

Enhanced Vermicomposting for Combination of Organic Waste through Subsequent Treatment with Selected Microorganisms

Shamini K. *, Fauziah S. H.

Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia

Abstract The high volume of waste dumped per day leads to serious environmental issues. Among the issues is the generation of methane via anaerobic degradation of waste that contributes towards global warming. There are numerous options in minimizing organic waste disposed into landfills. This includes composting and vermicomposting. This research is aimed to investigate the possibility of treating selected organic wastes via vermicomposting using formulated microbial cocktail. Preliminary treatments were conducted to determine the degradation rate via vermicomposting of selected organic wastes namely spent tea, sugar cane bagasse and banana stem. For this purpose, 1 kg of the organic wastes were placed in plastic containers (50cm x 15cm x 25cm) where 10 *Eudrillus Eugeniae* average size of 5.5cm were introduced. No worms were added into the control set-ups. Three microbial consortia namely M, 3I1 and 3I3 (consisted of *Basillusweihenstephanensis*, *Basilluspumillus*, *Pseudomonas alcaligenes*, *Flavobacteriumjohnsoniae*, *Staphylococcus hominis* and *Bacillus licheniformis*) of were added as the enhancer. With or without the application of 3I3 consortium has the largest difference compared to other experimental setups. It managed to enhance vermicomposting of combination of all three selected organic wastes in equal proportion by approximately 64% resulting with a degradation rate of 2.0×10^{-1} kg per day. The percentage of reduction for carbon to nitrogen ratio indicated 50% for the same combination of wastes in just 5 days. This results indicates that the microbial consortium prepared via this research were able to enhance of the degradation of organic wastes namely sugar cane bagasse, spent tea and banana stem in different combinations. The use of soil was also eliminated as this research focuses more towards economic approach in managing organic waste. However, more extensive research should be conducted to investigate the commercial viability of this approach since this is only done in laboratory scale.

Keywords Vermicomposting, *Eudrilluseugeniae* (African Nightcrawlers), Microbial consortium, Combined organic waste, Enhanced, Degradation, Carbon to nitrogen ratio

1. Introduction

Malaysia faced serious problems due to the ever increasing amount of MSW (Agamuthu *et al.*, 2004; Fauziah and Agamuthu, 2003) that solid waste is considered as one of the three major environmental problems faced by most municipalities besides water and air pollutions (World Bank, 1999). The waste generation rate in Malaysia is continuously rising every year. This is due to the increasing population, the attitude towards shopping and the high living standard, which resulted with impacts from the uncontrollable consumption. Major part of the solid waste generated in Malaysia is from the agricultural and industrial sector. In the past, the high volume of agro-waste generated were dumped into the landfill or buried in the ground. Accumulation of

organic wastes has a negative impact on the environment, as transformation of these refuses through composting alleviates their potential toxicity in the environment and recycles organic fractions for agricultural purposes (Garcia *et al.*, 1991). Wastes from agricultural industries contain very high concentrations of organic material, suspended solids, nitrogen and phosphorus. On the other hand, rejected agricultural materials such as straw, leaves and other by-products, which are burned, dumped and disposed of, account for nearly half of all agricultural production. In Peninsular Malaysia, a total of 4.2 million tons of crop residue and 2.3 million tons of livestock waste were produced. Excluding sewage, agricultural waste from livestock farms, pesticides, and fertilizers constitute highest source of organic pollutants to rivers and coastal waters (Agamuthu *et al.*, 2007). The major aim of agricultural waste conversions is to minimise the waste production. Recycling of the spent agricultural substrates into commercially value added product can minimise waste dumping into the landfill (Agamuthu *et al.*, 2007). The ever alarming issues of the

* Corresponding author:

shamsugeshaan@yahoo.co.uk (Shamini K.)

