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# Vermicomposting of two types of coconut wastes employing *Eudrilus eugeniae*: a comparative study

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## Abstract

**Background:** While the increase in the number of coconut-based industries in Malaysia supports economic growth positively, it affects the environment negatively by generating large amounts of coconut wastes. This study has endeavored to assess the possibility of vermicomposting different types of coconut wastes and, in doing so, evaluated the potential of using the African nightcrawler (*Eudrilus eugeniae*) to decompose coconut wastes. The study was conducted over a 50-day duration using two different types of coconut wastes: coconut husk (CH) and spent coconut flakes (SCF). The nutrient content of the vermicompost at various stages of treatments was determined. Three different percentage ratios were used: {C1-W or B1-W (100% waste), C2-W or B2-W (70% waste + 30% goat manure), and C3-W or B3-W (50% waste + 50% goat manure)}. Twenty healthy adult *E. eugeniae* (each 0.02 to 0.03 kg) were introduced to each treatment.

**Results:** Results showed that the degradation process was very fast in the spent coconut flakes which needed only 16 days for complete decomposition, while that in the coconut husk needed 2 months. Available phosphorous (P) and total potassium (TK) values declined in CH. The available P and TK in C3-W (50% waste + 50% goat manure) were less than the initial values by 26.6% and 53.69%, respectively. Moreover, P and TK values increased in SCF at the final stage as in B2-W (70% waste + 30% goat manure) which was 69.3% more than the initial level. The weights of the worms were recorded throughout the experimental period.

**Conclusions:** The study showed that vermicomposting could be an efficient method to convert coconut wastes into a valuable by-product.

**Keywords:** Agrowaste, Coconut waste, *Eudrilus eugeniae*, Vermicomposting

## Introduction

### Background of the study

Waste is an inevitable by-product that arises from various anthropogenic activities; it is also considered as one of the major sources of environmental degradation as it causes air, land, and water pollution and contributes to global warming (Peter 2010). Different kinds of industries, change of lifestyle, and population growth are assumed to be among the main factors that increase the rate of waste generation globally and locally. Hence, proper waste management options are vitally important in terms of cost-effectiveness and environmental sustainability.

Malaysia, like many developing countries, is facing an increase in the generation of waste and problems associated with waste disposal (Lina 2004). The Malaysian population was approximately 28.96 million in 2010, based on a projection growth with an average of 1.6% per year compared to that in 2009 which was 28.31 million (Malaxi 2010). As such, waste generation has increased by 3% annually, and recent studies showed that increased solid waste generation has alarmed waste managers (Fauziah and Agamuthu 2009). The national average of waste generation at 1.3 kg/capita is expected to be increasing linearly, reaching to 2.23 kg/capita by 2024 (Mohamad et al. 2009). Approximately 30,000 tonnes of municipal solid waste is generated daily, covering 83% of the country's waste generation which includes agrowastes. About 95% of the total wastes are sent to the landfill for disposal (Fauziah and Agamuthu 2009). Clearly, the way to limit the impact on the environment is by reducing

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the amount of waste that is generated. Failing this, waste must be recycled, composted, or reused. When these options are unsuitable, waste must be incinerated for the purpose of harvesting energy for heating houses or generating electricity, and only as a last resort, should landfills be utilized (Antonio and Domenico 2008).

Globally, 998 million tonnes of agricultural waste is produced in a year, and in Malaysia, 1.2 million tonnes of agricultural waste is disposed into landfills annually. In Malaysia, coconut is the fourth most important crop in terms of acreage, after oil palm, rubber, and paddy. Moreover, coconut has significant socioeconomic implications as it is estimated to provide a source of revenue for 80,000 households. It is important that new methods for treating agro-residues are being adopted and considered in order to achieve sustainable management of agricultural waste. The coconut-based industry in Malaysia has been considered as part of the country's economic sector for a considerably long time and has efficiently developed in recent years. In addition, large amounts of coconut waste are also generated which end up being dumped into the landfills, thereby taking up landfill space.

