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THE POTENTIAL OF LOCAL EARTHWORMS IN VERMICOMPOSTING GOAT MANURE (GM) AND SPENT COCONUT FLAKES (SCF)

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Abstract: Vermicomposting is a process that involves biological, chemical and physical transformations of solid organic materials such as agricultural residues of plant and animal through the use of microorganisms and earthworms. There are three main classes of earthworms, and only those from one class are usually used for vermicomposting. However, mostly foreign earthworms are used in the setup. Foreign earthworms are more expensive and harder to obtain than local earthworms. This makes the local farmers reluctant to try since they are expensive. The difference in vermicompost using two species of epigeic earthworms, a local earthworm and a foreign earthworm (*Eisenia fetida*), and normal compost without any earthworms was measured in this study. Both species of earthworms were placed in identical vermibeds consisting of partially composted goat manure and partially composted spent coconut flakes (SCF) with the ratio of 5:1 respectively in terms of weight. The vermibed moisture content was maintained at 60 – 70% throughout the whole process. The end products showed a difference from one another. The *E. fetida* showed a better result compared to the local earthworms in terms of the nutrient content presence and the adaptability of the earthworms during the whole process. However, the end product from the local earthworms was still better compared to the normal compost without any earthworms.

*Keywords***:** Vermicompost, *Eisenia fetida*, Coconut waste, Spent coconut flakes, Goat manure

Introduction

Every country in the world right now is investing a lot of money to implement green technology in most sectors. Studies on the use of organic fertilizer to reduce or replace chemical usage in agriculture have been increasing these pasts few years. Chemical use in agriculture brings impacts not only to humans as the main consumers but also to the environment. There are a few methods to replace chemical use in agriculture, such as green manure, organic fertilizer and vermicompost.

The study of using earthworms in processing organic waste started in Germany, according to Graff and Makeshin (1980). In the 1980s, research focused on the use of earthworms to break down animal and vegetable waste and also the use of earthworms in fish farming for animal feeds, as stated by Edwards *et al.,* (1985) and Edwards (1998). It was only in the late 20th century that researchers found the advantages of using earthworm's castings as organic fertilizers. Most of the studies were conducted and applied in Indian crops.

Vermicompost is a process that involves biological, chemical and also physical transformations of solid organic materials such as agricultural residues of plant and animal through the use of worms (Garg & Gupta, 2008). The physical process includes substrate aeration, mixing and grinding of soil, while the biochemical process occurs with the help of microbial decomposition of substrate in the intestine of earthworms (Hand *et al*., 1998). Vermicast is the product from the vermicomposting process that can be used to increase the nutrient content and fertility of soil through increased levels of soil enzymes (Chaoui *et al*., 2003). Organic matter stabilization can be increased through vermicomposting of organic waste (Edwards *et al*., 1998; Frederickson *et al*., 1997). This process also gives chelating and phytohormonal elements which have high content of microbial matter and stabilised humic substances (Tomati and Galli, 1995). Vermicomposting is also responsible for the spreading of important microorganisms as it is full of microbial diversity, population and activity (Kale *et al*., 1992 and Subler, *et al*., 1998).The purpose of this study is to investigate the ability of local earthworms in composting organic waste as good as or better than foreign earthworms (*Eisenia fetida*). This study also determined the nutrient content in the vermicasts produced.

Materials and Methods

Earthworm collection

There were two species of Epigeics earthworm that were tested in the experiment, namely *Eisenia fetida* and local earthworm. *Eisenia fetida* were used as positive controls since they were already being used commercially as vermicomposting worms. For *Eisenia fetida*, the samples were collected from the earthworm house located in Institute of Science Biology, University of Malaya. The samples were in a mixture of goat manure and mushroom compost and all the samples were in adult stage. The local earthworms were collected from the backyard of a neighbouring house in Taman Maidam, Kuala Terengganu. The earthworms were collected near an overflow sewage where the soil was very fertile and full of Epigeics earthworms.