Published online at <http://journal.sapub.org/microbiology>

Copyright © 2014 Scientific & Academic Publishing. All Rights Reserved

increasing rate of MSW had initiated various technologies and applications to manage the waste. Among the currently practiced options are material recovery and recycling, composting, anaerobic digestion, incineration and gasification. Waste management is also carried out to recover resources from it. (Agamuthu *et al.*, 2007). It is important to manage these wastes as improper waste management may contribute negative impacts to the environment including the emission of greenhouse gases (Senapati and Julka, 1993). This is because the waste disposed in landfill results in aerobic and anaerobic decomposition that emits landfill gases like methane (CH₄), nitrous oxide (NO_x) and high concentration of carbon dioxide (CO₂) (Agamuthu *et al.*, 2007). Thus various treatment alternatives have been identified to manage the ever increasing waste in the country. Conventional composting and vermicomposting can be categorized under this desirable waste management while incineration is the best example for energy recovery where wastes are burned to ash and the ash can be used in brick making industry. The last option in waste management and the most undesirable method is landfilling where the waste was sent and dumped onto a selected ground, far away from residential area. There the waste will be buried in layers.

As a result, emphasis is now on aerobic composting, defined as a microbiological process that converts waste into organic manure rich in plant nutrients and humus (Sharma.S *et al.*, 1999). Composting is defined as the biological degradation (either aerobic or partially aerobic) of the organic components of waste under controlled conditions to produce a stable end product called compost (Agamuthu, 2007). Compost is a dark, crumbly, and earthy smelling form of decomposed organic matter and it can be used to enhance soil fertility and plants growth (Agamuthu, 2004). The organic matter can improve the plant growth by adding water and nutrient-holding capacity to sandy soils, and adding essential nutrients to any type of soil (Agamuthu, 2004). Composting is a simple technique because it can be easily modified to suit local conditions. It generates carbon dioxide and water. Composting can decompose dry organic material up to 75% but only 50% for wet agro waste which require maximum temperature of 60-70°C to kill pathogens and all parasites if the temperature is properly maintained. Once the organic material (waste) is converted into useful end product, it will become 'valuable' and the termed is valorisation (Agamuthu, 2004). The favourable initial C/N ratio for composting is 30:1 (Agamuthu, 2004). Too high or too low of C/N ratio can give problem to composting bedding material. High C/N ratio (more than 35) can retards the composting process and increase the time of the process. Compost heap also needs less or no turning while water must be added till the moisture content is at 58-60% (optimum level) (Nair *et al.*, 2005).

Since composting is an inexpensive, simple and environmentally sound method for waste disposal, it has been widely applied in many countries. Many researchers have conducted similar researches but with different

application purpose namely solid wastes compost (Hachicha *et al.*, 2006), municipal solid wastes (Montemurro *et al.*, 2005) and as well as by-products from biotechnology works (Martinez and Tabatabai, 1997). All this research has been used to enhance both crop yield and to improve the soil quality. Composting also improves the handling characteristics of organic residues by reducing its volume and weight (Bertran *et al.*, 2004). Even though there are many advantages of employing this method for organic waste management but many researchers found one common major problem; odour (Rasalet *et al.*, 1988, Sharma *et al.*, 1998).

The organic waste management alternative chosen in this study is the degradation by worm; namely vermicomposting. Vermicomposting is getting more attention globally year after year for its vital role in agriculture and sustainable development (Lavelle *et al.*, 1988). Vermicomposting is process of breaking down of organic waste into soil and humus by worms (Ghatnekar *et al.*, 1998). Vermicomposting produces richer end product called "worm castings". On the other hand vermicomposting is a process of utilizing earthworms, an eco-biotechnological process that transforms energy rich and complex organic substances into a stabilized humus-like product (Benitez *et al.*, 2000).