#### Objectives of the study

This study was carried out toward the purpose of achieving the following objectives:

- (1) To assess the possibility of vermicomposting of different types of coconut wastes
- (2) To evaluate the potential of *Eudrilus eugeniae* to vermicompost coconut wastes
- (3) To generate comparative data on the degradability of the various types of coconut wastes

#### Methods

##### Collections and culturing of earthworm

The earthworm *E. eugeniae* which is commonly known as the African nightcrawler was used in this study and was obtained from a commercial supplier. The worms were cultured in large plastic containers that contained partially

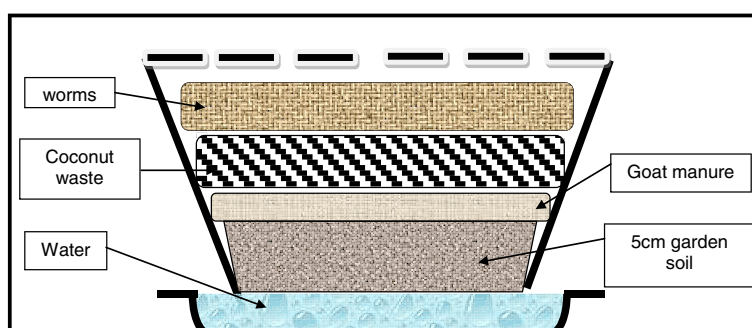
decomposed farm soil mixed with goat manure (GM) under laboratory conditions which maintained a temperature between 25°C to 28°C, as this worm cannot easily tolerate low temperatures.

##### Collection of coconut wastes and experimental setup

The used coconuts were obtained from different sources, while the feed materials such as farm soil and goat dung were obtained from the goat farm at University of Malaya campus. Whereas, the spent coconut flakes (SCF) were obtained from a local market; the coconut husk (CH) was obtained from Kapar Coconut Industry Sdn. Bhd (Selangor, Malaysia). The experiments were conducted in plastic containers which were 20 × 14 × 15 cm (length × width × depth), and the tops of the containers were perforated for aeration. A total of 24 plastic containers were used for both types of coconut wastes. The containers were divided into three different sets, and each set was composed of nine containers for the SCF, CH, and controls (without any earthworm). Each experimental percentage was run in triplicates to minimize any experimental error. *E. eugeniae* earthworms (0.02 to 0.03 kg) numbering 20 were randomly picked and introduced into each treatment. The different percentage ratios were utilized (Table S1.1 in Additional file 1). The layering system that was used in this study is illustrated in Figure 1.

##### Chemical and physical analyses

The experiment was analyzed for pH, C:N ratio, N, P, K, weight loss, and degradation rate. Samples were taken for day 0 (starting day) and the final stage (when the experiments totally degraded) for determining the trends with time. In addition, physical parameters, namely, conductivity, salinity, and color change, were observed. Total nitrogen and total organic carbon were detected by CHNS elemental analysis, while the total phosphorus was determined by ICPMS. The multipurpose Hach Sension 7 Benchtop conductivity meter (Thomas Scientific, Swedesboro, NJ, USA) was used to measure the conductivity and salinity of the samples.



**Figure 1** Layering system of vermicomposting experimental set-up for C2-W.

## Results and discussion

The physical and chemical parameters were determined for the starting day (day 0) and final day of degradation. The time taken for the degradation process to be complete was 50 days for CH compared to only 16 days for SCF. The color of the CH began to change after 12 days which was probably due to the initial stages of the degradation process by microorganisms as well as the action of the earthworms. The experiment's color completely changed to brown at the final stage. For SCF, the color of the coconut flakes changed from white to yellow after 5 days and turned completely brown after 16 days.

### pH

For CH, the pH values of all the experiments from the first day (zero 0) were slightly acidic in C1-W ( $5.2 \pm 0.1$ ), C2-W ( $5.8 \pm 0.6$ ), and C3-W ( $5.9 \pm 0.1$ ) as shown in Figure 2A. The pH values in SCF were slightly alkaline from the first day (day 0). The pH values in B1-W were  $6.8 \pm 1.0$ , whereas B2-W and B3-W recorded pH values of  $7.6 \pm 0.1$  and  $7.8 \pm 0.1$ , respectively (Figure 2B). The pH values at the final stage increased in all types of coconut waste setups. These increased pH values at the final stage of vermicomposting can be attributed to the decomposition of nitrogenous substrates, resulting in the

