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Comparative study of vermicompost produced in the mesophilic phase and ordinary compost

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Abstract

Vermicomposting is a biological process that uses earthworms to transform organic waste into compost. The aim of this study is to evaluate the effectiveness of vermicomposting, compared to conventional composting, through the analysis of physicochemical parameters. The species *Eudrilus eugeniae* was used to degrade pre-composted household waste. The results show that vermicompost has higher nitrogen (0.63%), phosphorus (11.60%) and carbon (15.38%) contents than conventional compost (0.53% N, 10.82% P, 14.86% C). On the other hand, potassium is higher in conventional compost (0.47% versus 0.31%). The heavy metal content is lower in vermicompost, reflecting a phenomenon of bioaccumulation by worms. The humic and fulvic acid content is also higher in vermicompost. These results confirm that vermicomposting produces a more stable product that is rich in nutrients and less contaminated by heavy metals.

Keywords: Vermicompost; Compost; Household Waste; Fertility; Humification

1. Introduction

Rapid urbanisation, industrialisation and population growth are leading to a steady increase in the production of municipal solid waste, which is a major problem for many African countries. This waste, which is often poorly managed, accumulates in unsanitary conditions and causes odour nuisance, particularly in urban areas. However, its high organic content makes it a potential resource for the production of compost and vermicompost, which can be used for sustainable agriculture [1].

Composting is a biological process in which microorganisms break down organic matter under aerobic conditions, producing carbon dioxide, water, heat and a stable organic amendment: humus. Vermicomposting combines the action of microorganisms and earthworms in mesophilic conditions. Worm excrement is particularly rich in nutrients, containing up to five times more nitrogen, seven times more phosphorus and eleven times more potassium than ordinary soil, as well as humic acids, which improve soil structure and fertility [2, 3].

Several factors influence the quality of compost and vermicompost. Temperature is crucial for microbial activity and for the growth and metabolism of earthworms [4]. Moisture must be maintained between 50 and 60% to allow for optimal biological activity without limiting aeration [5]. The pH varies depending on the rate of decomposition and the nature of the raw materials, and is an indicator of microbial development and worm health, which generally tolerate a pH between 4.5 and 9 [6]. Measuring carbon dioxide and substrate porosity are also key parameters for monitoring compost maturation and ensuring optimal gas transfer [7]. Finally, humic substances, particularly humic and fulvic acids, are commonly used to assess compost humification and maturation [8,9].

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Despite this knowledge, research on vermicomposting remains less developed than that on conventional composting, and a better understanding of its processes is needed to optimise its efficiency [10]. The objective of this study is therefore to evaluate and compare the physicochemical evolution of household waste subjected to conventional composting and vermicomposting, with a focus on the stabilisation of fermentable organic matter and the quality of the amendments produced.

To do this, waste taken from a compost heap that had been pre-composted for a week was placed in wooden bins and introduced with earthworms. The process was monitored for three months, and samples were taken at regular intervals for physicochemical analysis at the University of Lomé laboratory.

2. Materials and methods

2.1. Earthworms

The earthworms used were of the species *Eudrilus eugeniae*. This species is native to West Africa and was collected in the marshy areas of the Lomé lagoons. These are the most commonly used earthworm species for vermicomposting due to their wide temperature tolerance, high reproductive potential and global ubiquity.

Figure 1 Earthworms used in vermicomposting (*Eudrilus eugeniae*)

2.2. Composting materials

Household waste pre-composted for a week was used to avoid the thermophilic phase, which would hinder the survival of the earthworms. Manure and cardboard were also added to help maintain moisture.

2.3. Vermicomposting containers

The bins used for vermicomposting were made of wood and measured 1 m x 0.6 m x 0.5 m. These bins were equipped with a device for draining leachate.

Figure 2 Containers

Figure 3 Organic substrate in the container

2.4. Compost production

Compost is produced at the Ecosystème Naturel PRopre (ENPRO) site, a composting center in Lomé, with technical support from the Waste Management, Treatment, and Recovery Laboratory (GTVD). Urban waste is composted for one week in static piles that are aerated by turning. Then, part of the composted waste is left in windrows to mature for three months, while the other part is transferred to bins with earthworms and undergoes vermicomposting for three months as well.

The waste in the bins is covered with cardboard (which has very high absorbency) to retain moisture and protect the earthworms from light. The bins are watered sufficiently on the first day. The compost is then screened to 4 mm and analyzed at the GTVD laboratory. The vermicomposting bins were carefully monitored for moisture and worm behavior. The compost produced was used for experimental purposes.

