Alternative Feed Sources for Vermicompost Production

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ABSTRACT

Locally-available materials could be used to address soil fertility constraints. Vermicomposting is a promising technology where various organic materials are converted into processed compost by earthworms. This study evaluated local feed sources and their potential for vermicompost production. The vermicompost production was carried out in the plastic container under a roofed and net-sided production house. The plot design was laid out in Completely Randomized Design (CRD) with nine replications. Vermiculture feedstock treatments were cow manure (CM) and three cow manure and alternative feed stock treatments (75:25 on a dry basis) that included water hyacinth (WH), used coffee grounds (coffee), or Azolla. The results showed that cow manure combined with Azolla tended to produce more vermicompost after four weeks, but post-harvest earthworm weight was lower. The cow manure treatment produced higher earthworm weights. However, the earthworm population was not influenced by feed sources. The chemical characteristics of vermicompost were not different among feed source ratios or combination. A comparison of the feed stock material before and after vermiculture composting show that EC and total P increased in the compost, total K, organic C and the C:N ratio decreased, but pH and Total N remained constant.

1. INTRODUCTION

Low-fertility tropical soils are common (Razakatiana et al., 2020) and combined nitrogen (N) and phosphorus (P) deficiencies are a widespread problem in tropical soils (Smithson and Giller, 2002). For Cambodia, some production areas are characterized as having soils with low fertility, specifically Cambodia's commonly found sandy soils which have low nutrient levels and low SOM/SOC (Seng et al., 2001). These soils have low specific surface areas with low activity clay fraction, resulting in low nutrient and water retention. The use efficiency of applied mineral fertilizers is very low. The low economic return is an additional concern for farmers. Locally available materials could be used to address the soil fertility constraints of Cambodian soils. Local organic materials may consist of crop residues, farmyard manure, cow manure, kitchen waste, leguminous crop rotation, and other compostable feedstocks (Palm et al., 2001). Moreover, mineral fertilizers are not affordable for many small-scale farmers. Therefore, the sole reliance on mineral fertilizers is not plausible for long-lasting sustainable soil management.

The trend of urban farming, such as small-scaled home garden and pot-based cultivation, are increasing in popularity and need organic materials. Thus, composting is preferable over mineral fertilizer as it is perceived as environmentally friendly. Proper handling and use of compost may reduce environmental pollution (Dolliver et al., 2008). Compost can help recycling of farm wastes, but the decomposition and composting process can take a long time to get the final product (Ayilara et al., 2020). Vermicomposting is an innovative technology in which various organic materials are converted into processed compost by earthworms (Blouin et al., 2019). Cow manure is commonly used as a feedstock for earthworms, and it is commonly used by many farmers as a nutrient source. In vermicompost production, cow manure is the only feed source that cannot be avoided (Yuvaraj et al., 2021). However, the

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future availability of cow manure in Cambodia is decreasing because of the reduced use of cattle for draft power. Yuvaraj et al. (2021) reported that cow manure can be combined with other biowastes in vermicompost production. Therefore, there is a need to reduce sole reliance on cow manure as a feedstock for vermiculture and find supplementary local feedstocks such as aquatic fern Azolla, used coffee grounds, water hyacinth, or other plant biproducts. The effects of various feedstocks on vermicompost quality have been reported by other researchers (Amouei et al., 2017; Ansari and Rajpersaud, 2012; Karmegam et al., 2019; Kumari et al., 2020; Nath et al., 2009; Ramnarain et al., 2019).

The objective of this study was to evaluate the effect of various earthworm feedstocks on production and chemical characteristics of vermicompost. It is hypothesized that locally-available feed sources such as Azolla, used coffee grounds, water hyacinth can partially replace cattle manure which is decreasing. It will also pave the way to conduct in-depth study to maximize the alternative feed sources to cow manure in future studies.

2. METHODOLOGY

2.1 Experimental condition and design

The experiment was conducted under a production house with a size of 3 m × 6 m × 3 m (height×length×width). The house was sided by net to allow air flow inside. The plot design was laid out in Completely Randomized Design (CRD) with nine replications. Feedstock treatments were placed in black round plastic containers with a bottom diameter of 43 cm, surface diameter of 43 cm and a height of 13 cm. Cow manure (CM100%) was used as a standard feedstock for earthworm rearing and was treated as the control. Cow manure (CM) was supplemented at a ratio of 75:25 (dry basis) with three types of earthworm feedstocks that included water hyacinth (CM75%+WH25%), Azolla (CW75% +Azolla25%) and used coffee grounds (CM75% +Coffee25%).