Morphological identification of earthworm

For the identification of earthworms, the process was done by locating the position of clitellum of the earthworms and the position and number of setae found. The species identity of *Eisenia fetida* had been confirmed by Dr Zalina from the Institute of Science Biology, University of Malaya. The local earthworms failed to be identified even when their clitellum and setae position were found. The colour and length of the earthworms are also very crucial for earthworm identification. The earthworms' cocoons can also be used to identify the genus and species of earthworms.

Organic waste

In this experiment, a mixture of pre-composted air-dried goat manure (two months old) and air-dried spent coconut flakes (SCF) was used as the food source for the earthworms. The 5:1 weight ratio of cow manure: citronella plant was prepared following the method by Deka et al. (2011). The total weight of the mixture in each container was controlled at 1 kg. The goat manure was collected from a local farm in Kuala Terengganu and was composted for two months before being used. The goat manure was air-dried for 10 hours, then shredded into smaller pieces by a heavy-duty grinder to ease the consumption by the earthworms. Spent coconut flakes (SCF) were collected from a local store in a village in Kuala Terengganu, air dried and ground into smaller pieces. All of the mixture was ground into smaller pieces to ease and fasten the consumption rate by the earthworms. The nutrient content of the mixture was measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The mixture pH was also measured using a pH meter.

Vermicomposting design and set up

One treatment and two controls with three replication each were set up for this experiment. The treatment was the local earthworms and was labelled C, while the controls consisted of the positive and the negative controls. Positive control was the *Eisenia fetida* labelled B, while the negative control did not have any earthworms and was labelled A. Vermicomposting process was done in opaque container to provide suitable condition for the earthworms. Every container was modified to have holes at the bottom to drain excess water and at the top for respiration purposes. Each container was filled with the same amount of organic waste mixture with the total of 1 kg as described in Organic Waste section. The organic waste mixture was watered to obtain the desired soil moisture at around 60% - 70% of moisture throughout the experiment (Suthar and Singh, 2008). There were no specific method and instrument to identify the moisture without disturbing the vermicomposting process. Thus, the moisture was only controlled by preventing the bedding from drying or containing excess water. The moisture content was only measured at the beginning and at the end of the experiment. Ten adult earthworms were inserted in each container.

The containers were then covered with the lids with holes covered by a fine net to allow good aeration in the containers and prevent the earthworms from escaping. All the containers were placed under shaded area in complete randomised block design (CRBD). CRBD arrangement was used because there was one external factor that could not be controlled, which was light intensity. Earthworms are very sensitive towards light. Thus, light intensity might affect the results of this study. All the containers were labelled and tied up using fine wire to prevent them from falling off. The mixture was checked daily for the desired moisture.

Harvesting vermicasts

The experiment was conducted for 21 days. Thus, there were possibilities that the vermicomposting process had not finished especially in the local earthworm containers. To obtain the highest concentration of vermicasts, only the top part of the vermibeds were harvested. This was because the earthworms used in this experiment were top feeders and usually had their castings at surface area. The earthworms were separated using a sieve. The harvested vermicasts were subjected to several tests to identify the nutrient content, pH value and moisture content.

Physico-chemical analyses

The physico-chemical analyses conducted in this experiment were pH value, micro and macronutrients, temperature and moisture. The pH value was determined using pH meter. The micro and macronutrients content other than nitrogen and organic carbon were measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Kjeldahl's methods were used to measure the nitrogen level. To measure the organic carbon content, Walkley and Black method was used. To measure the vermicast temperature and moisture, a thermometer and a direct gravimetric method was used.

