Original Research Article

Characterization of the agronomic properties of different vermicompost from the co-composting of oil palm empty fruit bunches and green waste

ABSTRACT

The accumulation of palm oil industries waste is one of the causes of environmental pollution that is becoming an increasingly concern in Côte d'Ivoire. However, this waste, combined with other simple plant substrates, can be used in the vermicomposting process. That is the context in which this study is conducted, with the aim of determining the agronomic properties of different vermicompost made of oil palm empty fruit bunches combined with green waste (*Chromolaena odorata* leaves and grass clippings). For this purpose, plastic boxes of 1.5 L in volume were first filled with 800 g of soil. Then, 300 g of the different pre-composted substrates and 4 earthworms were added. In total, 4 treatments of 25 repetitions each were carried out. For all the treatments, treatments T3 (oil palm empty fruit bunches + Grass cutting + earthworms) and T4 (oil palm empty fruit bunches + *Chromolaena odorata* + Grass cutting + earthworms) presented the best values of the substrate decomposition capacity and physicochemical properties. The same is true for the mineral materials obtained. For these two treatments mentioned, the C/N ratio was around 15 and significantly higher than those of treatments T1 (oil palm empty fruit bunches + earthworms) and T2 (oil palm empty fruit bunches + *Chromolaena odorata* + earthworms), which were around 12. The pH values being variable at the beginning of vermicomposting were close to neutral at the end, thus indicating the maturity of the different vermicompost produced.Vermicompost resulting from co-composting of empty fruit bunches of oil palms and green waste appears to improve nutrient availability, structure and microbial activity of the vermicompost to promote good development of cultivated plants.

Keywords : Agronomic property, Co-composting, Green waste, Oil palm empty fruit bunches,Vermicompost.

1. INTRODUCTION

The pressures on available agricultural resources in many tropical African countries are increasing due to fast population growth [1]. To this end, within agricultural lands, few plant residues are left both in the soil and on the surface, which leads to land fragility and a decline in productivity [2,3]. Palliative measures such as the use of sustainable agriculture instead of conventional agriculture based on the intensive use of agrochemicals are envisaged in order to meet the future food needs of populations without exhausting natural resources [4]. In this context, the enrichment of soils with organic matter involves all organic waste products used as amendments or fertilizers [5]. However, in many African oil palm industries, liquid waste (liquid sludge, washing water, etc.) and solid waste (oil palm empty fruit bunches) are generally discharged into the environment without treatment [6]. This waste, which poses major management challenges, can be turned into useful products for other sectors such as energy and agriculture. In this respect, palm stalks can indeed be used as compost to improve soil fertility [7]. They can also be used in the vermicomposting process which is a new, reliable alternative to increase agricultural production and restore soil productivity [8]. Numerous studies have revealed the strong potential of palm stalks in the context of composting and co-composting with animal waste for the production of nutrients and organic matter capable of improving both the physical and chemical properties and the soil fertility [9,10,6,8]. Furthermore, despite good conditions for producing compost, it has limitations such as the need to set up a composting site, the high risk of weeds, the high working time, and the response of crops to this compost, which varies according to the type of organic matter used and the application rate [11,12]. These shortcomings could be improved by vermicompost, which uses less space with a final product directly assimilated by plants. Thus, the present study aims to determine the agronomic properties of different vermicompost produced from oil palm empty fruit bunches combined with green waste. For this purpose, (i) the variation in the quantity of the different substrates subjected to vermicomposting will be evaluated, (ii) the rate of organic matter and the pH produced by the substrates subjected to vermicomposting will be analyzed. (iii) the chemical parameters of the different vermicompost will be determined.