2.2 Earthworm and feed preparation

The mass culture of the African earthworm, *Eudrilus engeniae* was carried out by feeding in partially decomposed cowdung (CD) substrate. Cow manure was air-dried for 10 days. The dried cow manure was soaked in water for four days. The water hyacinth was ground chopped by a machine into approximate 2-3 cm length, then water hyacinth, used coffee grounds and Azolla were subjected to initial decomposition in separate plastic boxes for four weeks when the heat is lower before feeding them to the earthworms.

Containers were filled with 4 kg of feedstock materials on an oven-dry weight basis. The cow manure and supplementary feedstocks were homogenously mixed before filling the containers to a level of 3 to 5 cm below the container's edge. The earthworms were placed in each container at a rate of 234 earthworms per container, which was approximately 250 g of earthworm biomass.

2.3 Feedstock maintenance and vermicompost harvest

The feedstocks were kept moist by spraying water daily at a rate of 550 mL per container until two days prior to the vermicompost harvesting. Pests were controlled by manually removing them from the feedstock. Vermicompost harvesting was performed twice at two and four weeks after earthworms were introduce to the feedstock treatments.

2.4 Data collection

The temperature was recorded twice: two and four weeks after earthworms were introduced to the feedstock treatments. The number and weight of earthworms per container were determined after four weeks following the final harvesting. The productivity of vermicompost (%) was calculated by weight of harvested vermicompost divided by initial total mass of feedstock on a dry weight basis per container (Ramnarain et al., 2019). The vermicompost in each container was harvested by removing the earthworms that were longer than 5 cm and sieving the vermicompost with a 5 mm-sieve. The vermicompost were weighed and its moisture was recorded. The chemical characteristics of vermicompost was analyzed in the soil laboratory of Faculty of Agronomy, Royal University of Agriculture.

2.5 Statistical analysis

The data were analyzed using analysis of variance (ANOVA) to detect the significance among treatments. Means comparison testing was carried out using Tukey's HSD (Honestly Significant Difference) test at an appropriate level of significance. Both ANOVA and mean comparison were determined using Statistix 8 (Version 8.0, Analytical Software, 1985-2003).

3. RESULTS

3.1 Vermicompost production and earthworm population

The data analysis using ANOVA showed a significant difference in total vermicompost harvest among the feedstock treatments (Figure1). The cow manure and Azolla treatment (CM75%+Azolla25%) showed the highest production of vermicompost but was not significantly different from the CM100% earthworm feedstock treatment. The CM75%+ Coffee25% and CM75%+WH25% treatments produced the least amount of vermicompost.

The amount of vermicompost expressed on a dry weight biomass basis showed that replacing 25% of the cow manure with 25% used coffee grounds (CM100%+Coffee25%) resulted in a lower amount of vermicompost (1.82 kg per container) (Table 1). The CM75%+Azolla25% treatment produced a greater amount of vermicompost (2.18 kg per container), but it was not significantly different from either the CM100% or CM75%+WH25% treatments. The production of vermicompost using 75% cow manure and 25% Azolla 25% indicated higher productivity than the use of cow 75% manure and 25% used coffee grinds (54.50% Vs 45.59%).

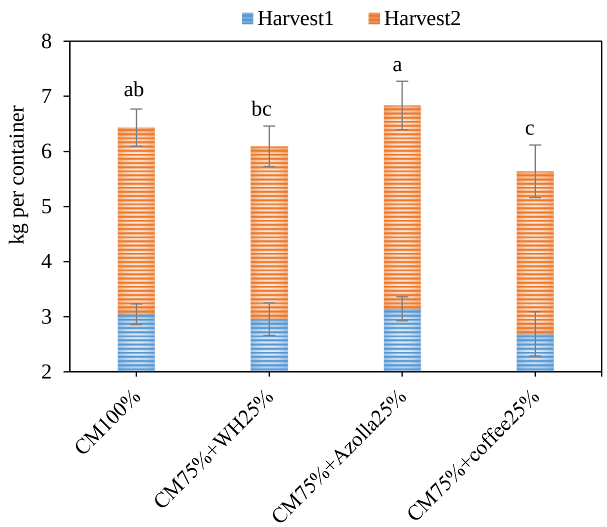

Figure 1. 1st harvest, 2nd harvest and total production of vermicompost per container with different feedstock combinations. Different letters on the bars denote significant difference at $p<0.05$ by Tukey HSD’s test. The error bars represent±standard deviation.

