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ORIGINAL RESEARCH

An effective organic waste recycling through vermicomposting technology for sustainable agriculture in tropics

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Abstract

Purpose The management of household wastes has been a real challenge for the capital city of Cameroon for some years now. In order to adopt ecological and sustainable strategies for better management of organic fraction of solid wastes, the present work was aimed to propose a sustainable alternative for the recycling of household organic waste through a vermicomposting process.

Method A vermicomposting of household organic waste was carried out during 46 days, preceded by 23 days of pre-composting. Then, three treatments were established by mixing epigeic earthworms with different proportion of pre-composted waste. Maturation parameters such as pH, electrical conductivity (EC), C/N ratio, ammonium ($N\text{-}NH_4^+$) and total organic matter (TOM) were monitored about four weeks. The agronomic quality of the vermicompost was also determined at the end.

Results During pre-composting, the temperature reached a maximum of 54.3±5.4°C suitable for the elimination of potential pathogen. The pH varied between 9.44 and 8.53 leading towards neutrality at the end of the vermicomposting process. The obtained mean values of C/N ratio and the TOM were respectively 11.04-11.68 and 25.82-27.19% in line with the AFNOR (NFU 44-051) guideline. The obtained vermicompost revealed high levels of nutrients such as N, P, K, Ca and Mg. The phytotoxicity test on lettuce showed germination rates above 50%, revealing the non-toxic nature of the vermicompost produced.

Conclusion The vermicompost were rich in nutrients and exhibited the non-phytotoxicity. Thus, vermicomposting can be applied in the context of Cameroon to transform organic waste into organic fertiliser suitable for sustainable agriculture.

Keywords Waste management, Vermicomposting, Epigeic earthworms, Maturation, Phytotoxicity, Agricultural inputs

Introduction

Population growth, combined with rapid urbanization and changing lifestyles, contributes to the generation of huge amounts of solid waste worldwide (Singh et al. 2011). Presently most of the waste generated is either disposed of in an open dump in developing countries or in landfills in the developed ones. Landfilling as well as open dumping requires lot of land mass and could also result in several environmental problems. Domestic waste management represents a major challenge in the city of Yaounde with an estimated production of waste of about 1200 tons.day^{-1} (HYSACAM 2017) and an average specific production of 0.62 kg.capita^{-1}.day^{-1} (Ngnikam et al. 2017). A fraction of waste produced in the city is anarchically dumped into the environment, forming unsightly and foul-smelling dumps on public roads, in gutters, waterways and open spaces (Ben Ammar and Foully 2014). This results in pollution of

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natural resources and development of breeding grounds for disease-carrying insects in this tropical area. The other fraction is collected by trucks and transported to a landfill site on the periphery of the city where there is a landfill. However, 76% of this waste produced represents the fermentable organic portion which is very little recovered (Ngnikam et al. 2017). The fermentable organic portion could be, however, recovered and used in the production of vegetables in urban or peri-urban areas of the city. In Yaounde, vegetable production is a real subsistence activity that not only provides fresh food for inhabitants and improves their income but also offers important employment opportunities to disadvantaged people (Roy 2009; Dongmo et al. 2010). However, the expansion of the city and the population growth increase the difficulties associated with this agricultural activity, particularly the problems of access to land and agricultural inputs. This results in an intensive and continuous exploitation of cultivated plots. In addition, the overuse of chemical fertilisers contributes to soil acidification, while their combination with organic manures reduces this acidity (Boubié et al. 1997; Kumar Bhatt et al. 2019). In the search for sustainable waste management strategies in Yaounde and to meet the organic amendment needs of vegetable producers, vermicomposting is found to be one of the ideal solutions. This green technology has a dual interest because it allows rapid conversion of organic waste into a value-added product called vermicompost and, the control of pollution by organic solid waste (Bhat et al. 2015). Vermicomposting is an appropriate, hygienic and cost-effective technique for converting organic waste by earthworms and microorganisms into a more stable product (US EPA 1980; Suthar 2010; Motcha et al. 2019). The end product resulting from this process, called vermicompost, is an organic fertiliser with excellent physicochemical and microbiological properties useful for soil fertility and plant growth. It is rich in N, P and K, micronutrients and microbes beneficial to the soil (Sinha et al. 2012; Kumar et al. 2018; Sakthika and Sornalaksmi 2019). Vermicompost also has high porosity, good drainage, good water retention capacity, microbial activity, excellent nutritional status and good buffering capacity (Atiyeh et al. 2001; Dominguez 2004). Thus, it is a sustainable alternative to chemical fertilisers which provides excellent growth to plant and protects crop; thereby, increasing agricultural productivity (Chauhan and Singh 2013, 2015; Gerusa et al. 2019). Contrary to some countries where vermiculture is developed notably in India (Sinha et al. 2012), and in Egypt (Abul-Soud et al. 2009), this technology and the identification of worms are almost non-existent in Cameroon. In this country, vegetable producers are faced with a scarcity of organic amendments, for their crops (Nguegang 2008). Producing vermicompost from household organic waste could enable them to solve this problem. However, the vermicomposting technology is still not vulgarized and the process is poorly mastered in the agricultural sector of Cameroon. Therefore, the aim of this work was to propose an effective and sustainable alternative for the recovery of organic household waste through vermicomposting process for the urban or peri-urban vegetables production in Yaounde.