2. MATERIAL AND METHODS

2.1. Study area

The present studywas carried out in the autonomous district of Abidjan within the Nangui ABROUGOUA University (UNA) located between 5°21 and 5°23 North latitude and 4°01 and 4°09 West longitude. UNA is halfway between the municipalities of Adjamé and Abobo. It is limited to the North by the municipality of Abobo, to the South by Adjamé-Williamsville, to the East by the Military Hospital of Abidjan (HMA) and to the West by the Adjamé-Abobo road axis and Filtisac (spinning mill) [13]. The climate is humid subequatorial.

2.2. Preparation and pre-composting of substrates

The substrates used for the experiment, composed of oil palm empty fruit bunches from an oil mill, *Chromolaena odorata* leaves and grass clippings collected from the UNA, were dried at room temperature for a week, then finely ground and sieved with a 1 mm mesh sieve. They were also pre-composted for 6 weeks to facilitate the activities of earthworms and the digestion of organic matter in the earthworms' digestive tracts (Fig 1).

Fig 1: Pre-composted substrates(A. Oil palm empty fruit bunches; **B.** *Chromolaena odorata* leaves; **C.** Grass clippings**)**

2.3. Experimental design

The compost bins consisted of 100 plastics boxes (1.5 L), with perforated closures for better aeration (Fig 2). The bottom of each box was pierced with tiny holes to allow water draining to avoid excessive water in the boxes. Each box was firstly filled with 200 g of lightly hydrated soil to provide shelter for the earthworms. Then, 800 g of the various pre-composted substrates were added and 4 earthworms were added. Each treatment was repeated 25 times. Each of these treatments had the following composition:

- **T1 :** Oil palm empty fruit bunches + Earthworms;
- **T2 :** Oil palm empty fruit bunches + *Chromolaena odorata* + Earthworms;
- **T3 :** Oil palm empty fruit bunches + Grass clippings + Earthworms;
- **T4 :** Oil palm empty fruit bunches + *Chromolaena odorata* + Grass clippings + Earthworms.

Fig 2: Composter made of 1.5 L plastic boxes

2.4. Nitrogen, phosphorus, and potassium determination

The total nitrogen (N) determination method was inspired by the Kjeldahl method NF, V04407 [14]. The carbon and nitrogen ratio were determined in the different treatments. The available phosphorus (P) was determined using the Olsen method modified by [15]. The potassium (K) concentration was determined using the saturation method with an ammonium acetate solution by bath [16].

Determination of the mineral matter content

For this operation, the test sample of 1g was calcined at 550°C for 4 hours. After calcination, the organic matter volatilizes and the mineral matter remains, which is calculated by the difference:

$$\mathbf{MM}(\%) = \frac{\mathbf{W1 - W0}}{\mathbf{SW}} \times \mathbf{100}$$

where **MM:** Mineral matter; W0: weight of empty crucible; **W1:** weight of crucible after calcination; **WS:** weight of test sample.

2.5. Determination of organic matter and organic carbon content

Organic matter was determined using the loss on ignition method [17, 18]. This method consisted of drying a 200 g sample of the substrate in an oven (Binder, Germany) for 2 hours at a temperature of 105°C (NF ISO 11465). Once dried, the sample was sieved using a 2 mm mesh sieve. Then 5 g of soil (M0) was taken from the sample and introduced into a platinum crucible of mass M1. This test sample of 5 g of substrate contained in the crucible was incinerated in a muffle furnace (Naberthem, Germany) for 4 hours at 550°C. The mass M_2 of the whole (crucible + ash) was determined. The mass M_0, M_1, and M_2 were determined using an electric balance (Shimadzu, Japan) with a precision of ± 0.01 g. The organic matter and organic carbon content were determined according to the following formulas:

$$\mathbf{OM}\ (\%) = \frac{[\boldsymbol{M_0} - (\boldsymbol{M_2} - \boldsymbol{M_1}) \times \mathbf{100}]}{\boldsymbol{M_0}}$$

$$\mathbf{TOC}\ (\%) = \frac{\mathbf{OM}\ (\%)}{\mathbf{1,724}}$$

where **OM:** Organic matter; **TOC:** Total organic carbon; 1.724: Conversion factor for OM and TOC.

