leads to nitrogen "hunger" according to the work of Zhang et al. (2012) and Hossain et al. (2017). When enriching the soil, the low nitrogen content of the amendment leads to soil nitrogen consumption by microorganisms. The C/N ratio is an important parameter in soil organic matter recovery. However, this parameter is the only one in our experiment that differs from one compost to another at the end of composting depending on the initial mixtures made. Thus, depending on the future use of the product and the nature of the soil to be enriched, the composition of the mixture to be composted will be adjusted.

Moreover, if we disregard the C/N ratio of the T50V compost, which is too high, it seems that this mixture resulted in a good degradation: highest rates of fine matter and total organic matter (Table 2), temperature stabilisation at the end of the experiment (figure 2). With the exception of pH and redox potential, T50V compost differs from other composts for all the parameters analysed. The balanced composition of this mixture probably explains its different behaviour from other composts, confirming that the quality of the product at the end of the process is closely linked to the inputs. Chenu et al, 2019 and Tremier et al, 2005 indicate that the quality of a compost obtained is conditioned by the nature of the initial products, the monitoring of physico-chemical parameters, and the quality of the final product. Especially the end use for which it is intended. The choice of the type of compost depends on the intended production objectives and the defects noted in the soil to be enriched.

3.3 Interrelationships Between The Different Parameters Of Compost

The Principal Component Analysis (PCA) applied to the physico-chemical parameters and the different compost treatments indicates that the first two axes express respectively 63.9% and 24.2% of the concentrated information, with a total of 88.1%.

The principal component analysis shows that the compost parameters TOC, MOT and, to a lesser extent, compost fines (CFC) are negatively correlated with the first principal component (axis 1), while the fines rejection parameters (RF) are positively correlated with the first principal component (Figure 3). This would mean that axis 1 represents the organic matter contained in the compost, which organic matter is related to the fine matter in the compost. In contrast, Kjeldahl nitrogen is positively correlated to the second main component, while the parameter pH water is negatively correlated to this second main component. As a result, axis 2 represents the acidity of the product, explained mainly by ammonium ions, with NTK measuring not only organic nitrogen but also ammoniacal nitrogen. Thus, two (2) processes can be observed on the PCA: humification process in one hand and the ammonification process in other hand.