Materials and methods

This study was conducted from March to June 2019 in the 7th sub-division of Yaounde at the market garden lowland of Nkolbisson located between latitudes 3°52›20.5›› and 3°52›51.2››N and longitudes 11°27’11.16 ‘’ and 11°27’21.96”E.

Feedstock preparation and pre-composting

Domestic organic waste was collected in some neighbourhoods of Yaounde and transported to the experimental site under shaded area. Then, it was separated manually to remove the non-fermentable fraction. The fermentable fraction composed of kitchen waste (vegetable stems and leaves, fruit and starchy peels, egg shells) was added to the carbon material made up of sawdust, paperboard without ink, dry corn leaves and stalks in order to adjust the C/N ratio. Waste was cut into small pieces and put in a single pile of about 656 kg on the ground and covered with a perforated tarpaulin. The pre-composting process was carried out for 23 days to complete the thermophilic phase and preserve the earthworms, and also to eliminate pathogenic germs (Ben Ayed et al. 2005). During this phase, the temperature was measured twice a week and the pile was turned 2 times in 3 weeks to improve aeration and oxidation of the organic matter (OM) (Temgoua et al. 2014). At the end of the pre-composting phase, a sample was analysed to mark the starting point of vermicomposting (Table 1).

Table 1 Physico-chemical characteristics of the pre-composted waste

Parameters	Pre-composted waste characteristics
Weight (kg)	450
pH	8.27±0.01
EC (µS.cm^{-1})	805±2
TKN (%)	0.405±0.002
P (mg.kg^{-1})	4.91±0.04
K (mg.kg^{-1})	2824±2
Ca (mg.kg^{-1})	81±1
Mg (mg.kg^{-1})	23±2
TOC (%)	19.14±0.04
TOM (%)	38.28±0.07
C/N ratio	47.27±0.29
N-NH$_4^+$ (mg.kg^{-1})	1705±3.60

Vermicomposting

Experimental unit

Vermicomposting was conducted in wooden boxes perforated at the bottom (60 cm x 60 cm x 65 cm). The pre-composted waste was weighed at 450 kg and transferred into the boxes. The epigeic earthworms which are suitable for vermicomposting (Dominguez and Edwards 2010) were collected from piles of detritus and dead leaves in the area, and were kept in their litter. Since there was scarcity of worms during the dry seasons, sufficient number of earthworms could be collected only after several collection campaigns. In each box of pre-compost, 400 epigeic earthworms were inoculated in way to create a discontinuous vermicomposting system. The experimental unit (Fig. 1) was composed of 3 treatments with 3 replications (V1: 25 kg pre-compost + 400 earthworms; V2: 50 kg pre-compost + 400 earthworms; V3: 75 kg pre-compost + 400 earthworms). This experimental set-up was installed under the shade of the tree and covered with cardboard to protect from the weather and maintain moisture and temperature conditions favourable to the degradation of the organic waste by earthworms and microorganisms.

Fig. 1 Experimental unit

Changes in maturation parameters

To evaluate the maturation parameters during vermicomposting, pH, temperature (T°C), electrical conductivity (EC, µS.cm^{-1}), moisture (%), total organic carbon (TOC %), total organic matter (TOM %), total nitrogen (TKN), C/N ratio and ammonium content (N-NH$_4^+$) were analysed throughout the process from the 4th week to the 7th week. During this period, samples of 500 g of vermicompost were taken weekly from each treatment. They were collected from top to bottom of each box, and the samples were transported to the Laboratory for analysis. After 46 days (end of the process), the vermicomposts were harvested and the samples were collected from each treatment and analysed to determine the nutrient content. The nutrients analysed were: TKN, P, K, Ca and Mg.