Earthworms stabilize organic residues by producing earthworm casts, which are called vermicompost (Riffaldi and Levi-Minzi, 1983). Earthworm casts are soil conditioners that have a high nutrient bioavailability for plant growth. The types of organic waste such as cow dung give great influence to the rate of vermicomposition while increasing the amount of macronutrients in the vermicompost (Muthukumaravel, 1996; Vasanthy *et al.*, 2005). An increase in nitrogen concentration may be due to nitrogenous metabolic products of earthworms which are returned to the soil through casts, urine, muco-proteins and earthworm tissue (Umamaheswari & Vijayalakshmi, 2003). It had been reported that the mixture of vegetable waste and cow dung is suitable, converting the important plant nutrients into a more soluble state for plant to utilize (Nair *et al.*, 2005) and for the production of higher quality vermicompost. Vermicomposting reduce the C: N ratio and retains more N than the traditional methods of preparing composts (Gandhi *et al.*, 1997). It increases macropore space ranging from 50 to 500 µm, resulting in improved air-water relationship in the soil which favourably affects plant growth (Marinari *et al.*, 2000). According to Maheswarappa *et al.* (1999), the application of organic matter including vermicompost favorably affects soil pH, microbial population and soil enzyme activities. It also reduces the proportion of water-soluble chemical species, which may cause possible environmental contamination (Mitchell and Edwards 1997). There are several factors that make the vermicompost good as fertilizer as well as, preferable technique in managing wastes. Earthworm is the organism which feed on all bio-degradable materials; hence vermicompost practice will partially aid in handling garbage disposal problems (Ndegwa and Thompson, 2001). It shows

ability to hold more nutrients over longer periods without any negative impacts to the environment (Ndegwa and Thompson, 2001). By applying vermicompost as fertilizer, it can encourage the growth of new shoots or leaves and improves the quality and shelf life of the plant. Vermicompost is a valuable input for sustainable agriculture and wasteland development. It only requires a small place such as a pot culture or in home gardens. The high nutrient content of vermicompost had been proven by studies in Maharashtra which used vermicompost in grapes plantation (Senapathi *et al.*, 1993). The results indicated that the production and the quality of the grapes were improved. But there are also disadvantages of vermicomposting namely due to temperature concern, the amount of wastes to be applied cannot be too much because the temperature will rise too high and kill off all the worms. Large quantities of waste must be spread out over large areas of ground to maintain the correct temperature as well as low temperature needs to be maintained along the process so the worms do not lose their moisture which leads to dehydration. Vermicomposting also requires extra care compared to the regular composting method. The earthworm species chosen for this research, *Eudriluseugeniae* commonly referred to as the African nightcrawler, occurs all over the world but mostly in West African regions (Shagoti 1985; Segun 1998).

Eudriluseugeniae grows well at a temperature of 30°C (Viljoen & Reinecke 1992), attaining maximum growth in about 15 to 20 weeks (Rodríguez & Lapiere 1992). It ranges in size from about 10cm in length to huge specimens of over 12cm as the size may depend on habitat (Segun, 1998). It has a purple sheen and the posterior segments are evenly tapered to a point (Blackburn, 1989). It is a non-burrowing type that live in the upper layer of the soil surface which is red or purple in colour and 10 to 15 cm long but their life span is only 28 months. Rani *et al.* (2007) found that the *Eudriluseugeniae* is capable of ingesting and excreting organic materials at a high rate as they eat 10% soil and 90% organic waste materials. It converts the organic waste into vermicompost faster and has the ability to tolerate temperatures ranging from 0 to 40°C but the regeneration capacity is more at 25 to 30°C and 40–45% moisture level in the pile than the burrowing earthworms (Rani *et al.* (2007). Gaur (1982) found that the nutrients are richer in the earthworm casts. Earthworm's activities in mixing and translocation of soil constituents can help to increase the soil fertility by removing the decomposed litter from the soil surface, ingesting it and transporting it to the subsurface layers. These characteristics make earthworms an attractive organism to monitor the impact of contaminants in soils (Fischer and Koszorus, 1992). Aside from worms, soil microbes are also crucial in degradation of organic matter. The consecutive section discusses the role of microbial population in composting and organic waste degradation enhancement. Various microorganisms are involved in the

composting process which includes actinomycetes, bacteria, fungi and yeast. Many countries around the globe have been practicing the application of microbes into their organic waste composting process. For example in Japan, there are 90 types of available microbial additives (MA) being used for animal manure composting process (Wakase *et al.*, 2008). Apart from Japan, North America also has numerous microbial additives used to treat their organic waste (Dubois *et al.*, 2004).

This research is aimed to investigate the possibility of treating selected organic wastes via vermicomposting using formulated microbial cocktail. Vermicomposting has been chosen for this research mainly is because the worms decomposition emit very minimal odour as they contribute to soil processes through faecal excretion in form of casts, burrows, feeding and digestion (Tian *et al.* 2000). During their feeding, earthworms greatly promote microbial activity, which accelerates the breakdown of organic matter and stabilization of soil aggregates (Dindal, 1985).