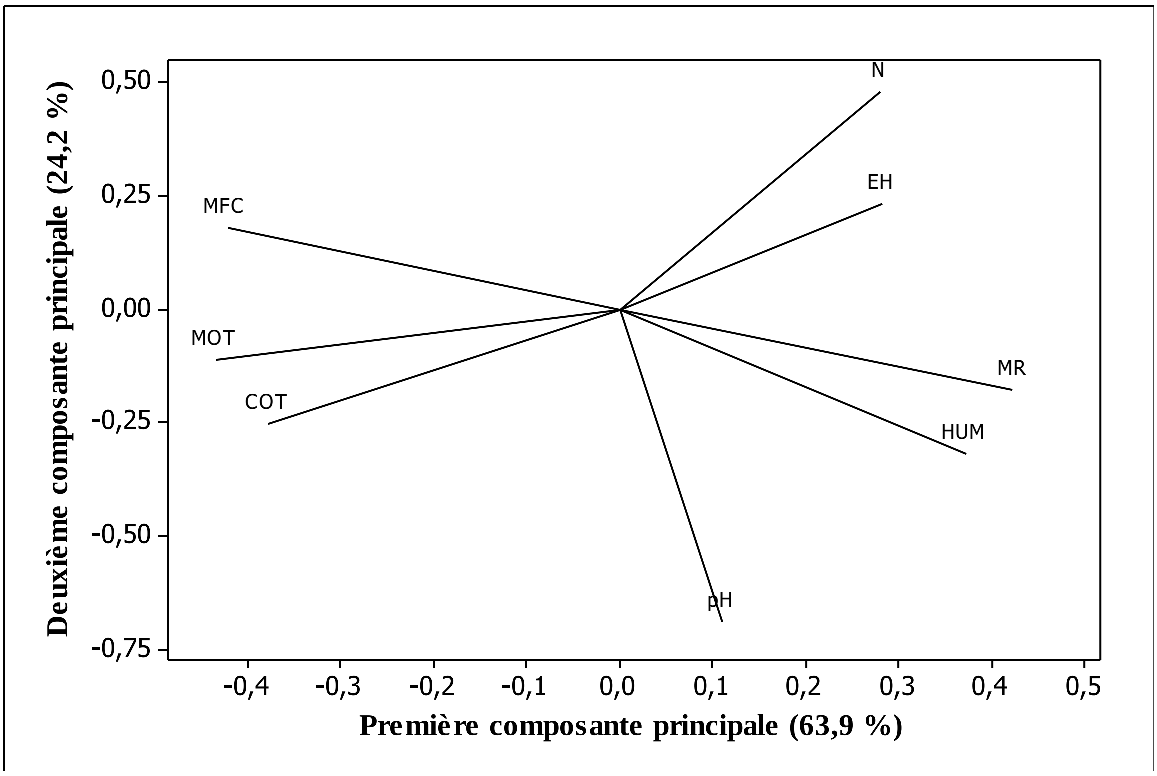

Fig. 3. Physico-chemical characteristics representation of compost treatments in the factorial plan

If we look at the representation of the different treatments on a factorial level (Figure 4), we can see that three (3) composts stand out clearly from the center of the graph: T50v, T50a and T25a. Concerning the T50V compost, previously identified as having values statistically different from other composts, it is positioned in the same place as the MOT and fine compost materials. Thus, this mixture could provide a substantial amount of well degraded organic matter.