2.6. Determination of the percentage of organic matter loss

The loss of organic matter was determined by the following equation:

$$\mathbf{POM} = \frac{\mathbf{OMi - OMf}}{\mathbf{OMi}} \times \mathbf{100}$$

where: **POM:** Percentage of organic matter loss; **OMi:**Organic matter in the substrates before the start of breeding**; OMf:**Organic matter in the substrates at the end of the breeding period.

2.7. Determination of the percentage loss of the quantity of the substrate

The percentage of substrate loss was determined using the following equation:

$$\textbf{PSR}\ (\%) = \frac{\textbf{Wi} - \textbf{Wf}}{\textbf{Wi}} \times \textbf{100}$$

Where:**PSR:** Percentage of substrate reduction; **Wi:** Weight of substrate before the start of breeding; **Wf:** Weight of substrate at the end of the breeding period.

2.8. Determination of pH

pH was measured with a HANNA HI 83114 portable pH meter. Twenty (20) g of sample were diluted into100 ml of ultra-pure water.

2.9. Statistical processing

The results of the measured parameters were analyzed using R 3.2.1 software. One-way analysis of variance (ANOVA1) was used to compare the means of the values of parameters. Before performing these comparison tests, the normality of the data was checked using the ShapiroWilk test. The significance level of the probability value for each test was set at $\alpha = 0.05$. When the analysis revealed significant differences, Turkey's HSD post-hoc test was used to test the differences.

3. RESULTS AND DISCUSSION

3.1. Variation in residue quantity

After two months of earthworm activity, treatment T4 (37.90±97.57%) gave the highest percentage of substrate loss, followed by treatments T3 (35.92±97.90%), T2 (21.88±98.18%) and T1 (14.02±97.94%). However, the substrate loss percentages of treatments T4 and T3 were both significantly different ($p < 0.05$) from those of treatments T2 and T1, between which no significant difference was observed (p>.05) (Table 1).

Table 1 : Variation in substrate quantity for the different treatments

Treatments	Initial dry matter (g)	Final dry matter (g)	PSR(%)
T1	300	257.92±2.06	14.02±97.94[b]
T2	300	234.34±1.82	21.88±98.18[b]
T3	300	192.05±2.10	35.92±97.90[a]
T4	300	186.28±2.43	37.90±97.57[a]

T1: Oil palm empty fruit bunches + earthworms; **T2:** Oil palm empty fruit bunches +*Chromolaena odorata* + earthworms; **T3:** Oil palm empty fruit bunches + grass clippings + earthworms; **T4:** Oil palm empty fruit bunches + *Chromolaena odorata* + grass clippings + earthworms. **PSR :** Percentage of substrate reduction
Values followed by the same letter in a column are not significantly different (p>.05) according to the tukey test.

3.2. Variation of organic matter rate and physical and chemical properties

Treatments T4 (29.14 ± 3.18%) and T3 (26.32 ± 2.96%) showed the highest percentages of organic matter loss, followed by treatment T2 (17.08 ± 4.01%) after 2 months. On the other hand, treatment T1 (10.53 ± 2.36%) showed the lowest percentage of organic matter loss. As for pH, at the start of the experiment, the highest values were observed in treatments T4, T2 and T3, with treatment T1 showing the lowest value. At the end of the experiment, a drop in the initial pH value was observed for all treatments. Overall, the pH values were close to neutral, and no significant difference was observed between them (P>.05) (Table 2).