Table 1. Total harvest and productivity of vermicompost

Treatments	Total mass of feed initially (kg, dried basis)	Total harvest vermicompost (kg, dried basis)	Productivity (%)
CM100%	4	2.05^{ab}±0.27	51.14^{ab}±6.75
CM75%+WH25%	4	1.98^{ab}±0.13	49.59^{ab}±3.16
CM75%+Azolla25%	4	2.18^{a}±0.07	54.50^{a}±1.71
CM75%+coffee25%	4	1.82^{b}±0.23	45.59^{b}±5.82
P-value		0.00**	0.00**

Value is the mean±standard deviation (SD); Different letters in a column denote significant difference at $p<0.05$ by Tukey HSD’s (Honestly Significant Difference) test.

Earthworm population and moisture at the 4-week harvest were not significantly different among the feedstock treatments (Table 2). Earthworm weight (>5 cm length) was significantly different among the feedstock treatments at the 4-week harvest. The feedstock with only cow manure (CM100%) indicated the highest weight value at 407.31 g per container, but this was not statistically different from the CM75%+WH or CM75%+Coffee25% feedstock treatments. The lowest weight of earthworm (362.06 g per container) was observed in the CW75%+Azolla25% treatment. The temperature measured from week 2 to week 4 showed a drop in temperature from 0.6 to 2 degree Celsius (Figure 2).

Table 2. Earthworm weight and population, temperature and moisture at harvest per container

Treatments	Earthworm weight (g)	Earthworm population (> 5 cm length)	Temperature at harvest (ºC)	Moisture at harvest (%)
CM100%	406.31^{a}±15.50	217±21	32.56^{a}±0.56	68.27±3.38
CM75%+WH25%	387.25^{ab}±40.66	220±15	32.26^{a}±0.86	67.33±3.17
CM75%+Azolla25%	362.06^{b}±34.49	221±14	33.09^{ab}±0.34	67.93±3.09
CM75%+coffee25%	394.63^{ab}±13.47	220±16	32.66^{b}±0.18	67.63±3.75
P-value	0.01*	0.96^{ns}	0.00**	0.99^{ns}

Value is the mean±standard deviation (SD); Different letters in a column denote significant difference at $p<0.05$ by Tukey HSD’s (Honestly Significant Difference) test.

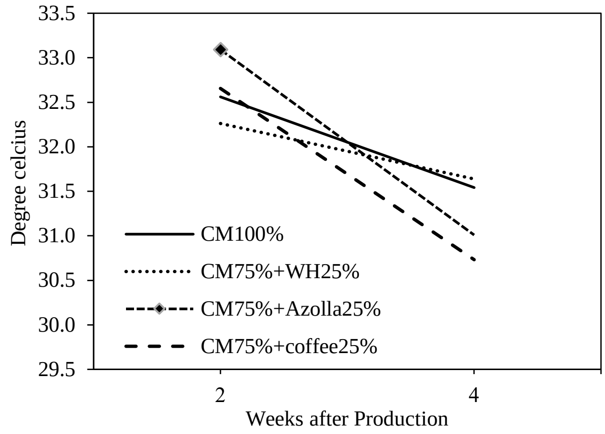

Figure 2. Changes in temperature 2 and 4 weeks after feeding

3.2 Chemical characteristics of vermicompost

There were no significant differences in chemical characteristics among the different vermicompost feedstock treatments (Table 3). The combined treatment mean pH and EC were 7.16 and 582.75 µS/cm, respectively (Table 2). The harvested vermicompost had combined treatment macronutrient means of 1.47% N, 4.77% P, and 1.82% K (Table 2). The combined treatment mean for total Ca was 1.02% and total Mg was 1.80%. The combined treatment ratio of carbon to nitrogen was 27.66.