2. Methods

2.1. Experimental Setup

Vermicomposting was conducted in plastic container with the standard size of 50cm x 15cm x 25cm containers. Preliminary treatments were conducted to determine the degradation rate via vermicomposting of selected organic wastes namely spent tea, sugar cane bagasse and banana stem. The combination ratio selected for this research are 100% waste, 75% waste 25% soil and finally 50% waste and 50% soil (Table 1). For this purpose, 1 kg of the organic wastes were placed in plastic containers where 10 *Eudriluseugeniae* average size of 5.5cm were introduced. No worms were added into the control set-ups.

2.2. Microbial Source

The identified bacteria from the preliminary individual vermicomposting set-ups were used to prepare the microbial consortium preparation. The species isolated from the screening process consisted of *Bacillus weihenstephanensis*, *Flavobacterium johnsoniae*, *Staphylococcus hominis* and *Bacillus licheniformis*.

The microbial consortium was prepared in three different combinations. The consortium M combined all microbes isolated from the vermicomposting set-up (Table 2) was added. The 3I1 and 3I3 combinations of microbes were categorized according to their similar morphological and physical characteristics. The microbial consortiums were prepared in the same concentration with constant optical density of 510nm. The organic substrates were mixed through once added with the microbial consortium. Finally, the worms were introduced into the set-ups.

Table 1. Description of vermibeds used for experimentations (^a(weight: weight)) Ratio^a(Waste: Waste)

Vermibed	Ratio ^a	Description
A	100%	100% spent tea
C	3:1	75% of spent tea waste and 25% soil
E	1:1	50% of spent tea waste and 50% soil
F	100%	100% of sugar cane bagasse
H	3:1	75% of sugar cane bagasse and 25% soil
J	1:1	50% of sugar cane bagasse and 50% soil
K	100%	100% of banana stem
L	3:1	75% of banana stem and 25% soil
M	1:1	50% of banana stem and 50% soil
TB	1:1	50% of banana stem and 50% spent tea
TS	1:1	50% of sugarcane bagasse and 50% spent tea
TSB	1:1	33.33% spent tea, 33.33% sugar cane bagasse & 33.33% banana stem
TBM	1:1	50% of spent tea + 50% of banana stem + 100ml M innoculum
TSM	1:1	50% of spent tea + 50% of sugar cane bagasse + 100ml M innoculum
TSBM	1:1:1	33.33% of spent tea + 33.33% of banana stem + 33.33% of sugar cane bagasse + 100ml M innoculum
TBM	1:1	50% of spent tea + 50% of banana stem + 100ml 3I1 innoculum
TSM	1:1	50% of spent tea + 50% of sugar cane bagasse + 100ml 3I1 innoculum
TSBM	1:1:1	33.33% of spent tea + 33.33% of banana stem + 33.33% of sugar cane bagasse + 100ml 3I1 innoculum
TBM	1:1	50% of spent tea + 50% of banana stem + 100ml 3I3 innoculum
TSM	1:1	50% of spent tea + 50% of sugar cane bagasse + 100ml 3I3 innoculum
TSBM	1:1:1	33.33% of spent tea + 33.33% of banana stem + 33.33% of sugar cane bagasse + 100ml 3I3 innoculum

Table 2. Description of microbial consortium preparation at different combinations of identified microbes

Label	Description of microbial consortium
M	<i>Bacillusweihenstephanensis</i> , <i>Basilluspumillus</i> , <i>Pseudomonas alcaligenes</i> , <i>Flavobacteriumjohnsoniae</i> , <i>Staphylococcus hominis</i> and <i>Bacillus licheniformis</i>
3I1	<i>Staphylococcus hominis</i> , <i>Bacillusweihenstephanensis</i> and <i>Basilluspumillus</i>
3I3	<i>Pseudomonas alcaligenes</i> , <i>Flavobacteriumjohnsoniae</i> and <i>Bacillus licheniformis</i>

2.3. Vermicomposting Setups

Unlike the preliminary set-up which was the individual vermicomposting of each organic waste combined with soil, there are also set-ups on the other combination. This includes combination of spent tea with sugar cane bagasse and combination of spent tea with banana stem at the same ratio. For the purpose of testing microbial cocktails as vermicomposting enhancer, setups of 1:1:1 (spent tea: sugar cane bagasse: banana stem) were used.