Physico-chemical analyses

The temperature was measured *in situ* in each box at two-day interval using a TFA digital thermometer equipped with a probe and an accuracy of ± 0.5°C. The pH and conductivity were determined from a 1:5 (w/v, compost/water) distilled water extraction of the vermicompost. The mixture was brought to room temperature on a magnetic agitator for 30 minutes. After filtration, the extract was used for determination of pH and EC with pH meter (HACH HQ11d) and conductivity meter (HACH HQ14d), respectively. The moisture content of the fresh samples was determined by weight loss during drying at 105°C in an oven (P SELECTA) for 24 hours. The determination of the total organic matter (TOM) was carried out by calcination of 50 g of vermicompost sample (previously oven-dried at 105°C) in an oven (Carbolite ELF 11/14B) at 550 °C for 2 hours. The proportion of TOC was calculated by dividing the TOM by the factor 2.0 according to Giroux and Audesse (2004). TKN content was determined by the micro-Kjeldahl method (APHA 1992). This dosage was carried out through wet acid digestion of 0.5 g samples followed by distillation in Buchi K-350 distiller unit and back titration with sulphuric acid (H_2SO 0.1N). Total P was determined by HACH method with a spectrophotometer (DR/3900). Potassium (K), calcium (Ca) and magnesium (Mg) were assayed by atomic absorption method using atomic absorption spectrophotometer (AAS) (Okalebo et al. 2002). All these analyses were performed in triplicate.

Phytotoxicity test

The phytotoxicity test consisted of assessing the germination capacity of lettuce seeds (*Lactuca sativa*) in vermicompost. For this purpose, lettuce seeds obtained from the market place were germinated on different substrate compositions using the modified method of Juste et al. (1983). The reference substrate was sand with a granulometry of 2 mm. The established substrate compositions (100% sand; 25% sand +75% vermicompost; 75% sand + 25% vermicompost and 100% pure vermicompost) were used in triplicates. The seeds were sown at a rate of 20 seeds per pot containing the substrate soaked with distilled water (Fig. 2). The pots were kept in the dark at room temperature for seven days and the germination rate (GR) was calculated by the following formula:

$$\mathrm{GR} = \frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ sown\ seeds} \times 100$$

Statistical analysis

The results presented are the mean of three replicates with standard deviation. A one-way ANOVA analysis was performed and a comparison of mean with Tukey test was done with the statistical significance level of $p<0.05$. All data were processed using R software and the graphical presentation was performed using Graph-Pad Version 6.

Results and discussion

Changes in temperature during pre-composting and vermicomposting

During pre-composting, a rapid increase in temperature was observed in the pile reaching a maximum of 55.1±5.4°C (Fig. 3). This temperature remained high in the range of 51.3-54.3°C for 9 days. The increase in temperature recorded during pre-composting indicates the oxidation of the organic matter by thermophilic microorganisms. Temperatures between 50 and 60°C for two consecutive days are essential for compost sanitation and weed seed removal (Ben Ayed et al. 2005; Awasthi et al. 2015). After 12 days, the temperature decreased considerably and stabilised at 32.6°C, moving towards the ideal room temperature for the start of vermicomposting. A similar temperature evolution was

Fig. 2 Germination substrate

recorded by Singh and Kalamdhad (2015). Fig. 4 presents the temperature variation during vermicomposting, a gradual decrease in temperature with some fluctuations was observed in all 3 treatments. The variations recorded throughout the experiment were as from the highest to the lowest: 32.6 ± 1.1°C to 22.9 ± 0.2°C in V3 followed by 28.8 ± 2.3°C to 22.3 ± 0.2°C in V2 and then 25.6 ± 0.9°C to 21.6 ± 0.3°C in V1. The decrease in temperature from 32.6°C to 22.9°C during vermicomposting indicates the phase of compost maturation according to Dominguez and Edwards (2010). In addition, Dominguez (2004) observed that earthworm activity is optimal between 15-30°C.

Changes in pH and electrical conductivity

For all treatments, the pH remained alkaline (8.53-8.60) (Fig. 5a). However, a significant increase ($p<0.05$) was recorded during the first month of the vermicomposting process for treatments V2 and V3. These pH values increased from 8.27±0.01 (pre-compost) to 9.44±0.12 (V2) and 9.40±0.20 (V3). In the 5th week, the pH decreased significantly in all 3 treatments and stabilised at a value of 8.53±0.35 (V1), 8.57±0.43 (V2) and 8.60±0.22 (V3). The increase in pH at the beginning of the process is attributed to the degradation of protein chains in organic matter that releases ammonia according to Bazrafshan et al. (2016). The decrease in pH during the week is attributed to the mineralisation of nitrogen and phosphorus compounds and the production of organic acids (Bhat et al. 2015; Pigatin et al. 2016). The pH change during vermicomposting is a result of the chemical composition of the feedstock according to Sharma and Garg (2019). Electrical conductivity (EC) values increased significantly in vermicompost till to the end of the process (Fig. 5b). This increase in EC