The changes of final vermicompost product from initial cow manure were observed in some parameters while pH and total N had minor changes (Figure 3). Electrical conductivity, total P and total Mg increased by 24, 28 and 35%, respectively. The large decrease was observed for total Ca, total K and C:N ratio by 412, 167, 14%, respectively.

Table 3. Chemical characteristics of vermicompost for different feedstock treatments

Treatments	pH 1:10 H_2O	EC (µS/cm)	Organic C (%)	Total N (%)	Total P (%)
CM100%	7.22±0.10	582.67±87.32	40.40±1.86	1.47±0.14	4.66±1.29
CM75%+WH25%	7.12±0.07	638.00±71.14	40.18±0.54	1.47±0.12	4.27±0.79
CM75%+Azolla25%	7.13±0.15	510.67±67.17	40.04±1.38	1.49±0.23	5.14±1.10
CM75%+coffee25%	7.18±0.08	563.00±53.22	40.86±1.58	1.46±0.21	5.34±0.81
Mean	7.16	582.75	40.37	1.47	4.77
P-value	0.68^{ns}	0.62^{ns}	0.90^{ns}	0.99^{ns}	0.23^{ns}
Treatments	Total K (%)	Total Ca (%)	Total Mg (%)	C:N ratio	
CM100%	1.68±0.44	1.09±0.23	1.84±0.26	27.55±1.49	
CM75%+WH25%	1.82±0.35	1.05±0.10	1.77±0.73	27.55±2.69	
CM75%+Azolla25%	1.86±0.22	1.16±0.22	1.75±0.51	27.14±3.57	
CM75%+coffee25%	1.92±0.54	0.78±0.54	1.85±0.56	28.38±4.30	
Mean	1.82	1.02	1.80	27.66	
P-value	0.90^{ns}	0.26^{ns}	0.99^{ns}	0.97^{ns}	

Value is the mean±standard deviation (SD). “ns” indicates non-significant difference.

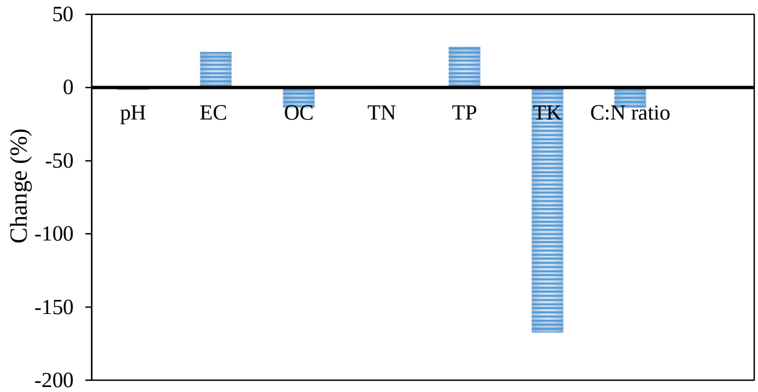

Figure 3. Changes in chemical characteristics of vermicompost products compared to initial cow manure

4. DISCUSSION

The final harvest of fresh and dried vermicompost product for the cow manure and Azolla combination tended to be higher, compared to other feedstocks used in this study. Feedstocks were pre-composted, which likely increased the rate of decomposition fed to earthworms. Azolla has the potential to decompose in 8-10 days and processed into a powder (Setiawati et al., 2018). Used coffee grounds typically decompose at a slower rate due to its lipid fraction and recalcitrant decomposable structural protein-N content (Kitou and Okuno, 1999), which may take several months for microbes to breakdown.

The weight of earthworms from CM75% +Azolla25% treatment collected after harvest seemed to be less, compared to the CM100% treatment. This implied, that even though the population of earthworm was not significantly different among the four feedstocks, cow manure is probably the main food source for the earthworms and could be used as substrate for mass culture and the alternative feedstocks used in this study did not harm the earthworm. The decrease in number of earthworms during the study period may be due to the decline in C/N ratio during the decomposition process (Amouei et al., 2017). The temperature dropped slightly from week 2 to week 4 and was below 35ºC. Although this temperature is out of the optimum temperature range for adult earthworms (Juarez et al., 2011), it did not notably affect the earthworms in this study. The daily watering may have stabilized the temperature for earthworm growth, and the decrease in temperature may have been a result of microbial degradation and dynamics.