All the setups were conducted in triplicates. All the samples collected from each setup were subjected for initial physico-chemical microbial analysis. For the physical analysis, pH and the colour changes were monitored. As for the physico-chemical analysis, Carbon to Nitrogen ratio, total organic carbon and Potassium (K) were tested.

3. Results

3.1. Physico-chemical Analysis

Different set-ups of vermicompost with the various organic substances required different period for degradation. Table 3 & 4 shows the initial reading for the selected

physical and chemical parameters for all individual organic waste and the organic wastes combinations respectively. At the initial state, the pH of the spent tea recorded to be the lowest among the three organic wastes (Table 2). The banana stem has a good initial pH which is suitable for vermicomposting which recorded 4.13 for the 50% combinations with soil (Table 2). As for the combination of organic waste, almost all the combination recorded a good balanced pH to initiate the vermicomposting process (Table 3). The pH changes for the combination of organic waste after the introduction of various microbial consortium, recorded an almost neutral pH at the initial stage (Table 7,8&9). After the completion of the process for each setup, all the individual waste showed a pH range within 7-7.5 which is neutral (Table 5). As for the combination setup, the final products showed slightly alkaline pH for all the combinations (Table 6). The same result can be observed after the introduction of microbial consortium which means the introduction of microbial consortium did not contribute any changes in pH (Table 10,11&12). As for the final product textural appearances, the formation of castings were more visible in a shorter period of time after the introduction of microbial consortium 3I3. The castings were for

combination of all waste and also almost the same result can be seen in the combination of spent tea and banana with the addition of microbial consortium M.

The initial C/N ratio for spent tea was the lowest among all organic waste set-ups while the sugar cane bagasse set-up indicates the highest value. The final reading for the vermicomposting set-ups indicates that spent tea has the lowest C/N (8.36) (Table 5) ratio among all set-ups. A more drastic reduction of C/N ratio (69%) can be observed in sugar cane bagasse set-up while the reduction for C/N ratio for combinations and the banana stem set-ups were not too drastic. (Table 5) The reduction of C/N ratio were also drastic for the combination of organic waste after the addition of microbial consortium but it was not too significant and almost similar to before the addition of microbial consortium (Table 7,8,9, 10,11&12). Overall, the most drastic reduction of carbon to nitrogen ratio can be observed in combination of all organic waste with the

addition of inoculum 313 which reduced from 29.2 to 14.2 in just 5 days (Table 12).

Available P and K in sugar cane bagasse recorded higher initial value compared to the other waste types. Various changes in parameter were observed after the completion of the vermicomposting process. Table 5&6 detailed the results obtained from the analysis of individual and combined organic waste respectively. The final reading for the vermicomposting set-ups indicates that spent tea has the lowest C/N (8.36) ratio among all set-ups. A more drastic reduction of C/N ratio (69%) can be observed in sugar cane bagasse set-up while the reduction for C/N ratio for combinations and the banana stem set-ups were not too drastic. The Available K and P were still more abundant in sugar cane bagasse set-ups. Finally, the initial and final recording of physico-chemical analysis for the combination setup after the application of microbial consortium, the results are indicated in Table 7,8,9,10,11&12

Table 3. Physico-chemical characteristics of day zero of individual organic waste