Table 1 Composition of each vermicomposting bin during the experiment

	Composition of containers
L1	10 kg of cardboard + 10 kg of manure + 130 kg of substrate + 0.5 kg of earthworms
L2	10 kg of cardboard + 10 kg of manure + 130 kg of substrate + 1 kg of earthworms
L3	10 kg of cardboard + 10 kg of manure + 130 kg of substrate + 1.5 kg of earthworms

2.5. Physicochemical characterization

2.5.1. Organic matter

This is determined by loss on ignition after passing the dry compost sample through a muffle furnace at 550°C for 2 hours.

Organic matter (OM) is determined by calculating the difference between dry matter (DM) and mineral matter (MM) (residue after calcination).

$$\% \text{ MO} = \frac{Ms-MM}{Ms} \times 100$$

The percentage of total organic carbon is established by: % COT $=\frac{\%MO}{2}$

2.5.2. pH

The pH is determined on aqueous suspensions in accordance with standard AFNOR NF ISO 10-390. In a beaker, 10 g of compost or sieved vermicompost are mixed with 100 ml of distilled water. The pH is measured after ten minutes of homogenization at room temperature using a pH meter with a combined electrode (JENWAY).

2.5.3. Total nitrogen

In a flask, mix a mass P of compost or leachate; 10 ml of concentrated sulfuric acid, and 0.5 g of Kjeldahl catalyst. Heat until the samples change color. The cooled mineralized sample is recovered with 100 ml of distilled water for distillation. A blank is carried out under the same conditions.

The mineralized sample and 50 ml of 40% soda are placed in the distillation flasks for distillation, and the ammonia released is collected using a 250 ml Erlenmeyer flask containing 10 ml of 1N boric acid [11].

The distillate is titrated with 0.02N sulfuric acid H2SO4 in the presence of a color indicator (methylene blue + methyl red).

Total nitrogen is given by the following formula

$$\%\text{N}=\frac{1.4\times N\times(Ve-Vt)}{P}$$

- N: Total nitrogen
- Ve: Volume of sample titrant (ml).
- Vt: Volume of control titrant (ml).
- N: Normality of titrant solution (0.02N sulfuric acid).
- P: Weight in grams of test sample (g).

2.5.4. Total phosphorus determination

A mass of 0.5 g of compost, previously dried in an oven, is calcined in a furnace at 600 °C for 6 hours. The ashes are taken up with 5 ml of concentrated HCl and evaporated to dryness on a hot plate. The final residue is taken up with 5 ml of HCl diluted to 1/10, then filtered and made up to 100 ml with distilled water [12]. The phosphate ions in the extracted solution are measured by spectrophotometry using the phospho-molybdate blue method.

2.5.5. Measurement of available phosphorus (BRAY method)

Mix 1 g of compost or vermicompost in a centrifuge tube with 15 ml of extraction solution (a mixture of ethylenediaminetetraacetic acid and ammonium fluoride). After vigorous shaking for one minute, centrifuge at 2000 rpm for 15 minutes. The available phosphorus is then measured in the supernatant using a spectrophotometer.

2.5.6. Humic and fulvic acid content

Before extracting the humic substances, 5 g of compost or vermicompost was treated with distilled water (3 times). After 2 hours of stirring, the mixture was centrifuged at 4000 rpm for 10 minutes, filtered, and then the residue was recovered. To the residue, 45 ml of 0.1 N NaOH was added. After stirring, centrifugation, and filtration under the same conditions as before, the supernatant was recovered for the determination of humic substances. The clear extract is acidified with 6N sulfuric acid. After 24 hours at 4°C, the acid-soluble fraction containing fulvic acid (FA) is separated from the insoluble fraction containing humic acid (HA) by centrifugation at 4000 rpm for 10 minutes. The two humic fractions are measured after carbon oxidation with 0.1N $KMnO_4$ in an alkaline medium [13, 14].

2.5.7. Measurement of trace metals and major elements

The samples are hot mineralized with aqua regia (1/3 HNO_3 +2/3 HCl) according to AFNOR NF ISO 11 460 of June 1995 [15, 16].

The composts and the earthworms emptied of their digestive tract contents are dried at 60°C and then ground. To 3 g of each compost and 2 g of earthworms contained in Teflon beakers, 3 ml of aqua regia (10% H_2O_2) is added. The samples are heated to 150°C for 2 hours until the acid evaporates. After mineralization, distilled water is added to bring the volume to 25 ml for ETMs and 100 ml for major elements. The samples are then filtered using 0.45µm Whatman paper. The concentrations of the various elements are measured by flame atomic absorption spectrophotometry. The gas mixture used for the flame is air-acetylene.