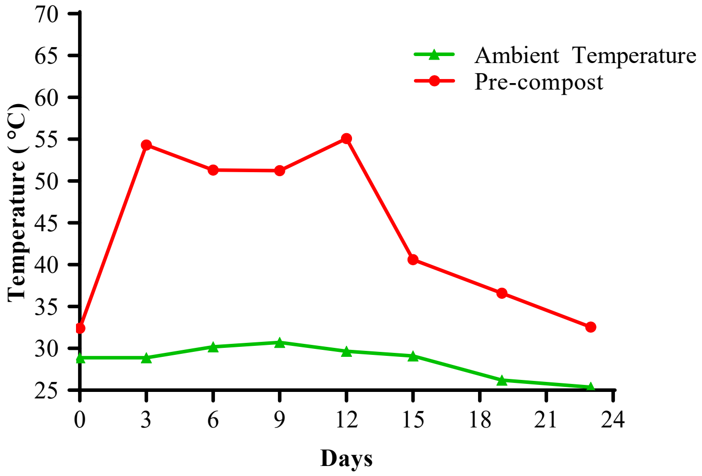

Fig. 3 Evolution of temperature during pre-composting

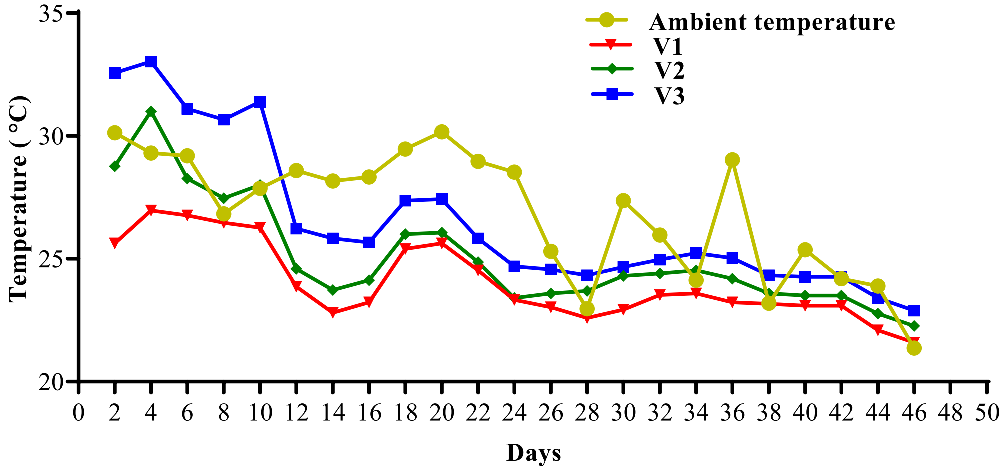

Fig. 4 Evolution of temperature during vermicomposting

would be the result of the release of different soluble salts in the vermicompost resulting from the mineralisation of organic matter by the combined action of earthworms and microorganisms (Kaviraj and Sharma 2003; Singh and Kalamdhad 2015). Huang et al. (2004) respectively. In this study a significant increase (p<0.05) in electrical conductivity was found in the three treatments at the end of vermicomposting compared to the initial pre-compost with the values of 1071±31.8 µS.cm^{-1} in V2 followed by 995±90.7 µS.cm^{-1} in V3 and 916±49 µS.cm^{-1} in V1.

Changes in moisture content

The monitoring of the moisture content during vermicomposting (Fig. 6) showed a significant (p<0.05) reduction in humidity in each treatment over time. Initially, the moisture content was 70±0.86% in the pre-compost. At the end of the 46 days of experiment, the moisture content decreased to 50.99±1.3%, 53.1±1.52% and 54.3±1.23% for treatments V1, V2 and V3, respectively. This water loss is attributed to leaching and evaporation due to intense microbial activity during the process. These values are within the range of humidity (10.6 - 80%) obtained by Manyuchi and Phiri (2013). However, these humidity values obtained are lower than the optimum value (80%) obtained by Pandit and Maheshwari (2012) on vermicomposting of sugarcane waste.