The analysis of chemical properties of the feedstock treatments showed no significant difference among the treatments. The modification of only 25% of the feedstock with alternative sources (water hyacinth, Azolla, and used coffee grounds) may have been too small to make changes in their chemical characteristics. The lack of difference of total N among the treatments contrasts with other studies (Ramnarain et al., 2019; Amouei et al., 2017) which reported higher total N in the vermicompost end product. The reason for the difference in total N may be due to the different composting production durations, initial feeds and conditions. This study showed a decline in total K in vermicompost, which has been reported in other studies (Ramnarain et al., 2019). The C/N ratio of vermicompost in this study was 27, which is higher than previously reported to be smaller than 22 (Karmegam et al., 2019; Deepthi et al., 2021). The drop in C/N ratio compared to initial cow manure was probably due to the use of carbon as energy source during the composting process (Ansari and Rajpersaud, 2012; Ramnarain et al., 2019), leading to low C in the final production and resulting in a low C:N ratio. The reduction of C/N after vermicompost was also reported by Deepthi et al. (2021) and Wang et al. (2022). The decomposition rate in this study ranged from 46 to 55% over a month period. The composting rate of feedstock by earthworms in this study was twice as fast as composting studies that did not include earthworms. The lack of differences observed in the chemical properties before and after composting including pH were also observed by Karmegam et al. (2019). The average pH of final product was around neutral (7.16), which was in a similar range reported by Ramnarain et al. (2019) and Kumari et al. (2020). Additionally, the pH range of the vermicompost in this study is consider a normal vermicomposting product pH (Suthar, 2008; Nath et al., 2009). However, Wako (2021) found the variation of vermicompost pH was dependent on initial feedstock. For instance, the use of soybean and maize feedstock could raise the pH up to between 8.1-8.4, which could be harmful to the earthworms and affect composting rates. Thus, the feedstocks used in this study (cow manure, water hyacinth, Azolla, used ground coffee) are not limiting the earthworm's ability to compost the feedstock based on pH. Karmegam et al. (2019) reported an increase of EC and total P. This study did not show a difference in EC or total P among the feedstock treatments, but EC and total P did increase over the 4-week composting period. The increase in total P is a result of phosphatase in the earthworm's gut (Parthasarathi et al., 2016; Ramnarain et al., 2019; Wako, 2021). The increase of EC during composting showed the role of earthworm to enhance EC in vermicompost and may indicate the release of plant nutrients for mineral salts (Nath et al., 2009). The solubility of mineralized compounds may have increased, leading to the increase in EC (Amouei et al., 2017). However, the EC in this study was less than 8 ds/m or 8,000 µS/cm, which is harmful to most earthworms and plants.

The decrease in organic C in the final product is a result of organic matter degradation, mineralization and respiratory activity of earthworms and other microorganisms, leading to the loss of carbon in the form of CO_2 (Karmegam et al., 2019; Amouei et al., 2017). The reduction of organic carbon and organic matter content in vermicompost was also reported by Wang et al. (2022) and Jayakumar et al. (2022).The decline of total K and total Mg was also reported by (Ramnarain et al., 2019).

5. CONCLUSION

The ratio of different combinations in feedstocks may affect the rate of vermicomposting decomposition. A combination of cow manure and Azolla tended to produce higher vermicompost productivity, but lower earthworm weights following final vermicompost harvest. The use of cow manure only as feedstock produced the highest earthworm weights. However, the earthworm population was not influenced by the different feedstocks used in this study. Azolla could be used with cow manure to increase vermicompost production. However, cow manure can be used without Azolla as standard medium for earthworm rearing. The chemical characteristics of vermicompost were not difference among the different feedstock ratios and combinations used in this study. However, there was a change in chemical characteristics between the feedstocks and the resulting vermicompost in which pH, total N remained constant while EC and total P increased after vermicompost process. Total K was observed to have reduced significantly in the vermicompost as compared to the feedstock and organic C and C:N ratio also decreased, but to a lesser degree. Future research should focus on other potential feedstocks, which can replace or be used with cow manure to increase the vermicompost quality.

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