Statistical analysis

There were three treatments in total including positive and negative controls. Each treatment had three replicates. All the collected data were analysed by One Way ANOVA using SPSS software version 20. This was because there was only one factor (treatments) with more than two levels and the same earthworms and beds would be used for the whole process. To confirm whether there was a significant difference between samples in all of the parameters, a Tukey HSD test was used. A Complete Randomized Block Design (CRBD) was used with a random and factorial arrangements. The CRBD was used because there was an external factor that could not be controlled which was the light intensity exposed to the vermibox. A random and factorial arrangement were used because each replicate was placed in a different box and did not share any vermibeds or spaces.

pH value

Table 1 shows the average pH value in all of the compost after 21 days. There was a significant difference since the value was (p=0.00) which was lower than 0.05 ($p \leq 0.05$), effect of the presence of earthworms on the pH value of the vermicast after 21 days incubation period. The initial pH reading before the experiment started was 8.05, which was slightly alkaline. The pH value decreased throughout the incubation period.

This was probably due to the presence of large concentration of goat manure that contributed to the more neutral end product. A study by Tahir and Hamid (2012) showed that the larger the ratio of SCF to goat manure, the

Results and Discussion

Table 1: The physico-chemical characteristics in all of the compost after 21 days.

Treatments	pH value	Total Nitrogen (%)	Total Phosphorus (mg/kg)	Total Potassium (mg/kg)	Total Organic Carbon (%)	Total Organic Carbon : Total Nitrogen ratio
Initial	8.05a	0.29a	18905a	29884a	10.07a	34.9a
Negative control, A	7.46b	0.24b	17236a	26537a	8.02b	33.6a
Positive control, B	6.95c	0.29a	20386a	27230a	5.83d	20.4c
Local earthworm, C	7.62b	0.28a	20512a	25747a	7.21c	25.4b

Note: Mean values followed by different letters in a column were significantly different based on Tukey HSD test.

more acidic the final product would be. They stated that 100% SCF would make the end product acidic while 50% of SCF would only make the end product within the neutral range. Sample B (positive control) showed significantly higher reduction in pH value compared to Sample A (negative control) and Sample C (local earthworms) while sample A and C were not significantly different.

According to De Bertoli *et al.* (1983) and Miller (1992), pH value around 6.7 to 9.0 supported a healthy and good microbial activity during composting process. They stated that a pH of 5.5 to 8.0 was the optimum range for microbial activity. The pH value in this experiment was between the reported range, so it was suitable for microbial activity. Based on Kiyasudeen (2016), most epigeic earthworms can tolerate a pH of 5.0 to 9.0.

However, Muthukumaravel *et al.* (2008) stated that the pH should be increasing at the final process of vermicomposting due to the decomposition of nitrogenous substrates resulting in the production of ammonia. This ammonia which formed a large proportion of the nitrogenous matter was excreted by the earthworms as their castings. This could be the main cause of the increase in pH value. Even though this experiment showed a decrease in pH value compared to initial reading, the final pH value obtained was still identical to the study by Muthukumaravel *et al.* (2008); Tahir and Hamid (2012); Deka *et al.* (2011). Even though the number of earthworms used was half compared to the number in previous studies stated above which was 10, the end results were still the same.

They started with more acidic vermibed while this experiment started with a slightly alkaline condition because of a higher concentration of goat manure used. The end results still showed a neutral product for this study and the previous studies. This study used 5:1 ratio of goat manure to SCF while Deka et al. (2011) used the same ratio but 5-part cow manure and 1-part plant waste. The different concentration of food source was the reason for the different starting pH values. Nonetheless, only few information was known on the effect of substrate pH during vermicomposting according to Munnoli et al. (2010).

Nitrogen

Table 1 shows the average percentage of total nitrogen in all of the compost after 21 days. There was a significant difference since the significant value was (0.00) lower than 0.05 ($p \leq 0.05$). The initial total nitrogen content was 0.29%. Sample A showed the lowest final total nitrogen reading at 0.24 %. Based on the results, the nitrogen content in Sample A (negative control) showed a significant difference compared to other samples and the initial reading. Sample B and Sample C did not show any significant difference even with the initial reading.

