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Effects of Four Different Media from Selected Agricultural Wastes on the Total Production and Nutrient Profile of Vermicompost

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ABSTRACT
Large volumes of agricultural waste and residue are produced by agricultural activities in the tropics annually. Burning is still a common method of disposal, although it pollutes the environment. Vermicomposting is an alternate technique for managing agricultural waste. This study was conducted to ascertain the yield and particular chemical characteristics of vermicompost produced by earthworm breeding in various agricultural wastes. Agricultural waste including mushroom culture by-products, cow dung, oil palm branch residue, and sugarcane bagasse were used as raising base of African Nightcrawler earthworms (*Eudrillus eugeniae*). The completed vermicompost yields and selected chemical properties were determined. Earthworms in cow dung produced the maximum amount of vermicompost in terms of dry weight, followed by those in mushroom culture by-products, oil palm branch residue, and bagasse. The largest amounts of humic acid, nitrogen (N), and potassium (K) were found in vermicompost from cow dung. The maximum electrical conductivity (EC), organic matter, magnesium (Mg), and manganese (Mn) were found in vermicompost from oil palm branch residue. Bagasse vermicompost had the greatest pH, phosphorus (P), iron (Fe), zinc (Zn), and copper (Cu) values. Vermicompost derived from different feedstocks will produce different total nutrients contents and vermicompost quality. As a result, cow dung is recommended to be used as the primary material and mixed with specific other agricultural waste products as raising base materials to generate high grade vermicompost.

Keywords: Vermicompost, Nutrient Profile, Mushroom Culture By Product, Cow Dung, Oil Palm Branch Residue, Bagasse

1. Introduction

Vermicompost is defined as peat-like, finely broken-down materials produced by a non-thermophilic process that involves the biodegradation and stabilization of organic materials through interactions between earthworms and microorganisms. Utilizing specific earthworm species might fasten the conversion of organic waste and result in a better-quality end product (Ndegwa & Thompson 2001). Within 30 days, 5 kg of worms or an estimated 10 000 worms) can convert around 1 tonne of garbage into vermicompost at the optimal temperature (20–30 °C) and moisture (60–70%) (Singh et al. 2008; Joshi et al. 2013). The plants receive essential nutrients from the vermicompost in a form that they can readily absorb (Wang et al. 2017). Verminculture is therefore considered a practice that may benefit both soil health and agricultural productivity.

Vermicompost has been shown to benefit a variety of crops, including vegetables, grains, legumes, flowering plants, and field crops (Atiyeh et al. 2000; Blouin et al. 2019). Vermicompost is said to have a much higher nutritional content and bioavailability than composts made under traditional thermophilic conditions (Lazcano et al. 2009; Joshi et al. 2013). Vermicompost use as organic fertilizer significantly improved crop production, soil physico-chemical characteristics, and microbial biological activity (Rekha et al. 2018). In addition to being nutrient-rich, vermicompost also has high-quality humus, plant growth hormones, enzymes, and compounds that can shield plants from pests and diseases (Dhanuja et al. 2020).

Vermicompost can be created from a variety of agricultural wastes, including straw, husk, leaves, stalks, weeds, and more. In addition to the more popular aeration composting, the digestive system of an earthworm may also compost manures such those from cows, goats, and sheep. The source of the raw materials used as bedding and feed, as well as the type of earthworm used, affect the amount of nutrients in vermicompost (Bisen et al. 2011; Manaig 2016; Hitinayake et al. 2018; Zarei et al. 2018;). Using diverse earth worm species (*Eisenia fetida* and local collections), vermicomposting of various feedstocks in Ethiopia, such as sorghum straw, tef straw, industrial waste, fruit waste, and khat waste, demonstrated difference amongst earthworms for their reproduction and vermicast production.