3. Results

3.1. Changes in organic matter % OM

The evolution of organic matter during the vermicomposting process (Figure 4) and composting (Figure 5) shows that initially the organic matter content is higher in the vermicompost than in the windrows. This is explained by the addition of manure and cardboard to the vermicomposting bins. From the first day to the fifteenth day, there is a gradual decrease in organic matter in almost all vermicompost, but a slower decrease in organic matter in compost piles, showing intense worm activity during vermicomposting compared to microorganisms during composting.

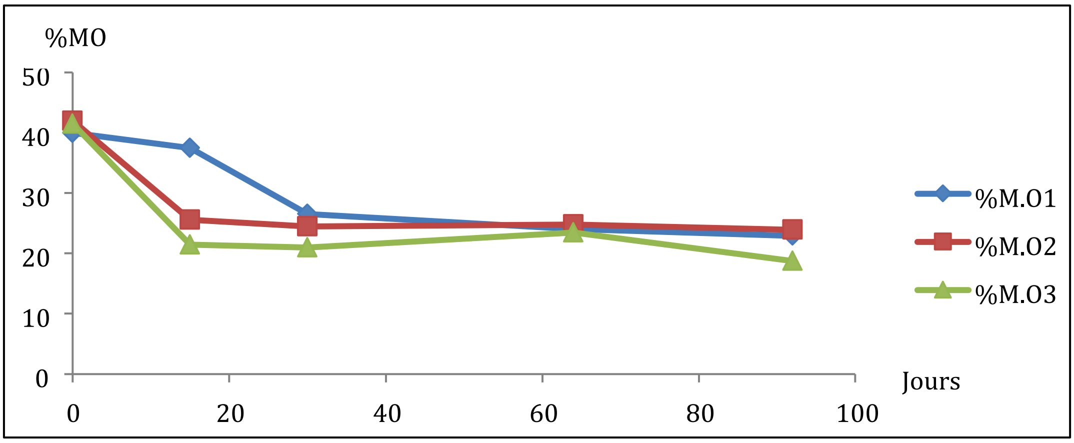

Figure 5 Changes in organic matter during composting

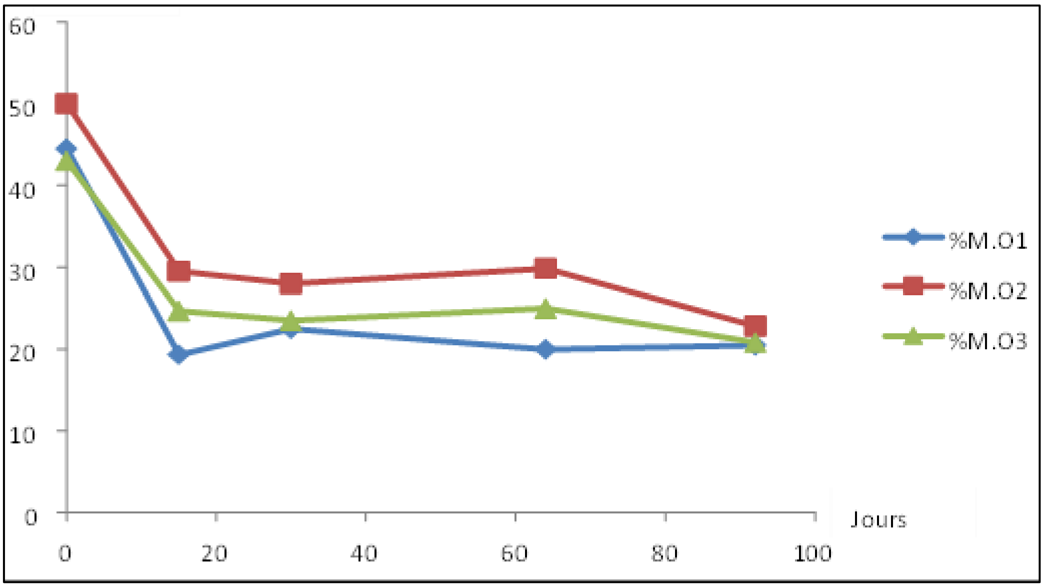

Figure 4 Changes in organic matter during vermicomposting

3.2. Physicochemical composition

3.2.1. Organic matter and nutrients

The chemical composition of the composts is shown in Table 2.