Table 2 :Physico-chemical parameters of the substrates

Treatments	OM_i(%)	OM_f(%)	POM (%)	pH_i	pH_f
T1	76.68±4.02	68.60±1.46	10.53±2.36	6.83±0.06	6.05±0.03
T2	82.60±1.16	68.49±3.28	17.08±4.01	8.06±0.03	6.14±0.01
T3	88.96±5.43	65.54±3.02	26.32±2.96	8.02±0.01	6.03±0.03
T4	93.38±4.21	66.16±2.13	29.14±3.18	8.35±0.05	6.16±0.02

T1: Oil palm empty fruit bunches + earthworms; **T2:** Oil palm empty fruit bunches + *Chromolaena odorata* + earthworms; **T3:** Oil palm empty fruit bunches + grass clippings + earthworms; **T4:** Oil palm empty fruit bunches + *Chromolaena odorata* + grass clippings + earthworms; **POM:** Percentage of organic matter loss; **OMi**: Organic matter in the substrates before the start of breeding**; OMf:**Organic matter in the substrates at the end of the breeding period ; **pHi:** Initial hydrogen potential; **pHf:** Final hydrogen potential.

Table 3 shows some of the chemical characteristics of the nutrients in the vermicompost obtained. On the whole, the nutrient content of the various vermicomposts complies with standards, but with better levels for treatments T4 and T3. Mineral matter (MM) release percentages for treatments T4 (92.44±5.70%) and T3 (91.16±2.08%) were higher and statistically different (p<.05) from those for treatments T2 (76.37±2.11%) and T1 (71.92±3.02%). The same trends were also observed for the percentage of phosphorus (P) and organic carbon (OC). Nitrogen (N), potassium (K) and carbon-to-nitrogen (C/N) ratios were also significantly higher in treatments T4 and T3 than in T1 and T2. However, there was no significant difference between them (p>.05).

Table 3: Chemical parameters of vermicompost

Treatments	MM (%)	TOC (%)	N (%)	P (%)	K (%)	C/N
T1	71.92±3.02^{b}	18.68±1.08^{b}	1.69±3.45^{a}	0.09±2.61^{b}	1.96±2.03^{b}	11.05±5.83^{a}
T2	76.37±2.11^{b}	22.60±3.48^{b}	1.88±4.09^{a}	0.13±4.01^{b}	2.30±2.25^{a}	12.02±3.02^{a}
T3	91.16±2.08^{a}	29.96±3.06^{a}	1.98±3.31^{a}	0.47±6.34^{a}	3.62±1.92^{a}	15.08±3.29^{a}
T4	92.44±5.70^{a}	32.38±5.12^{a}	2.15±2.59^{a}	0.51±5.17^{a}	3.84±2.67^{a}	15.05±4.41^{a}

T1: Oil palm empty fruit bunches + earthworms; **T2:** Oil palm empty fruit bunches + *Chromolaena odorata* + earthworms; **T3:** Oil palm empty fruit bunches + grass clippings + earthworms; **T4:** Oil palm empty fruit bunches + *Chromolaena odorata* + grass clippings + earthworms;**MM :** mineral matter ; **TOC :**Total organic carbon ; **N :** nitrogen ; **P :**Phosphorus ; **K :**Potassium ; **C/N :**Ration carbon to nitrogen,
Values followed by the same letter in a column are not significantly different (p>.05) using Turkey's HSD post-hoc test.