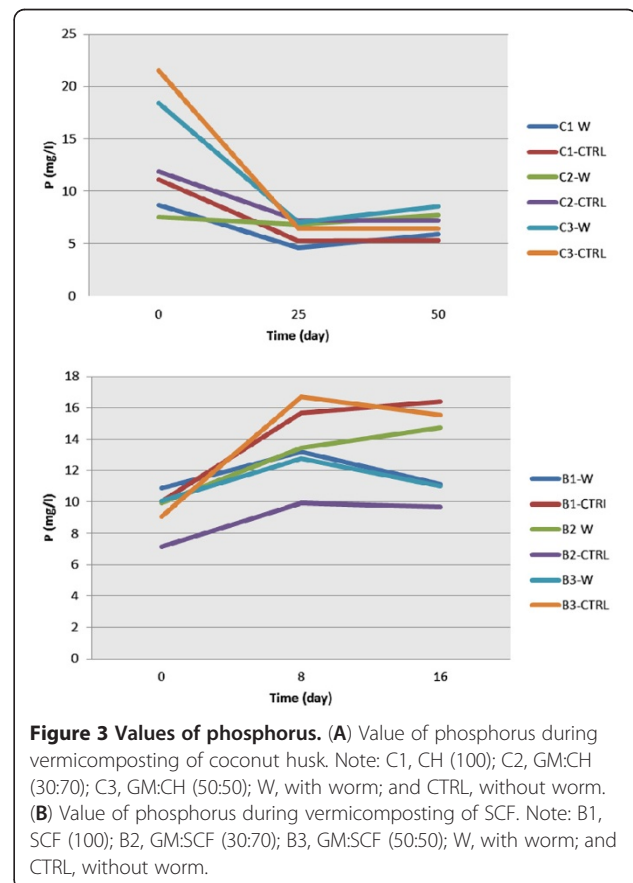
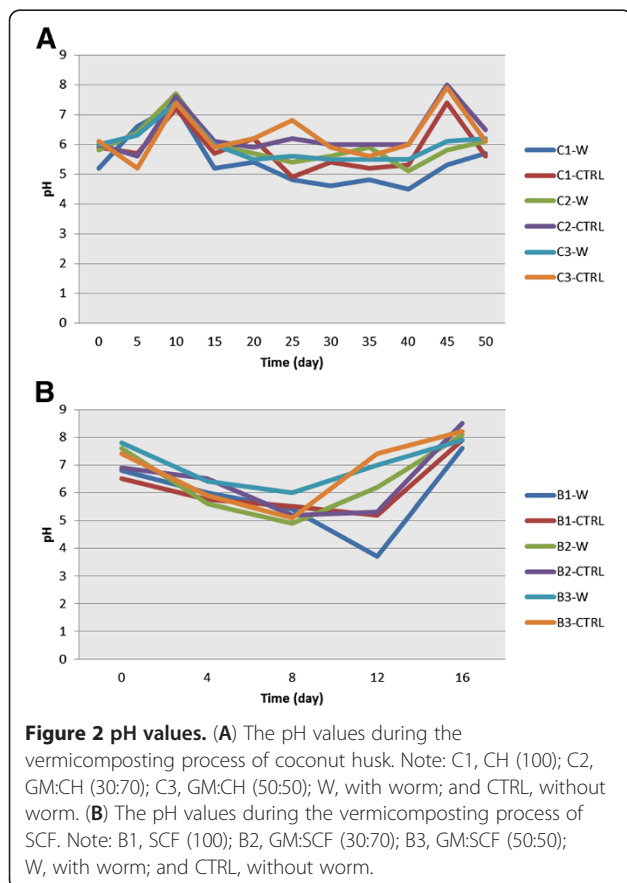
production of ammonia which formed a large proportion of the nitrogenous matter excreted by the earthworms (Muthukumaravel et al. 2008).