There are significant amounts of agricultural residues and trash produced by agricultural activities such as the production of plants and animals as well as in the agroindustry. According to a report by Prasertsan & Sajjakulnukit (2006), Thailand produced 28 026 711 and 4 099 859 metric tonnes of bagasse and oil palm branch residue, respectively, while 13 998 196 and 19 005 628.14 metric tonnes of waste from animal manure and rice straw were produced, respectively. Additionally, one of the agricultural wastes that is widely distributed and is burned to prevent excessive accumulation is rice residues like rice husk and straw. In order to maintain good soil for high fertility, a high content of organic matter in the soil must be maintained.

One promising management approach is to convert the agricultural wastes into a vermicompost. Vermicomposting is able to decompose residues that are difficult to decompose such as mushroom culture by-products in which the main constituents are sawdust, bagasse, oil palm branch residue and so on. Besides, converting such residues by conventional composting process is very time consuming. Vermicompost contains considerable levels of organic carbon, nitrates, phosphates, exchangeable calcium, and other vital plant nutrients (Lim et al. 2015; Song et al. 2015). Vermicompost typically has notable positive benefits on plant growth, according to most of these studies. However, there have been very few experimental investigations exploring effects of different media on the total production and nutrient profile of vermicompost. Hence, the objective of this research was to investigate the yield and selected chemical properties of vermicompost produced by African Nightcrawler earthworms (*Eudrillus eugeniae*) raised in various materials, namely mushroom culture by-products (MBP), oil palm branch residue (OP), and sugarcane bagasse (B) as the raising base materials in comparison to using cow dung (CD).

2. Material and Methods

2.1 Sampling and preparation of MBP, CD, OP, and B

Dry CD and MBP were collected from the animal farm and mushroom houses in Mealand Agricultural Center, Rajabahat Yala University, Thailand. Sugarcane bagasse was collected from sugarcane juicing sites around the suburban areas of Yala province, Thailand. The OP was collected from palm oil mill factories in Pattani province, Thailand. Total N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu of the aforementioned samples were analyzed by standard methods described in Section 3 of Materials and Methods. These materials were allowed to decompose under shading for one month.

2.2 Medium preparation and earthworm raising

The earthworm raising base materials was prepared by mixing pre-decomposed materials with loamy soil at a ratio of 9:1, based on volume basis (v/v). The loamy soil mixed with these organic materials have the following chemical properties: pH value of 7.3 (1:1 soil: water), 4.60% organic matter, 0.23% total N, 58 mg/kg available P, and 148 mg/kg exchangeable K. Water was added to raise the moisture to around 60% of the water holding capacity. The materials were placed into round black plastic containers (27 cm in diameter and 23 cm in height) which have small holes for drainage and aeration. Before putting in the raising base material, the hole was closed with small plastic net. After two weeks of incubation under shading, a total of 60 individual mature African Nightcrawler earthworms (*Eudrillus eugeniae*) were embedded onto the surface of the media which consists of four different raising base materials. The earthworms were fed with cucumber, Chinese cabbage, and convolvulus. The moisture content of the media was monitored and maintained at an appropriate level. The experiment consisted of 4 treatments, namely MBP, CD, OP, and B. Each treatment was replicated with 5 replications.

2.3 Vermicompost collection and analysis of selected chemical properties and total nutrients

Vermicompost from each experimental unit was collected on the 60th day. During collection, the fresh weight from each experimental unit was recorded. After that, the vermicompost from each experimental unit were air dried for two weeks, and the dry weight was determined after constant weight was attained for each experimental unit. Next, the air-dried vermicompost from each experimental unit was ground with a mortar. The pH and electrical conductivity (EC), humic acid, organic matter and total carbon (C) were determined by using a pH and EC meter (1:5 vermicompost: water) (Tan 2016), gravimetric analysis (Tan 2014), and the Walkley and Black method (Walkley & Black 1934; Tan 2016), respectively.