Overall, the best values for substrate decomposition capacity and physico-chemical properties (organic matter content, pH, chemical parameters) of the various vermicompost products made from oil palm stalks were obtained with treatments T3 (Oil palm empty fruit bunches + grass clippings) and T4 (Oil palm empty fruit bunches + *Chromolaena odorata* + grass clippings). This indicates the possibility of obtaining quality vermicompost from the co-composting of oil palm empty fruit bunches with poaceous residues (grass clippings) and especially with the combination of different types of plant residues (*Chromolaena odorata* + grass clippings). These results corroborate those of [19], who showed in their study on the use of three agricultural by-products (cocoa bean husks, coffee parchment and sawdust) for vermicompost production that combining several substrates makes it possible to make the most of their beneficial contributions and minimize any disadvantages linked to their respective chemical compositions. In the case of these two treatments (T4 and T3), their high mineralization capacity may reflect the ability of the *Eudriluseugeniae* used for vermicomposting to play an active role in decomposing the organic matter present and releasing plant-available nutrients. These results concur with those of [20] who, proved that favorable environmental conditions facilitate the capacity of earthworms to mineralize available organic matter. Moreover, the higher mineral content of vermicompost of treatments T3 and T4 is linked to the activity of the microbial flora present in the earthworms' digestive tract. This digestion reflects the decrease in organic matter and total carbon during vermicomposting due to the fact that during the process, microorganisms consume carbon as an energy source for their metabolism, thus mineralizing organic matter. Our results are in agreement with those of [21], who used vermicomposting of municipal organic waste to demonstrate the effectiveness of earthworms in ensuring efficient mineralization of the substrates at their disposition. Concerning the C/N ratio, treatments T3 and T4 showed the highest values. However, these were lower than the optimum C/N ratio of the initial composts, which should be between 25 and 30, although ratios between 20 and 40 are also acceptable [22]. This drop in values would reflect the relatively rapid mineralization of nitrogen and consequently its availability in composts [23]. Studies by numerous authors have also shown that the C/N ratio is an indicator of compost maturity and quality, and that this ratio at the end of composting should be around 10-15 [24; 25]. This is in accordance with the results obtained in the present study. During the vermicomposting process, similar results were obtained by [26]. They showed a variation in N, P and K contents in composts depending on the substrates used. From a general point of view, since the vermicompost produced are considered to be very rich in nutrients, we can deduct from these results that the oil palm stalks constituting the base substrate would be very rich in nutrients, which could be beneficial for soils and plants. These results corroborate the work of [6] and [7], who showed that palm stalks are rich in nutrients. Also, the amount of nutrients contained in grass clippings and *Chromolaena odorata* leaves would have increased the N, P and K contents in oil palm empty fruit bunches. In addition, the nutrient richness of raw oil palm empty fruit bunches could also be due to the fertilizers employed on the oil palm plantations. Depending on the mix of materials being vermicomposting, the quantity of each material could have a significant effect on nutrient levels. For example, both T4 and T3 were found to be richer in nutrients than T1 and T2. These results corroborate the work of [19] on the use of three agricultural by-products (cocoa bean husks, coffee parchment and sawdust) for the production of vermicompost, which showed that the combination of several substrates makes it possible to make the most of their beneficial contributions and minimize any drawbacks linked to their respective chemical compositions. Moreover, for all the treatments subjected to vermicomposting, the pH decreased reaching neutral. According to [28], this drop in pH can be explained by the production of organic acids following the degradation of carbohydrates, lipids and other substances. Also, the production of CO_2 during aerobic degradation contributes to the acidification of the environment by the dissolution of CO_2 in water which produces carbonic acid. These results are in accordance with those [29], who state that under experimental rearing conditions, the pH of the substrate tends to decrease.

4. CONCLUSION

The co-composting of oil palm empty fruit bunches and green waste leads to very good activity earthworms, which ensures excellent decomposition and mineralization of the substrate at their disposal. And this, especially for green waste such as grass clippings and when it is at the same time as *Chromolaena odorata* both easy to access. The same is true for the resulting vermicompost having the physicochemical properties meeting the standards of a mature vermicompost likely to be used as an organic amendment and having the capacity to improve the agronomic performance of a plant. The combination of oil palm empty fruit bunches with grass clippings only or with grass clippings and *Chromolaena odorata* both easy to obtain seems to be suitable to the production of vermicompost with advantageous agronomic properties for a good development of many cultivated plants.

CONSENT (WHEREEVER APPLICABLE)

All authors declare that 'written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

ETHICAL APPROVAL (WHEREEVER APPLICABLE)

All authors hereby declare that "Principles of laboratory animal care" (NIH publication No. 85-23, revised 1985) were followed, as well as specific national laws where applicable. All experiments have been examined and approved by the appropriate ethics committee.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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