A study conducted by Tahir and Hamid (2012) showed there were possibilities that the nitrogen values decreased and increased in different samples. According to them, the increase in nitrogen content may due to the initial presence (physicochemical properties) in the substrates and the process of mineralization of nitrogen by microbes and earthworms. They also stated that the reduction of nitrogen content was also probably due to the mineralization of nitrogen. The increase in pH was assumed to be the factor for reduction of nitrogen as a volatile ammonia (Ndegwa and Thompson, 2000).

According to Suthar (2009) and Deka et al. (2011), there were many factors that may contribute to the status of nitrogen value in vermicompost, such as the feed mixtures, the excretory products, mucus, body fluids, enzymes, and even the decaying tissues of dead earthworms would increase the level of nitrogen inside the vermicasts. There were some dead earthworms located in all of the local earthworm's vermibeds. The ratio of the feed mixture affected greatly the growth of the earthworms and the production of good quality vermicomposts. This was because the ratio affected the pH value and the structure of the feed mixture. In this study, a combination of goat manure, spent coconut flakes and a layer of top soil was used.

The identical amount of nitrogen in sample B and C with the initial reading and the different results from previous findings was probably due to the large concentration of goat manure used. Most of the previous studies used more plant waste and less manure in their vermibeds as stated in section 4.1. Leaching of nitrogen from excess water might also cause the small amount of nitrogen to be present in the vermicasts. There were a few times that heavy rain caused the vermibeds to become watery, which might have caused the leaching of nitrogen.

Phosphorus

Table 1 shows the average value of total phosphorus in all of the compost after 21 days of incubation period. There was no significant difference detected (p=0.08). The initial reading of total phosphorus was 18905 mg/kg while the final readings were around 17000 to 20500 mg/kg. A previous study by Fernandez-Gomez et al. (2010) reported that there was an increase in the phosphorus content up to 97.9% due to mineralization of phosphorus in bio-waste materials.

The result obtained was different than any of the previous studies since it only showed a slight difference from the initial reading. However, there were no studies that stated whether the phosphorus should increase or decrease after vermicomposting process. According to Suthar (2009), if the phosphorus readings were reduced, it may be due to the presence of goat manure which enhanced the mineralization and mobilization of phosphorus. He also stated that if the reading was increasing, it may be due to the high ratio of phosphorus present in the sample and the physical breakdown of matter by the earthworms. The release of phosphorus might be caused by phosphorus-solubilizing microbes in the vermicasts. Even when the feed mixtures were almost identical as they used goat manure, the results obtained were not identical. The result in this experiment showed no increase nor decrease after 21 days. Suthar (2008, 2009) stated that the increase in phosphorus was partly contributed by the earthworms' gut phosphates and further release of phosphorus through phosphorus solubilizing microbes in the vermicasts. He also stated that the phosphorus level in the final product depended on the quality of organic waste and amended materials with the waste.

In this study, goat manure and SCF were used with ratio of 5:1 respectively. This ratio was taken from a previous study by Suthar (2009) that also used goat manure and different types of plant waste such as vegetable solid waste and wheat straw. The difference in final reading was probably due to the duration of the experiment and the type of plant waste used. The duration of his study was 15 weeks compared to this study which took place for only 3 weeks. The other reason was probably the number of earthworms used, which was 20 earthworms, compared to only 10 earthworms in this study. The longer the time given for the composting process, the higher the amount of nutrient in the final product. The same amount of phosphorus measured in this experiment was probably due to the slow feeding rate, the hot climate and short period of the experiment duration.