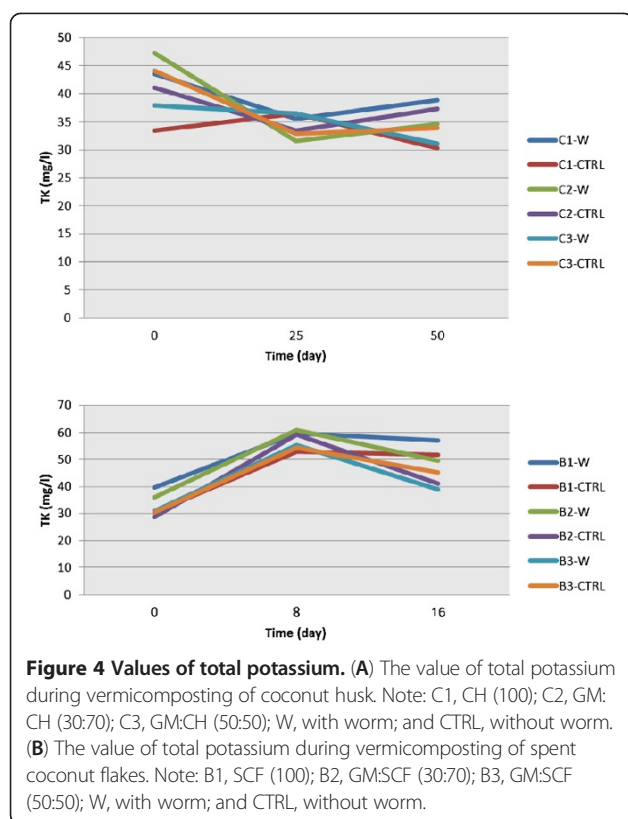
### Total phosphorus

The highest reduction at the final stage of the P value in CH was in C3-W from (18.42 mg/l to 8.53 mg/l) (Figure 3A). The P value increased in SCF at the final stage, and the highest increase was in B2-W from (10.02 mg/l to 16.40 mg/l) (Figure 3B). The highest reduction of the P value was in C3-CTRL and was possibly due to the presence of GM which enhanced the mineralization and mobilization of phosphorus. However, the increase of the P value in SCF may be due to the high ratio of phosphorus present in the vermicbed or the physical breakdown of the materials by the worms. The further release of P might be attributed to the P-solubilizing microorganisms present in worm casts (Edwards and Bohlen 1972; Suthar 2008).

### Total potassium

The total potassium (TK) values decreased in CH at the final stage of vermicomposting (Figure 4A), while in SCF, the TK values for B1-W, B2-W, and B3-W increased (Figure 4B). These reductions in TK values in CH at the





final stage of vermicomposting were possibly due to the leaching of this soluble element through the action of excess water draining through the mass. However, the TK value increased in SCF, and the increase could be attributed to the acid production during the decomposition process by the microorganisms for the solubilization of insoluble K. The TK values of SCF controls (without worms) at the final stage increased.

#### Total organic carbon

The total organic carbon (TOC) values of the CH experiments (with worm) decreased at the final stage of vermicomposting (Table S2A in Additional file 1). The highest reduction of TOC was in C3-W from 10.477% to 3.621%, and the lowest reduction was in C1-W from 4.856% to 3.481%. For SCF, the TOC values also in all of the experiments declined at the final stage of vermicomposting as shown in (Table S2B in Additional file 1). The final reduction in TOC values of all types of coconut wastes was possibly due to the rapid respiration rate that leads to the loss TOC in terms of CO<sub>2</sub> or was probably due to the fact that the organic carbon was utilized as by the worms and resulted to TOC reduction.

#### Total nitrogen

The total nitrogen (TN) values of the CH experiments (with worm) decreased at the final stage of vermicomposting