Plant nutrients in the total form was analyzed. The total N was determined by the Micro Kjeldahl method (Tan 2016). After the determination of total C and total N, C:N ratio values were calculated. Other elements were determined after wet digestion of the vermicompost by an acidic mixture of nitric and perchloric (5:1v/v). Total P was detected with the molybdate blue method and total K with a flame photometer, whereas total Ca, Mg, Fe, Mn, Zn, and Cu were detected with an Atomic Absorption Spectrophotometer (Tan 2016).

2.4 Data analysis

The total dry weight of the finished vermicomposts, as well as the selected chemical properties and total nutrients in the vermicomposts from all treatments were subjected to Analysis of Variance (ANOVA) to detect the treatment effects, and the means were separated by using Duncan's Multiple Range Test (DMRT) at P≤0.05.

3. Results and Discussions

3.1 Dry weight of finished vermicomposts produced under different raising base materials

Earthworms in CD generated the significant highest dry weight of vermicompost followed by those in MBP, OP and B. Their dry weights were 744.58, 387.58, 270.05, and 14.27 g, respectively. The dry weights were significantly different among treatments (P≤0.05) (Figure 1). The earthworms raised in CD produced similar amounts of vermicompost to that of earthworms raised in composted fresh plant in a study by Nuchnoon et al. (2017). Sirithanakorn et al. (2014) reported that earthworms (*Eudrilus eugeniae*) raised in CD produce egg sacks, new earthworms, and increase the weight of vermicompost compared to those raised in composted water lily, composted banana leaf sheet, and coco-peat. Vodounnou et al. (2016) also revealed that earthworms (*Eisenia fetida*) raised in cow dung had the best growth rate and could produce new earthworms followed by pig, rabbit, poultry and sheep dung.

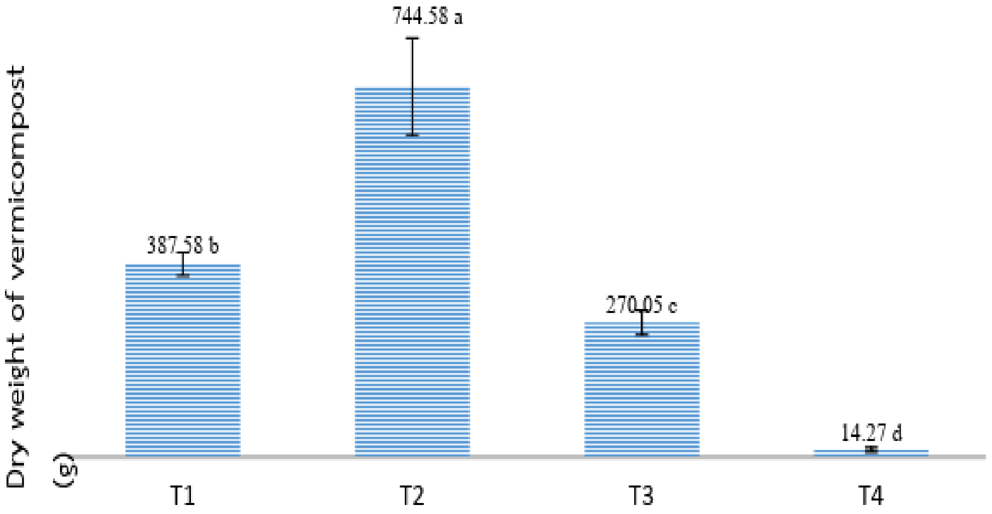

Figure 1- Dry weight of finished vermicomposts produced under different raising base materials.
Means between columns with different letter(s) indicate significant difference between treatments by Duncan Multiple Range Test at P≤0.05. Bars represent the mean values ± standard error

The B treatment yielded the least vermicompost, because the very hard texture was difficult to consume by the earthworms. Normally, earthworms eat decayed or rotten organic materials. Thus, it is better to allow more time for the pre-decomposition process to allow the material to properly decay before using for this purpose. The other advantage of pre-decomposition is to improve the vermicompost quality by killing pathogens *via* heat from the composting process (Ndegwa & Thomson 2001). The vermicompost produced from African Nightcrawler raised in CD bedding was darker in color and softer in texture than those in other bedding materials. Vermicomposts from MBP and OP showed dark brown in color and a little bit hard granule (figure 2)