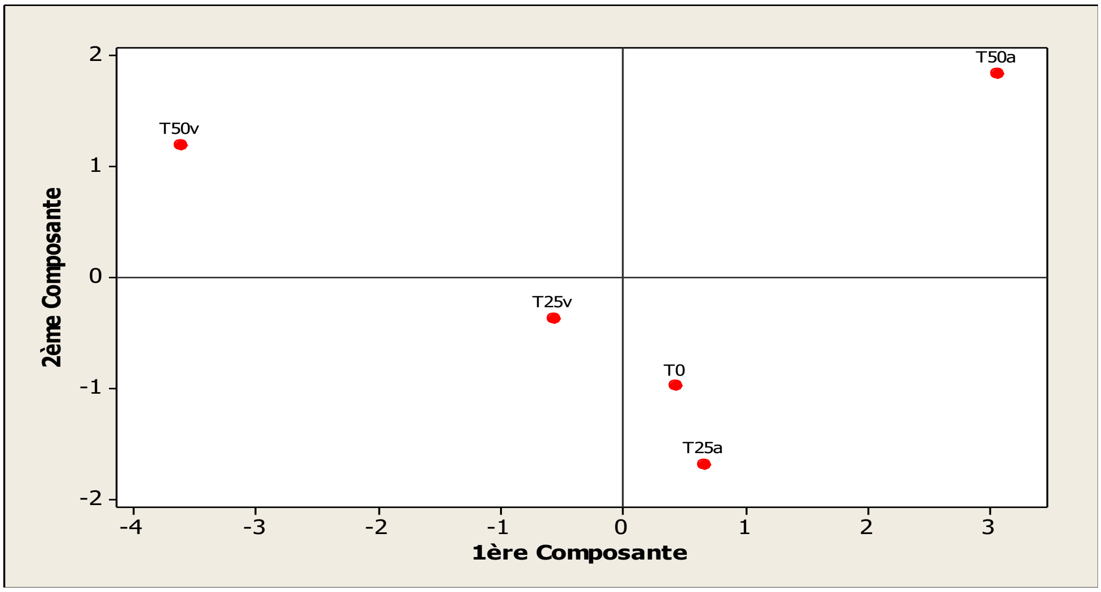

Fig. 4. Representation of the different compost treatments in the factorial plan

T50a, a treatment obtained by substituting 50% of the animal excreta with the fermentable fractions of DSM, saw an increase in the proportion of plant matter and a decrease in the proportion of animal excreta. This would explain the high values of the above-mentioned compost parameters, as the starting materials were only slightly transformed by the microorganisms. The biodegradation phase does not seem to have been completed in this compost. The T50v treatment is on the fine material side of the compost and the organic matter side. Furthermore, the T50V and T50a treatments are opposite to the "Organic Matter" axis. Thus, the more plant debris is substituted, the greater the fine matter in the compost. Moreover, the T25a and T50a treatments are opposed around the axis of acidity. The use of the fermentable fraction of solid household waste as a substitute for animal dejecta would therefore lead to a discrimination around this phenomenon, with a higher proportion of ammonium for compost containing a larger fraction of the fermentable fraction. These results confirm the correlations observed between the different parameters (Table 3). The correlation matrix of the physico-chemical characteristics of the composts shows a significant correlation at the 1% threshold between pH and TOC (r = 0.41), pH and Nitrogen (r = 0.476), and also between p.e. and TOC (r = 0.348), then p.e. and N (r = 0.528).

Table 3. Table 3: Correlation between the different physico-chemical parameters of the different compost treatments (Pearson's coefficient)

	Total Organic Carbon	N	Humidity	pH	E_H	Total Organic Matter
COT		-0,286	-0,210	0,410**	0,343*	0,787**
N			0,168	0,476**	0,528**	-0,325*
Humidity				0,267	0,250	-0,351*
pH					0,920**	0,159
E_H						0,131
Total Organic Matter						

** Significant correlation at the 5% threshold; ** Significant correlation at the 1% threshold*

3.4 Parameters For Assessing Compost Maturity

Compost maturity is the final step in the composting process. It is one of the main criteria for assessing the quality of this product in agronomy. The maturity of composts corresponding to the stability of the organic matter on the physical, chemical and biological level is a function of the different proportions of the initial constituents and of the respect of the conditions (humidity, oxygenation) for the composting process (El-Fadel et al., 2002). It is, however, relative, as the maturity of the product depends closely on its future use (Table 4).

The stage of maturity of the compost is generally assessed by taking in account the agronomic, chemical and/or empirical parameters also used in the field. While they lack a scientifically objective approach and require practical experience on the part of the person evaluating the compost, empirical parameters nevertheless provide good indicators of the aerobic degradation of organic matter and the progress of the humification process. It is a matter of observing and manipulating the compost in order to define its stage of evolution. This method has the advantage of being rapid but not very scientific. A well humified compost has the following characteristics (Khalil, 2005, Doublet et al., 2011):

(1) it does not stick;
(2) it does not give off an ammonia smell;
(3) its temperature is low even if the humidity remains good;
(4) it is granular and dark in colour;
(5) its original constituents are no longer distinguishable to the naked eye.

At the end of the four-month manufacturing process, the various composts obtained respond well to these characteristics, both before and after screening (Photo 18 and 19). Indeed, they have an odour near to the smelled in the undergrowth and have a dark brown colour, corresponding to the probable presence of humic substances. They do not stick either and their original constituents are no longer or hardly distinguishable to the naked eye.

It results from the monitoring of the composting process that the 5 treatments have identical behaviour in terms of compostability of the different constituents. The representation of the physico-chemical parameters in the factorial plan shows that there are three types of compost obtained with the more mature T50v treatment.

The T50v treatment, with parameters statistically different from the others, could bring a substantial quantity of organic matter as a soil amendment, despite a slightly high C/N. This defect could be compensated by an addition of nitrogen compounds.

Photo 2: Fine materials from manufactured composts tests

Photo 3: Rejected materials from manufactured composts tests

4 CONCLUSION

In view of the work above, composting preceded by sorting is an option for the recovery of solid household waste and a solution to the consequences of the practice of backfilling the shallows with waste in an environment where the waste management system is sometimes not very operational.

It results from the monitoring of the composting process that the five (5) treatments have an overall identical behaviour in terms of compostability of the different constituents. The different composts obtained respond well to the characteristics of maturity, have an odour near to the smelled in the undergrowth and have a dark brown colour, corresponding to the probable presence of humic substances. They do not stick either and their original constituents are no longer or hardly distinguishable to the naked eye.

A more in-depth study over a longer period of time, integrating the maturation process, associated with a follow-up of soil recovery will be envisaged in our subsequent work.

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