Table 2 Organic matter and nutrient content in composts

	Vermicompost	**ordinary compost**	*** References**
pH	7.1	8.7	
Organic matter (%OM)	30.76	29.72	
Total organic carbon (%TOC)	15.38	14.86	
Total nitrogen (%N)	0.63	0.53	0.7-0.8
C/N ratio	24.41	28.04	
Fertilizing elements			

Phosphorus (%P_2O_5)	11.60	10.82	0.8-1.36
Available phosphorus (%P_2O_5)	1.30	5.87	
Potassim (%K_2O)	0.31	0.47	1.51-1.98
Calcium (%CaO)	5.77	6.3	1.62-3.85
Magnésium (%MgO)	0.346	0.356	0.28-0.42
Humic substances			
AH (mg/g)	146.3	101.2	
AF (mg/g)	124.3	88	
AH/AF	1.17	1.15	

*Composting of urban waste in the city of Lomé (Togo) [17].

These analyses show that the highest levels of these elements are found in vermicompost rather than compost. This can be explained by the addition of manure to vermicomposting bins to help earthworms survive at the start of the process.

On the other hand, [18] states that the nitrogen content of an organic substrate increases during vermicomposting.

Other studies also indicate that vermicompost is richer in N and P than simple compost [19, 20, 21, 22], while [23] found no significant differences.

We obtained a neutral pH of 7.1 for vermicompost. In contrast, conventional compost had a basic pH of 8.7. In terms of the pH of the composts, the results show that conventional compost has a higher pH than vermicompost. According to [24]., earthworms prefer a pH of between 4.2 and 8. According to [25]., composting and vermicomposting have a pH close to neutrality, and Fayolle obtained a neutral pH of 6.7 for vermicompost made from household waste mineralized for four weeks at 22.5°C in the presence of earthworms.

The C/N ratio of vermicomposting is low compared to that of composting. This is linked to the activities of *Eudrilus eugeniae* worms in decomposing organic matter, thereby reducing the total carbon content in the final product. The combined action of these worms and microorganisms during vermicomposting also mineralizes organic nitrogen, leading to an increase in total nitrogen in the final product. This parameter is most commonly measured to assess the maturity of compost. [26], estimate that a ratio of less than 20, or even 15, characterizes mature compost. On the other hand, [27]. consider that a value below 25 characterizes mature compost. During our test, the C/N ratio was 24.41 in the presence of *Eudrilus eugeniae* and 28.04 in the compost.

Comparing the humic substances (AH and AF) during the two processes, we observe a high humic substance content in vermicompost, while the AH/AF ratio, proposed as an indicator of humification processes and as a maturity index [28, 29], is slightly higher in vermicompost than in ordinary compost.

3.2.2. Trace metal content

Metal concentrations are shown in Table 3 below.

Table 3 Trace metal content in compost and earthworms (mg/kg)

	Content of trace metals in mg/kg			
	Cd	Pb	Cu	Zn
Worms (earthworms)	0.167	0.673	5.606	66.72
Vermicompost	0.076	9.538	21.082	77.892
Ordinary compost	1.895	30.18	34.685	81.52
*Value in compost**	*3*	*180*	*300*	*600*

*AFNOR standard, NF U 44-051

The trace metal content in compost and earthworms is shown in Table 3 and is well below the NF U 44-051 standard. Worm compost and ordinary compost both come from the same windrow (pile of waste), but the TME content is higher in ordinary compost than in worm compost. This difference can be explained by the bioaccumulation of TME by earthworms [30]. The ETM content in earthworms also confirms this assertion.

4. Conclusion

All of the physical and chemical parameters monitored are generally within normal ranges. During this experiment, the nutrient content of the vermicompost obtained was estimated at 0.63% N, 11.60% P, 0.31% K, and 15.38% C. At the same time, the measured heavy metal concentrations (77.892 mg/kg Zn, 21.082 mg/kg Cu, 0.076 mg/kg Cd, and 9.538 mg/kg Pb) were significantly lower than those in ordinary compost (81.52 mg/kg Zn; 34.685 mg/kg Cu; 1.895 mg/kg Cd; 30.18 mg/kg Pb). This reduction reflects the bioaccumulation capacity of *Eudrilus eugeniae* worms, thus contributing to a less polluted final product.

In addition, the humic substance content of vermicompost (146.3 mg/g AH and 124.3 mg/g AF) is higher than that of ordinary compost (101.2 mg/g AH and 88 mg/g AF). This highlights the faster mineralization and humification of organic matter during vermicomposting, reflecting a more advanced degree of maturity in the final product. Although the AH/AF ratio used as an indicator of humification and maturity processes remains similar in both composts, the results confirm the superiority of vermicompost in terms of quality.

Ultimately, vermicomposting appears to be a more environmentally friendly and efficient process than conventional composting. The vermicompost obtained is of better agronomic and environmental quality and can be used directly as an organic amendment in agricultural soils.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest to be reported.

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