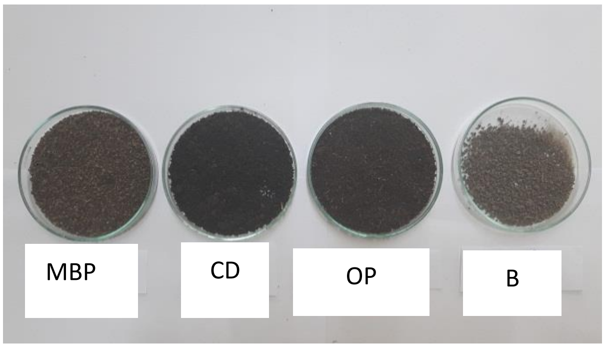

Figure 2- Vermicomposts from different raising base materials

3.2 Chemical properties of finished vermicomposts produced from different raising base materials

Vermicompost from B and CD showed significantly higher pH than those of MBP and OP. The pH level is one of the indices for assessing the vermicompost quality. The pH range of all the produced vermicomposts was between 6.33 and 7.65. When organic matter is broken down by microorganisms during vermicomposting, organic acids are produced, which causes the pH to change to almost neutral (Das et al. 2012). The increase in the vermicomposts pH also could be due to the earthworm's calciferous glands in the internal digestive track which secrete calcium carbonate ($CaCO_3$) to eliminate carbon dioxide (CO_2) produced from breathing (Dores-Silva et al. 2014). Additionally, the elevated pH during the vermicomposting process may be caused by the primary substrate's increased mineral N content. The release of their nitrogen content as ammonia volatilization during the vermicomposting process resulted in an elevation in pH in these beds with regard to the brief period of decomposition of bigger molecules such proteins, amino acids, and lipids. The results in this study corroborate with those of Sodaei et al. (2007) and Velasco-Velasco et al. (2011).

In terms of EC, vermicompost from OP showed the significant highest EC (985.33 µS/cm). The EC of vermicomposts from other raising base materials were not significantly different. The findings show that all of the vermicompost samples had salinity levels below 2 dS/m, indicating that they are appropriate for application to crop cultivation without endangering the soil and plants (Ofusu-Budu et al. 2010). This result could be explained by the simpler leaching in vermicompost and, to a lesser extent, by the ion consumption and buildup in the earthworm biomass (Rahman et al. 2017).

Vermicompost from CD yielded the highest amount of humic acid (45.86%) followed by those from MBP (34.26%), OP (25.47%), and B (12.53%). This might be as a result of the earthworms' greatest capacity to digest cow dung in comparison to other materials, which are more difficult to do since they contain lignin. According to Malherbe & Cloete (2002), the lignin portion of lignocellulose, which is the most resistant to biodegradation, is the reason why it is difficult to degrade lignocellulose during composting. This polymer's composition affects both its own decomposition and the decomposition of hemicelluloses in addition to determining how quickly it breaks down. Biodegradation is challenging because of the structural and macromolecular features of lignin, especially when the lignin content is high (generally greater than 20%) (Vikman et al. 2002). In the study by Vichaivit et al. (2012), the humic acid was equivalent to vermicomposts made from pig manure and peat coir mixtures in the ratio of 1:1 v/v fed with various kinds of fresh organic materials such plant leaves, fruit peels, tubers, and food scraps. Organic matter and total C in the OP vermicompost was significantly higher than CD, MBP, and B vermicomposts. The values were much lower than that of the standard organic fertilizer criteria of 30% announced by the Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand (Table 1). This could be due to the higher rate of decomposition facilitated by the earthworms. Earthworms consume the organic material while microbial degradation occurs during the vermicomposting process. Table 1 shows that MBP, CD, and B vermicomposts had lower percentages of total C than OP vermicompost, indicating that earthworms hastened the decomposition of the organic matter, which had less lignin than oil palm branch debris. Since carbon is a significant component of organic molecules, the foundation of all living things, these molecules are also the source of energy for the composting process (Ansari & Sukhraj 2010).