Parameters	A*	C*	E*	F*	H*	J*	K*	L*	M*
pH	5.76±1.2	6.1±1.6	6.25±2.2	3.16±0.9	3.14±0.9	2.13±1.3	6.09±1.1	6.59±1.4	6.72±1.45
Total Organic C (%)	3.85±0.8	13.33±4.2	16.9±3.5	14.0±3.5	9.2±2.6	4.3±1.9	19.23±4.2	18.13±2.1	32.9±3.6
Available P(mg/kg)	1.16±0.5	1.69±0.2	2.11±0.3	1.36±0.5	1.69±0.7	2.47±0.8	0.95±0.10	0.86±0.22	1.20±0.9
Exchangeable K(mg/kg)	4.06±1.7	5.48±2.1	7.54±2.5	5.06±2.2	5.48±2.3	7.54±2.1	2.06±0.18	3.18±1.04	3.87±1.3
C:N ratio	11.13±3.3	11.62±3.2	11.30±1.9	58.12±10.9	57.55±18.7	58.25±17.2	26.13±10.3	26.62±8.7	33.20±11.3
Conductivity (µs)	35±7.5	44±6.4	73±7.3	256±6.3	133±10.8	87±9.4	65±22.1	72±20.3	95±30.1

*The different label (A, C, E, F, H, J, K, L, M) indicates different organic waste used. A: 100% spent tea, C: 75% spent tea 25% soil, E: 50% spent tea 50% soil, F: 100% sugarcane bagasse, H: 75% sugar cane bagasse 25% soil, J: 50% sugar cane bagasse 50% soil, K: 100% banana stem, L: 75% banana stem 25% soil, M: 50% banana stem 50% soil.

Table 4. Physico-chemical characteristics of day zero of combination organic waste

Parameters	TB*	TS*	TSB*
pH	5.97±1.2	2.22±0.9	5.58±1.84
Total Organic C (%)	19.23±5.8	18.13±7.2	32.9±11.5
Available P(mg/kg)	0.95±0.16	0.86±0.23	1.20±0.11
Exchangeable K(mg/kg)	2.06±0.7	3.18±1.1	3.87±1.2
C:N ratio	37.17±11.3	30.8±9.1	27.30±16.2
Conductivity (µs)	92±21.4	196±28.1	236±37.4

*The different label (TB, TS & TSB) indicates different combination of selected organic waste. TB: 50% spent tea 50% banana stem, TS: 50% spent tea 50% sugar cane bagasse, TSB: 33.33% spent tea 33.33% sugar cane bagasse 33.33% banana stem

Table 5. Physico-chemical characteristics of final vermicompost of individual organic waste

Parameters	A*	C*	E*	F*	H*	J*	K*	L*	M*
pH	5.76±3.2	6.1±3.7	6.25±3.6	4.68±1.2	4.66±1.36	5.66±2.4	7.40±1.3	7.45±2.3	7.43±1.94
Organic C (%)	2.75±0.4	9.11±1.5	16.76±2.4	6.35±2.1	5.20±1.5	1.71±1.02	10.75±2.5	9.58±1.8	16.16±3.1
Available P (mg/kg)	1.23±0.5	1.58±0.4	2.23±0.6	1.97±0.6	2.18±0.45	2.67±0.67	1.23±0.6	1.18±0.4	2.44±0.53
Exchangeable K(mg/kg)	4.26±1.5	5.68±3.1	8.02±3.2	5.46±1.7	6.08±2.01	8.32±3.1	3.10±1.4	3.62±1.10	5.82±1.47
C:N ratio	7.77±3.2	7.23±1.8	10.08±3.1	21.17±16.5	18.41±6.8	14.37±6.2	20.17±11.1	18.23±10.2	15.4±4.2
Conductivity (µs)	148±10.4	121±33.5	129±56.2	140±22.1	191±31.2	226±26.2	137±5.2	184±3.2	265±3.7

*The different label (A, C, E, F, H, J, K, L, M) indicates different organic waste used. A: 100% spent tea, C: 75% spent tea 25% soil, E: 50% spent tea 50% soil, F: 100% sugarcane bagasse, H: 75% sugar cane bagasse 25% soil, J: 50% sugar cane bagasse 50% soil, K: 100% banana stem, L: 75% banana stem 25% soil, M: 50% banana stem 50% soil

Table 6. Physico-chemical characteristics of final vermicompost of combination organic waste

Parameters	TB	TS	TSB
pH	9.22±2.1	8.42±2.2	9.47±3.1
Organic C (%)	10.75±3.1	9.58±3.2	16.16±3.7
Available P (mg/kg)	1.23±0.3	1.18±0.22	2.44±0.39
Exchangeable K(mg/kg)	3.10±1.2	3.62±1.38	5.82±2.04
C: N ratio	19.2±6.4	25.3±12.2	13.2±5.2
Conductivity (µs)	613±25.2	121±23.2	685±46.7