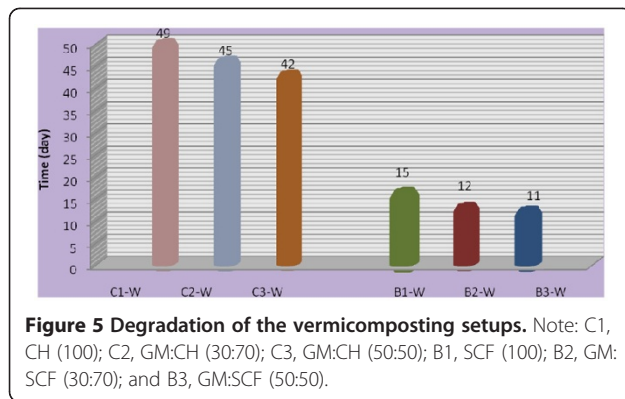
(Table S3A in Additional file 1). For SCF, the TN value increased at the final stage in B2-W and B3-W (from 0.394% to 0.556% and from 0.371% to 0.437%, respectively) (Table S3B in Additional file 1). However, the TN value decreased in B1-W from 0.396% to 0.288%. The reduction of TN values at the final stage of vermicomposting in CH experiments was possibly due to the mineralization of the nitrogen, and the increase of pH in the final stage was assumed to be the significant factor for losing nitrogen as volatile ammonia (Ndegwa and Thompson 2000). However, the TN values increased at the final stage in SCF experiments, and it could be attributed to the initial presence (physicochemical properties) in the substrates and the mineralization process of nitrogen by microbial and enzyme activity in the gut of the worms.

#### Carbon-to-nitrogen ratio

The carbon-to-nitrogen ratio (C/N) decreased at the final stage of vermicomposting in CH and SCF. The highest reduction of C/N in CH experiments was in C3-W, while the lowest reduction was in C2-W (Table S4A in Additional file 1). For SCF, the highest reduction of C/N was in B1-W, while the lowest reduction was in B3-W (Table S4B in Additional file 1). The reduction of C/N at the final stage of vermicomposting for CH and SCF was possibly due to the decline of TOC through the degradation process via the release of CO<sub>2</sub> with a decrease of TN via the release of volatile ammonia. The C/N was within the acceptable range for the vermicompost which was addressed by the EPA that preferred C/N at a ratio of less than 20:1 (Adi and Noor 2009). Moreover, the final C/N declined in the control setups of all types of coconut wastes (except in B2-CTRL which was increased). The highest reduction of C/N in CH controls was in C1-CTRL from 14.9% to 11.4%, and the lowest was in C2-CTRL from 13.5% to 11.3%. For SCF, the C/N declined in B1-CTRL, from 45.8% to 22.9%, and B3-CTRL, from 31.2% to 13.6%. The reduction of C/N in all types of coconut waste control setups was possibly due to the reduction of TOC via the respiration process in the form of CO<sub>2</sub>.

#### Degradation of coconut wastes

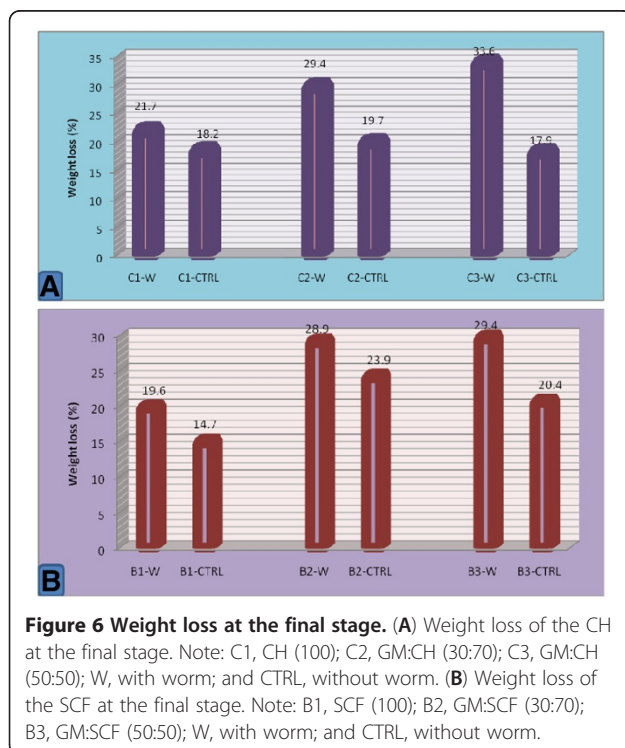
The complete degradation of the C3-W setup was 42 days, while C2-W and C1-W were totally degraded after 45 and 49 days, respectively. Also, the time needed for degradation of the spent coconut flake setups, namely, B3-W, B2-W, and B1-W, was 11, 12, and 16 days, respectively. The degradation of the various types of coconut wastes is shown in Figure 5. Faster degradation in spent coconut flake setups was possibly due to the size of the spent coconut flake particles which were smaller and softer than those of the coconut husk. Additionally, spent coconut flakes also contained high moisture content (52.6%) compared to the coconut husk (14.3%). Spent



coconut flakes were also less fibrous compared to coconut husk. (Michael 2006) had reported similar findings where spent coconut flakes were found to contain low fiber (4 g/100 g SCF), while coconut husk contained high lignin at 43.0%. Therefore, it is possible that the presence of lignin and fiber may have slowed the degradation rates. This indicates that the higher the ligno-cellulose contents of the waste, the slower the vermicomposting process.