Table 1- Selected chemical properties of finished vermicomposts produced from different raising base materials

Raising base materials	*pH (1:5, V:water)*	*EC (1:5, V:water) (µS/cm)*	*Humic acid (%)*	*Organic matter (%)*	*Total C (%)*	*C:N ratio*
MBP	6.51^b	384.00^b	34.26^b	7.54^b	4.37^b	$6.1:1^a$
CD	7.44^a	451.00^b	45.86^a	5.56^b	3.21^b	$2.5:1^b$
OP	6.33^b	985.33^a	25.47^c	9.14^a	5.30^a	$4.4:1^a$
B	7.65^a	491.00^b	12.53^d	6.94^b	4.03^b	$7.75:1^a$

Means within column with different letter(s) indicate significant difference between treatments by Duncan Multiple Range Test at $P \leq 0.05$

In terms of C:N ratio, the values for all vermicomposts from four different raising base materials were below 20 (Table 1). The C:N ratio, one of the most commonly used indices of the maturity of organic waste, decreased during the vermicomposting process, which was acceptable according to Dominguez and Edwards (2011). The rapid decomposition of organic waste, as well as the mineralization and stabilisation throughout the vermicomposting process, caused the drop in the C:N ratio (Kaushik & Garg 2003). According to Majlessi et al. (2012), organic waste has reached an advanced stage of maturation when the C:N ratio falls to less than 20. The reduction of substrate's C:N value is due to nitrogenous excretion and microbial respiration during the decomposition process (Solis-Mejia et al. 2012).

3.3 Macronutrients and micronutrients of raw feedstocks and finished vermicomposts produced from different raising base materials

The total N in the raw feedstock was the highest (2.33%) in OP, followed by CD (1.76%), MBP (0.43%), and B (0.28%) (Figure 3). The total N in the finished vermicomposts from CD (1.26%) and OP (1.20%) were not significantly different, and both were distinctly higher than in those from MBP (0.72%) and B (0.52%) (Figure 3). The higher amounts of N in vermicomposts from

CD and OP may be caused by the reduction of organic matter, mineralization of organic compounds including protein and amino acids that contain N, and conversion of ammonia-N to nitrate-N (Pramanik et al. 2007). The N level of the vermicomposts from CD and OP might be due to mucus release, nitrogen-containing compounds, growth-stimulating hormones, and enzymes generated by earthworms (Tripathi et al. 2015). In comparison to Warma & Anglopez (2002) and Suthar (2006), the outcomes of the current investigation were relatively less significant. The final N content in the vermicomposts mostly depended on the starting N in the raw feedstock and the degree of decomposition. The total N concentration in the completed vermicomposts (Figure 3) was lower than the total N concentrations in the raw feedstock, which may be related to the rise in pH in the vermicomposts (Table 1) and the N lost by ammonia volatilization (Figure 3). As observed in Figure 3, the total P in the raw feedstock was 0.44%, 0.39%, 0.35%, and 0.15% in B, OP, CD, and MBP, respectively.