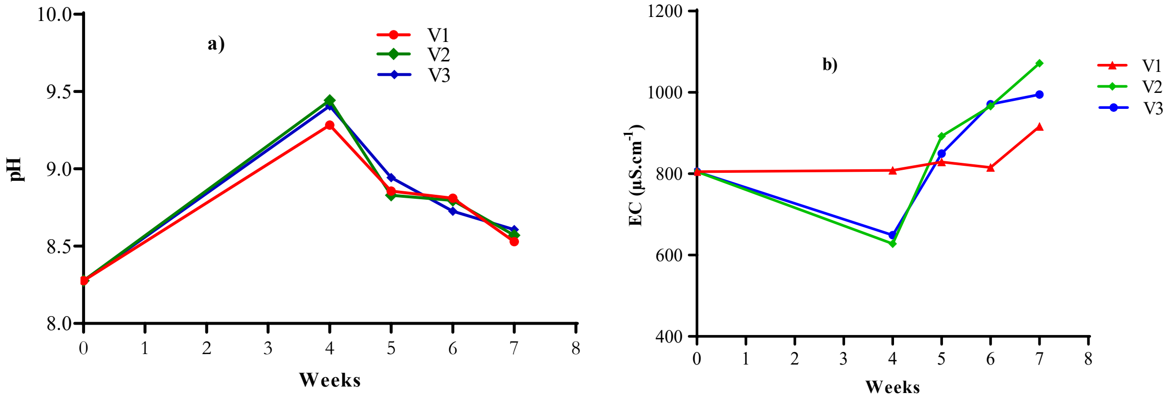

Fig. 5 Evolution of pH (a) and electrical conductivity (b) during vermicomposting

Changes in TOM and TOC content

The Fig. 7 describes a steady and significant (p<0.05) decrease in TOM and TOC content in all treatments during vermicomposting. The TOM content in the initial pre-compost (38.3±0.07%) decreased to 26.36±1.07%, 25.82±1.26%, and 27.19±1.15% for treatments V1, V2 and V3, respectively after 7 weeks of vermicomposting (end of the process). In the same way, TOC levels decreased from 19.14±0.04% (Pre-compost) to 13.17±0.53%, 12.91±0.63%, and 13.60±0.58% for

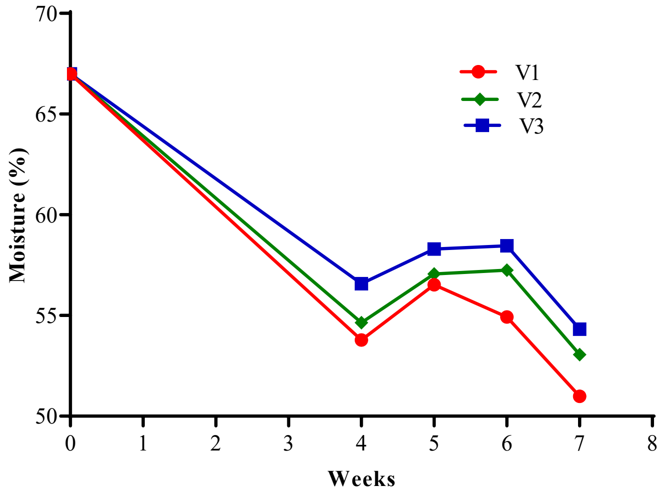

Fig. 6 Evolution of moisture during vermicomposting

V1, V2, and V3, respectively. Ramnarain et al. (2019) reported similar observations after 120 days of vermicomposting of different organic materials using *Eisenia foetida*. The decrease in TOM and TOC during vermicomposting results from the fact that during the process, earthworms and microorganisms consume carbon as a source of energy for their metabolism. Several studies have shown that a decrease in TOC indicates complete degradation, compost maturation, mineralisation and waste degradation (Hait and Tare 2011; Djumyom et al. 2016; Sharma et al. 2017).