Potassium

Table 1 shows the average value of total potassium in all of the compost after 21 days of incubation period. There was no significant difference (p=0.08) in the amount of potassium (K) between each sample including with the initial reading. The initial reading of total potassium was 29884 mg/kg and the final readings were around 25000 to 27200 mg/kg. Based on a previous study by Deka et al. (2011), there was an increase in K content in all of their samples as much as 5.3 to 6-fold in vermicompost and a single fold in normal compost. Their initial reading was only 184.2 mg/kg, while this study had an initial reading of 29884.0 mg/kg due to the excessive goat manure. The manure had a high K content and this can be proved by the huge difference in the initial reading from this study and theirs. They used 5:1 ratio with 5-parts being Citronella waste and 1-part cow manure, while this experiment used 5-parts goat manure and 1-part SCF.

The final reading did not show a difference probably because the earthworms preferred a slightly less manure concentration in the bedding and a longer duration of the experiment to produce a good yield. Raphael and Velmourougane (2010) also stated that there was an increase in K content in their findings after vermicomposting process of coffee pulp. The increase in K content might be due to microorganisms that were present in the gut of the earthworms and in the bedding in the process of degradation of bio-waste materials (Kaviraj and Sharma, 2003). The decomposition process by the microorganisms for the solubilization of insoluble potassium produced acid that increased the K content in the final product (Tahir and Hamid, 2012).

However, some studies showed different results, such as Yadav and Garg (2009) who found that potassium content varied in different feedstock. The reduction in potassium content might be due to the leaching of soluble potassium through the action of excess water draining through the vermibed (Tahir and Hamid, 2012). In this experiment, there were times when heavy rain occurred and caused the bedding to be slightly watery. The excess water might cause the potassium to leach out from the bedding, resulting in decrease in K content. However, it cannot be concluded that the potassium should increase or decrease after vermicomposting process.

Total organic carbon

Table 1 shows the average percentage of total organic carbon (TOC) in each compost after 21 days of incubation period. There was significant difference (p=0.00) in the amount of total organic carbon (TOC) between each sample including with the initial reading. Each sample showed a reduction in TOC when compared to the initial reading. The initial reading was 10.07% and the lowest was from sample B which was 5.83%. Each sample showed a significant difference starting from the lowest which was sample B (positive control) followed by sample C (local earthworms).

The findings in this experiment were the same as most of the previous studies. According to Deka et al. (2011), all of the samples showed a reduction in TOC level in their final product including the compost without the earthworms. They also stated that the vermicompost showed a higher reduction compared to the normal compost. This finding was also supported by Suthar (2009) who reported that there was 67% of TOC loss during the vermicomposting process. He stated that earthworm could mineralize cattle dung more easily than other organic waste because it contained a larger population of decomposing microbes such as bacteria and protozoa. The different types of manure used probably caused the reduction to be higher in his experiment than in this experiment. Tahir and Hamid (2012) also recorded a decrease in TOC value for the final product. The duration of the experiment also affected the TOC content greatly since it would give more time for the microbes and earthworms to decompose the mineral in the bedding.

Khwairakpam and Bhargava (2009) stated that some TOC were lost due to the consumption of the available carbon as a source of energy by the earthworms and the microbes. Earthworms function to modify the physical, biological and chemical structure of the waste decomposition system, promoting the colonization of microbes (Suthar, 2009; Tahir and Hamid, 2012). This condition will cause the losses of carbon through respiration in the form of CO_2 not only by the earthworms but also from the microbes that live in there. It also means that the higher the amount of earthworm present, the higher the reduction rate of TOC in the bio-waste. This is probably why the vermicompost was so much better than the normal composting process.

Carbon-to-Nitrogen ratio

Table 1 shows the average total organic carbon (TOC) to total nitrogen (TN) value in all of the compost after 21 days of incubation period. There was significant difference (p=0.00) between the samples. Each sample showed a reduction in C:N ratio from the initial reading except sample A (negative control). The initial reading was 34.9 and the lowest reading recorded was from sample B (positive control) which was 20.4, followed by sample C (local earthworms) with 25.4.