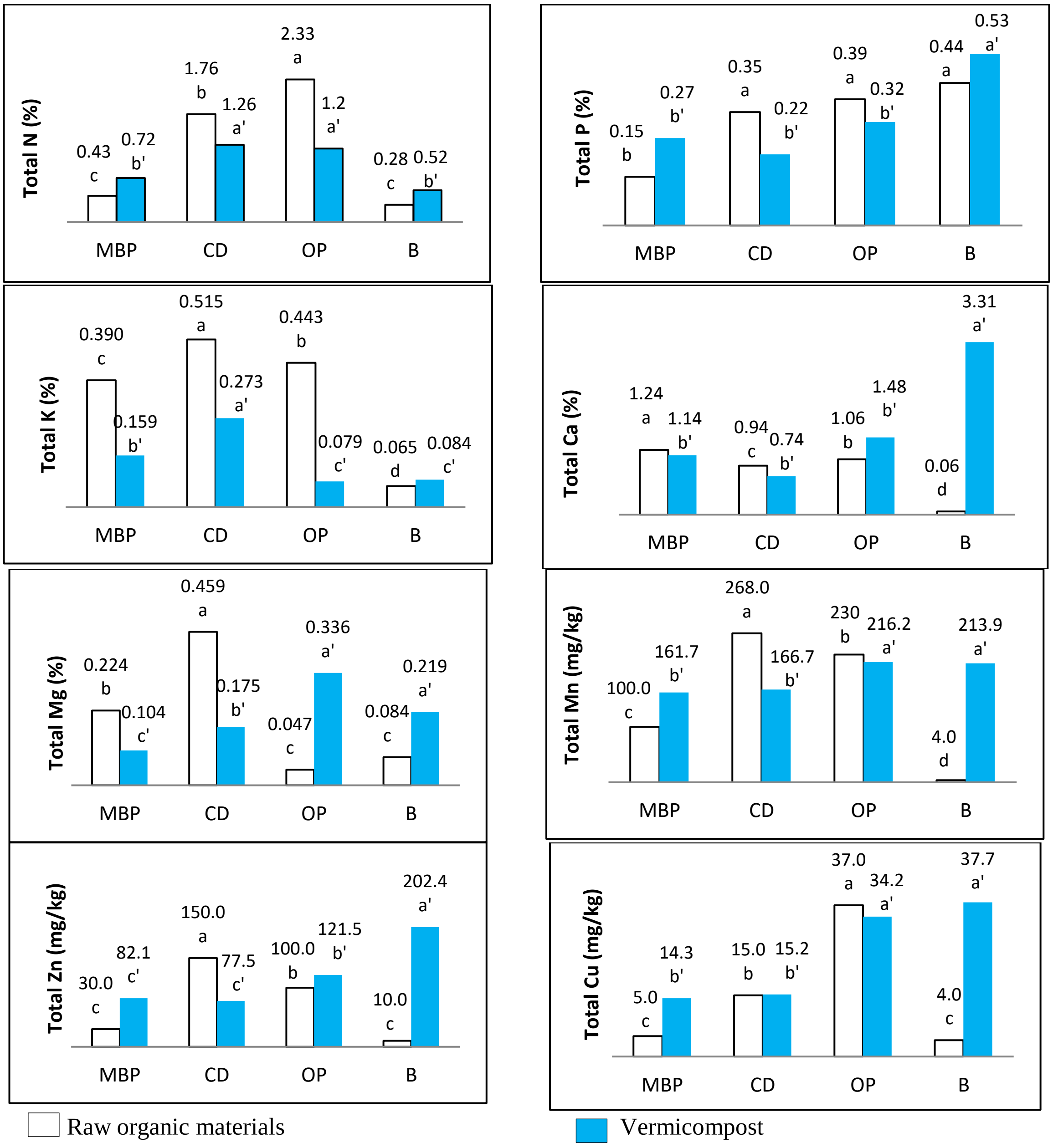

Figure 3- Comparison of total macronutrients and micronutrients between raw feedstock and finished vermicomposts produced from different raisin base materials. Means between columns with different letter(s) indicate significant difference between treatments by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$

The total P in the finished vermicompost from B (0.53%) was significantly higher than that in OP (0.32%), MBP (0.27%), and CD (0.32%) (Figure 3). The total P content in the finished B and MBP vermicompost varied between 0.27% and 0.53%, which was higher than in the raw feedstock. The primary process for the solubilization of insoluble P is the generation of acid by microbes during the decomposition of organic waste. Additionally, the earthworm gut's phosphatases and P-solubilizing bacteria found in the worm casts both contribute to the release of accessible P content from organic waste during vermicomposting, converting P into forms that are more bio-available to plants (Goswami et al. 2013).