Changes in N-NH_4^+ and total nitrogen (TNK) contents

Fig. 8a shows that N-NH_4^+ content was very high at the beginning of vermicomposting and decreased during the process indicating the compost maturity. A significant decrease ($p<0.05$) in N-NH_4^+ content was observed for all treatments. After 46 days, N-NH_4^+ content decreased from 1705±3.60 mg.kg^{-1} (pre-compost) to 270.33±24.01 mg.kg^{-1}, 311.33±22.72 mg.kg^{-1} and 351.67±23.44 mg.kg^{-1} in treatments V1, V2 and V3, respectively. The decrease in ammonium content is due to nitrification of N-NH_4^+ ions to N-NO_3^- or the loss by volatilisation as ammonia (NH_3) through the action of microorganisms during the vermicomposting process (Selim et al. 2012; Sharma et al. 2017). The N-NH_4^+ values obtained indicate the maturity of the vermicompost produced according to Tognetti et al. (2007). This author illustrated that the N-NH_4^+ content in a mature compost must be less than 400 mg.kg^{-1}. Thus, the values obtained in this study show that the vermicomposts can be applied in the field without hazards to crops. As presented in Fig. 8b, the results show that the content of total nitrogen (TKN) increased gradually and significantly ($p<0.05$) in all three treatments during the process. At the start of vermicomposting, the total N content was 0.405±0.002% (Pre-compost), then, this significantly increased in all treatments reaching values of 1.19±0.02% (V1), 1.11±0.07% (V2) and 1.13±0.04% (V3) at the end of the experiment. The Nitrogen content in the final vermicompost depend on the composition of feedstock and the activity of earthworms. Sharma and Garg (2019) obtained similar trends during recycling of lignocellulosic waste through vermicomposting. The increase in total nitrogen content is related to the degradation of proteins contained in OM and to N excretion by earthworms (Bhat et al. 2017).

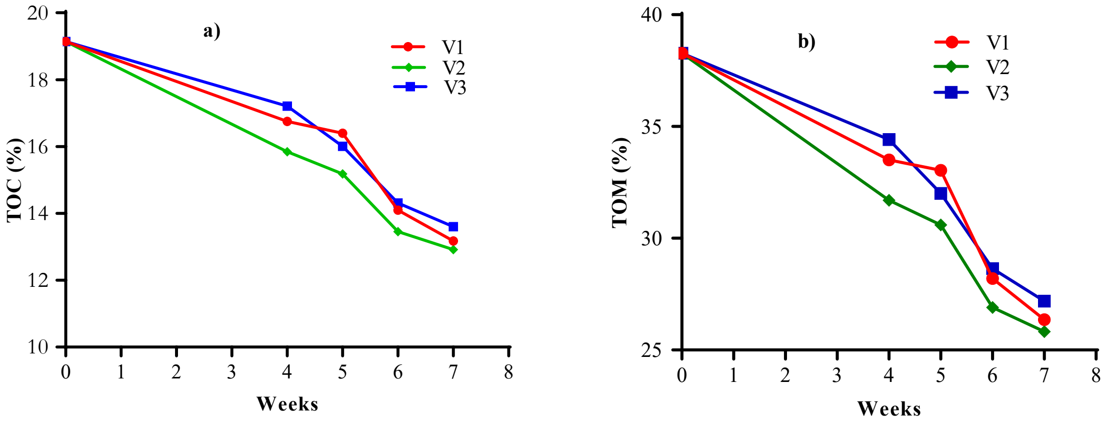

Fig. 7 Evolution of TOC (a) and TOM (b) during vermicomposting

Change in C/N ratio

The C/N ratio is a widely used parameter as an indicator of compost maturity. Fig. 9 shows a gradual and significant ($P<0.05$) decrease in this C/N ratio below 20:1 in all the treatments throughout the 46 days of vermicomposting. The values decreased from 47.25±0.29 in the pre-composting at the beginning of the process to 11.96±0.53 (V1), 11.68±0.46 (V2) and 11.04±0.31 (V3), respectively at the end of the process. The evolution of the C/N ratio in this study indicates the mineralisation and stabilisation of organic waste during vermicomposting in accordance with the work of Kohli and Hussain (2016). The decrease in this C/N ratio is related to the loss of total organic carbon through degradation of organic matter and the increase in total nitrogen

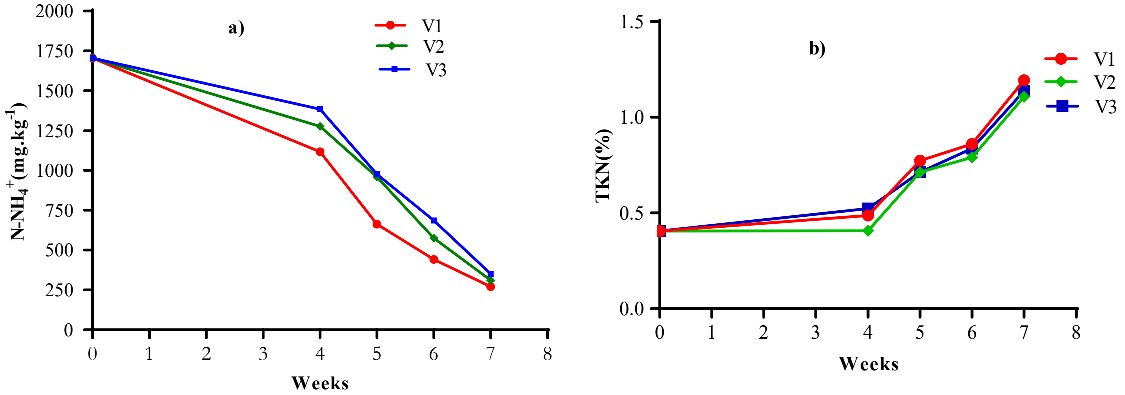

Fig. 8 Evolution of N-NH$_4^+$ (a) and Total Kjeldahl nitrogen (b) during vermicomposting