Based on previous studies, it was shown that the C:N ratio reduced in the final product. Several studies conducted by Garg and Gupta (2008), Deka et al. (2011) and Tahir and Hamid (2012) have reported that there was reduction in the C:N ratio in the final product after the vermicomposting process. Garg and Gupta (2008) also reported that the reduction was up to 85.2% in C:N value in the vermicompost. According to Deka et al (2011) and Tahir and Hamid (2012), the reduction in C:N value was due to the loss of carbon as CO_2 through microbial and earthworm's respiration. Simultaneously, addition of nitrogen by earthworms and microbes in the form of mucus and nitrogenous waste materials helped to lower the C:N ratio in the end product.

The final reading of C:N value in this experiment was within the acceptable range according to Environmental Protection Agency (EPA) that suggests the C:N ratio should be around 20 (Adi and Noor, 2009). A study from Ndegwa and Thomson (2000) reported that a reduction in C:N increased the earthworm biomass production, while an increase in C:N ratio produced a more stable end product. Thus, they recommended that a C:N ratio of 25 was suitable for vermicompost product and a C:N ratio of 10 was suitable for breeding of earthworms using bio-solids as a feed substrate. On the other hand, Aira et al. (2006), reported that earthworm biomass increased as the C:N increased when pig slurry was used as food source.

They stated that the number of earthworms increased 5.5 times as the C:N ratio increased from 11 to 19. Nonetheless, it has been proposed that a proper balance of C and N levels contributes to a proper development of earthworms and microbes as well as their interaction (Zhao et al., 2011). Kiyasudeen et al. (2016) found that the optimal ratio can enhance the production of vermicasts. However, different feed source has different physical and chemical properties that require different C:N ratio for a successful vermicompost process.

Earthworms

In this experiment, there were two species of Epigeic earthworm used which were *Eisenia fetida* and unknown local earthworms. *Eisenia fetida* acted as the positive control while the unknown earthworms were the treatment. However, by the end of the experiment, the species of the unknown earthworms still could not be identified even with the help of experts. The local earthworms were also difficult to reproduce during the trial period and the actual experiment. Some of these local earthworms also dried up at the end of the experiment probably due to high atmospheric temperature and low humidity. This experiment was conducted in hot season which had low precipitation and long period of sunlight. The experimental setup was covered with layers of shade (black net) to increase the humidity inside and to cover the experimental setup from direct sunlight. This was due to the inability of the earthworms to survive with intense heat and light during the trial period.

Some of the vermicompost setup was disturbed by predators and other macro-organisms such as red ants and other insects. During the experiment, insect eggs were observed on the vermibed surface. Most of the eggs were removed by hand to prevent the insects from disturbing the vermicompost process. Red ants were found around the vermibox but not inside. This statement was supported by Kiyasudeen et al., (2016) who stated that earthworms became usual preys to other animals such as ants and birds. A small number of mushrooms was also located at box B2 which probably belonged to *Coprinus* sp.

The size of the local earthworms was much smaller than the foreign earthworms. The average weight of the local earthworms was around 0.0146g and 0.8338g for the foreign earthworms. At the end of the experiment, most of the local earthworms died from dehydration. Even when the vermibed was covered with black net and watered regularly, the hot climate at that time was the cause of the death. However, only a small number of foreign earthworms died at the end of the experiment. The total number of local earthworms that survived were only 6 out of 30 and for the foreign earthworms 22 out of 30. This included 5 juvenile-staged earthworms.

Conclusion

Even though the foreign earthworms had better results than the local earthworms, the local ones still showed a positive difference compared to the normal compost without any earthworms in most of the parameters measured. Thus, the vermicompost from the local earthworms will serve better than just normal composted manure. The vermicompost can supply more nutrient and better-quality supplement for plants at a cheaper and faster method when compared to normal compost. It can be concluded that local earthworms will help local farmers in composting process since they are cheap and can be used as organic fertilizers. The vermicompost produced can either be used by the farmers or sold for a side income. Organic farm waste can also be managed by allowing it to be decomposed at a faster rate by the local earthworms.

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