#### Weight losses in the vermicomposting setups

For the coconut husk, the final weight loss was highest in C3-W (33.6%), followed by C2-W (29.4%) and C1-W (21.7%) as shown in Figure 6A. However, in SCF, the weight loss was higher in B3-W (29.4%) than in B2-W



(28.9%) and B1-W (19.6%) (Figure 6B). The distinct weight losses between these experiments were possibly due to the presence of goat manure which catalyzed microbial degradation of the waste. Such activities encourage the release of CO<sub>2</sub> via the mineralization process of organic matter and the release of moisture through evaporation. The weight losses in CH and SCF experiments with worms were higher than those in the controls (without worms). The presence of worms in the system demonstrated the enhancement of the biological processes, leading to higher weight loss compared to setups without worms. Also, the worms' physical activities like the blending and mixing of the waste increased the surface area exposed to microorganisms, hence creating more favorable conditions for microbial activities and faster decomposition.

#### Multiplication of earthworms (weights and numbers) in different experiments

After 50 days of vermicomposting the coconut husk, the highest earthworm weight gain was in C1-W (3.39 ± 0.71 g), and the lowest weight gain was in C2-W (-0.57 ± 0.72 g). The number of earthworms declined at the final stage of vermicomposting, and the highest reduction was in C1-W (9.0 ± 2.0 g), while the lowest reduction was in C3-W (4.0 ± 3.0 g) as shown in Table S5A in Additional file 1. For the spent coconut flakes, the highest weight gain was in B2-W (7.67 ± 1.6 g), and the lowest was in B1-W (1.99 ± 0.2 g). The number of worms declined at the final stage of vermicomposting spent coconut flakes. The highest reduction in worm numbers was in B1-W (8.0 ± 2.0), and the lowest decline in worm numbers was in B3-W (4.0 ± 1.0) as shown in Table S5B in Additional file 1.

The final earthworm weight gains were possibly due to the availability of adequate nutrients in the vermibeds for the worms, particularly inside the mixture of waste with GM. Moreover, GM also may have played an important role in earthworm weight gain by providing more nutrients. Additionally, the earthworms may have utilized microorganisms present in their substrates as a food source and could digest them selectively (Suthar 2009; Singh and Sharma 2002).

The final number of worms decreased in all types of coconut wastes. The reduction of the worm's numbers was possibly due to the change of pH (acidic condition) because this type of earthworm is very sensitive to pH change. Also, the texture and hardness of the waste may have had an impact on the worms' reproduction. In addition, the decrease in worm numbers was probably due to the high level of protein that can cause rapid disrepair and heating which often results in creating an environment that is unsuitable to worm production (Adi and Noor 2009).

## Conclusion

This study concludes that the two types of coconut wastes utilized, which were coconut husk and spent coconut flakes, can be composted within different periods of time (50 and 16 days, respectively). Degradation processes were faster in SCF than in CH. The vermicompost of coconut wastes can be utilized as an organic fertilizer instead of being disposed in landfills. The results also showed that the smaller the size of the shredded waste, the more rapid the decomposition process. The success of *E. eugeniae* to vermicompost coconut wastes was also studied, and it was found that, generally, the number of worms declined during the process.

## Additional file

**Additional file 1: Supplementary tables.** A file showing five tables with different data and results during vermicomposting of spent coconut flakes and coconut husk.

## Competing interests

The authors declare that they have no competing interests.

## Authors' contributions

TAT is the main author, did the field and laboratory task, and drafted the manuscript. FSH designed the experiment, gave supervision, drafted the proposal, and participated in the correction of the manuscript. Both authors read and approved the final manuscript.

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