through the excretion of mucus, enzymes and nitrogenous excreta by earthworms in final product according to Suthar et al. (2012). Overall, these conditions therefore describe the quality of a mature vermicompost (Zhou et al. 2014).

Nutrient contents of vermicomposts

The nutrient contents of vermicompost notably N, P, K, Ca and Mg increased significantly ($p<0.05$) in all final vermicomposts compared to the initial pre-compost (Table 2). Several authors reported that during the vermicomposting process, earthworms and microorganisms interaction changes the chemical properties of the initial waste material, accelerating the mineralisation process and making nutrients available in the final product (Suthar et al. 2014; Bhat et al. 2017). After 46 days of vermicomposting, there was a significant increase in the P content of the harvested vermicomposts. Treatment V2 (21.64±6.52 mg.kg^{-1}) was the best in terms of phosphorus content, followed by V1 (19.36±5.84 mg.kg^{-1}) and V3 (11.05±2.63 mg.kg^{-1}). V2 and V1 were significantly more concentrated in total phosphorus than V3. Similar findings have been obtained by Alidadi et al. (2016). During the transit of organic matter through the gut of worms, organic acids and phosphatase solubilise the phosphorus and make it available (Dominguez et al. 2000; Bhat et al. 2017). Potassium (K) content was significantly ($p<0.05$) increased in harvested vermicomposts after 46 days. The highest values were recorded in treatments V1 (5979.3±81.93 mg.kg^{-1}) and V3 (5206.67±50.57 mg.kg^{-1}), compared to V2 (4152±35.9 mg.kg^{-1}), which was significantly different ($p<0.05$) from the other treatments. The increase in potassium content is due to increased microbial activity during the vermicomposting process (Suthar 2010; Vasanthi et al. 2013). The potassium concentration obtained in this study was higher than those obtained by Bhat et al. (2015) in the vermicompost of organic solid waste in rural area in India.

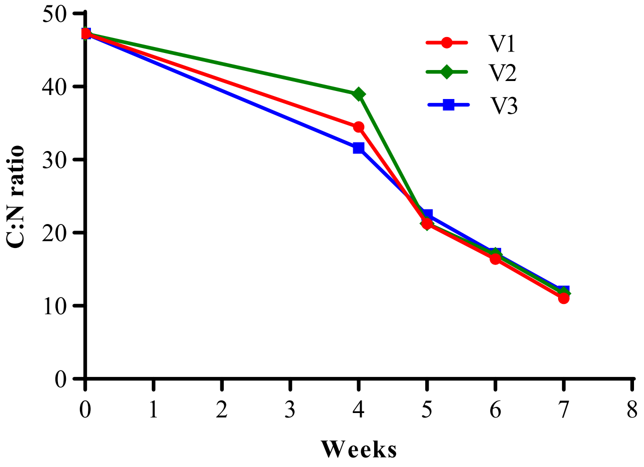

Fig. 9 Evolution of C/N ratio during vermicomposting

There was a significant difference (p<0.05) between these three vermicomposts for Ca and Mg content. In fact, treatment V2 (730±45.83 mg.kg^{-1}) had the highest calcium content (730±45.83 mg.kg^{-1}), followed by treatment V1 (526.67±50.33 mg.kg^{-1}) and treatment V3 (320±34.64 mg.kg^{-1}). Treatment V1 (521.33±15.27 mg.kg^{-1}) was the best in terms of Mg content followed by V2 (312±20.25 mg.kg^{-1}) and V3 (226.67±30.55 mg.kg^{-1}). Previous studies have found higher calcium levels (18922 mg.kg^{-1}; 1160-7480 mg.kg^{-1}) than those obtained in this study (Pigatin et al. 2016 ; Manyuchi et al. 2018). The nutrients were not linear with the dose of pre-compost. Indeed, the variation in nutrients content (N, P, K, Ca and Mg) in the different treatments might be due to the type of the waste, their composition, and the imperfect homogeneity of pre-composted waste. To solve this problem of nutrient variability in the different treatments, it would be interesting to extend the duration of pre-composting in order to improve the homogeneity of the pre-composted waste.