As seen in Figure 3, the total K in the raw feedstock was 0.515%, 0.443%, 0.390%, and 0.065% in CD, OP, MBP, and B, respectively (Figure 3). The total K in finished CD vermicompost (0.273%) was significantly higher than those from the other organic materials (Figure 3). The total K in OP vermicompost (0.079%) and from B (0.084%) were not significantly different. Greater enzymatic and bacterial activity in the earthworm's digestive system results in increased mineralization of organic compounds containing K and other elements, as seen by the increased total K in vermicomposts (Garg et al. 2006). The primary cause causing an elevated K level during the vermicomposting process was the earthworm's intestine's rich bacteria (Pramanik et al. 2007).

Figure 3 displays that the total Ca in the raw feedstock was 1.24%, 1.06%, 0.94%, and 0.06% in MBP, OP, CD, and B, respectively. Vermicompost produced from B had Ca levels that were noticeably greater (3.31%) than those from other treatments (Figure 3). The increased level of inorganic C in the vermicompost was predominantly caused by gastrointestinal mechanisms connected to calcium metabolism (Suthar 2008). The total Mg in the raw feedstock was 0.459%, 0.224%, 0.084%, and 0.047% in CD, MBP, B, and OP, respectively (Figure 3). The total Mg in OP vermicompost (0.336%) and B vermicompost (0.219%) were significantly higher than those from MBP (0.104 %) and CD (0.175 %) vermicomposts (Figure 3).

Total N-P_2O_5-K_2O of MBP, CD, OP and B vermicompost were 0.72-0.62-0.19, 1.26-0.50-0.33, 1.20-0.73-0.10, and 0.52-1.21-0.10, respectively. Overall, the macronutrient values reported in this study were lower than the organic fertilizer quality criteria announced by the Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand (Total N $\geq$ 1, $P_2O_5 \geq 0.5$, $K_2O \geq 0.5$% w/w). Thus, it should be further studied for enrichment of primary plant nutrients, especially K_2O. Cassava peels may be an interesting material that yields a high amount of total K after digestion by *Eisenia fetida* (Saravanan & Wesely 2018).

The amount of total micronutrients in the raw feedstock and finished vermicomposts produced from different raising base materials are presented in Figure 3. Total Mn concentrations in all vermicomposts were not significantly different they showed in the range of 161.68-216.21 mg/kg. The B vermicompost showed the highest concentration of total Zn (202.38 mg/kg), followed by that of OP (121.53 mg/kg), MBP (82.13 mg/kg), and CD (77.46 mg/kg). The total Zn concentration in OP was significantly higher than those in other vermicomposts. On the other hand, total Zn concentration in the vermicompost from MBP and CD were not significantly difference. The B and OP vermcomposts showed the highest concentration of total Cu (37.73 mg/kg and 34.20 mg/kg, respectively) (Figure 3). Earlier studies reported values 2.00–37.70 mg/kg for Cu, 5.70–120.00 mg/kg for Zn and 10.00–105.00 mg/kg for Mn (Chaudhuri et al. 2000; Kitturmath et al. 2007; Giraddi 2007; 2011; Waseem et al. 2013). According to Dominguez & Edwards (2011), vermicompost typically contains adequate amounts of micronutrients, which have been substantiated by our results for total Fe, Mn, Zn, and Cu concentrations in the finished CD, MBP, B, and OP vermicomposts.

4. Conclusions

The vermicompost produced by African Nightcrawler earthworms (*Eudillus eugeniae*) raised in CD gave significant higher dry weight. The vermicompost from CD also had a neutral pH (7.44) and highest yield of humic acid. However, vermicompost made from several agricultural waste products showed varying levels of each plant nutrient element's greatest concentration. Thus, CD should be used as the main material and mixed with other agricultural waste products as raising base materials or enriched specific the purpose minerals to make high grade vermicompost.

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