Phytotoxicity

The results of phytotoxicity test of the obtained vermicompost on lettuce seeds (*Lactuca sativa*) are presented in Table 3. The germination test is one of the phytotoxicity endpoints that indicates the maturity of the compost (Kabil et al. 2016; Chennaoui et al. 2018). In general, the vermicomposts produced did not show any significant toxicity. The germination test on lettuce seeds revealed the highest germination rate of 76.67% in treatment of 75% sand and 25% V2 vermicompost followed by treatment of 75% sand 25% V3 vermicompost (75% germination) and treatment of 100% V2 vermicompost (70% germination) (Table 3). These results are consistent with those of Attrassi et al. (2005) who consider that the phytotoxicity of compost may be related to the applied rate. Compaoré et al. (2010) and Chennaoui et al. (2016) obtained slightly higher germination rates with corn and beans and on wheat and tomato, respectively. This difference could be due to the type and quality of the seed used for the test. According to Kabil et al. (2016), the germination depressing effect of compost would depend both on the type of compost and the species or variety of plants used.

Table 2 Physico-chemical characteristics and macronutrient contents in final vermicomposts

Parameters	Pre-compost	Treatments V1	Treatments V2	Treatments V3	Switzerland Guidelines (Trachsel et al. 2010)	French Guideline (NFU 44-051) (SATEGE 2016)
pH	8.27±0.01^{a}	8.53±0.35^{ab}	8.57±0.43^{ab}	8.60±0.22^{b}	<7.8	/
EC (µS.cm^{-1})	805±2^{a}	916±49^{b}	1071±31.8^{c}	995±90.7^{d}		
TKN (%)	0.405±0.002^{a}	1.19±0.02^{b}	1.11±0.07^{c}	1.13±0.04^{bc}	1	<3
P(mg.kg^{-1})	4.91±0.04^{a}	19.36±5.84^{b}	21.64±6.52^{b}	11.05±2.63^{c}	/	/
K (mg.kg^{-1})	2824±2^{a}	5979.3±81.9^{b}	4152±3.9^{c}	5206.67±50.57^{b}	/	/
Ca (mg.kg^{-1})	81±1^{a}	526.67±50.3^{b}	730±45.83^{c}	320±34.64^{d}	/	/
Mg (mg.kg^{-1})	23±2^{a}	521.33±15.2^{b}	312±20.25^{c}	226.67±30.55^{d}	/	/
TOC (%)	19.14±0.04^{a}	13.17±0.53^{b}	12.91±0.63^{b}	13.60±0.58^{b}		/
TOM (%)	38.28±0.07^{a}	26.36±1.07^{b}	25.82±1.26^{b}	27.19±1.15^{b}	<50	≥20
C/N ratio	47.27±0.29^{a}	11.04±0.31^{b}	11.68±0.46^{b}	11.6±0.53^{b}		>8

For each parameter, means following with the same letter $^{(a, b, c, d)}$ are not significantly different at 5% threshold at the Tukey test.

Table 3 Phytotoxicity test of vermicompost on lettuce seeds (*Lactuca sativa*)

Substrate	Germination rate (%)
Sand (100%)	100^{a}
25 % Sand + 75 % V1	60.00±22.91^{bc}
25 % Sand + 75 % V2	63.33±15.27^{bc}
25 % Sand + 75 % V3	66.67±18.92^{bc}
75 % Sand +25 % V1	63.33±12.58^{bc}
75 % Sand +25 % V2	76.67±5.77^{b}
75 % Sand + 25 % V3	75.00±14.14^{bc}
100 % V1	65.00±0.00^{bc}
100 % V2	70.00 ±13.23^{bc}
100 % V3	55.00 ± 9.13^{c}

Means following with the same letter are not significantly different at 5% threshold

Conclusion

Vermicomposting is a fast and efficient ecological way to recycle organic household waste. This study showed at the end of 46 days of vermicomposting that all treatments had reached maturity. They were rich in macronutrients (N, P, K, Ca and Mg). The vermicompost (V1) was richer in total nitrogen, K and Mg, while the vermicompost (V2) contains more calcium and phosphorus. The vermicompost (V3) was the least rich of the three except in potassium. The germination rate of lettuce seeds (>50%) shows that the harvested vermicomposts did not present any significant phytotoxicity. A moderate rate of vermicompost application (25%) of V2 and V3 vermicompost produced maximum germination of lettuce seeds. Thus, vermicomposting technology is viable to manage household wastes by adding value to it.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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