*The different label (TB, TS & TSB) indicates different combination of selected organic waste. TB: 50% spent tea 50% banana stem, TS: 50% spent tea 50% sugar cane bagasse, TSB: 33.33% spent tea 33.33% sugar cane bagasse 33.33% banana stem

Table 7. Physico-chemical characteristics of day zerovermicompost (Introduction of consortium M)

Parameters	TBM	TSM	TSBM
pH	6.14±3.1	6.15±2.5	5.76±3.2
Total Organic C (%)	11.13±3.1	13.45±4.2	18.43±4.2
Available P(mg/kg)	1.33±0.8	1.09±0.9	0.98±1.0
Exchangeable K(mg/kg)	2.14±1.02	2.36±1.05	2.20±0.85
C: N ratio	27.17±11.2	29.2±10.5	34.8±12.54
Conductivity (µs)	185±14.4	306±46.2	281±64.5

KEYS: TBM= 1:1(Banana stem + spent tea+M) TSM= 1:1(Bagasse+ spent tea+ M) TSBM=1:1:1(Banana Stem + spent tea+ sugar cane bagasse +M)

Table 8. Physico-chemical characteristics of day zerovermicompost (Introduction of consortium 311)

Parameters	TB311	TS311	TSB311
pH	6.11±2.1	6.12±2.3	5.74±3.2
Total Organic C (%)	26.35±7.8	28.9±10.5	29.35±11.5
Available P(mg/kg)	0.93±0.9	1.26±0.9	1.21±0.8
Exchangeable K(mg/kg)	1.98±0.92	1.87±0.26	2.22±1.2
C: N ratio	23.12±10.3	33.30±12.4	37.7±15.7
Conductivity (µs)	190±21.5	296±33.8	294±35.7

TB311=1:1(Banana Stem + spent tea + 311) TS311=1:1:1 (Sugar cane bagasse+ spent tea +311) TSB311= 1:1:1(Banana Stem + sugar cane bagasse+ spent tea+ 311)

Table 9. Physico-chemical characteristics of day zerovermicompost (Introduction of 313)

Parameters	TB313	TS313	TSB313
pH	6.13±2.1	6.15±2.3	5.72±1.5
Total Organic C (%)	14.23±4.1	19.45±5.2	26.13±7.2
Available P(mg/kg)	1.18±1.5	1.23±0.5	0.89±0.11
Exchangeable K(mg/kg)	2.18±1.01	2.36±1.09	2.42±1.1
C: N ratio	29.2±6.3	24.1±11.3	38.8±16.1
Conductivity (µs)	203±22.8	310±28.7	289±47.8

TB313=1:1(Banana Stem + spent tea + 313) TS313=1:1:1 (Sugar cane bagasse+ spent tea + 313) TSB313= 1:1:1(Banana Stem + sugar cane bagasse+ spent tea+ 313)

Table 10. Physico-chemical characteristics of final vermicompost(Introduction of consortium M)

Parameters	TBM	TSM	TSBM
pH	7.71±2.1	8.01±3.1	7.92±2.6
Organic C (%)	8.16±2.2	10.09±3.2	13.18±3.2
Available P (mg/kg)	3.1±1.2	3.65±1.43	3.48±0.98
Exchangeable K(mg/kg)	4.09±1.32	4.22±1.48	4.62±1.65
C:N ratio	13.1±5.2	18.98±6.3	17.3±8.2
Conductivity (µs)	255±18.4	331±22.5	127±15.3

KEYS: TBM= 1:1(Banana stem + spent tea+M) TSM= 1:1(Bagasse+ spent tea+ M) TSBM=1:1:1(Banana Stem + spent tea+ sugar cane bagasse +M)

Table 11. Physico-chemical characteristics of final vermicompost (Introduction of consortium 311)

Parameters	TB311	TS311	TSB311
pH	8.06±2.4	7.94±3.4	8.15±4.3
Organic C (%)	16.01±5.3	18.2±5.1	16.5±6.2
Available P (mg/kg)	4.02±1.67	3.26±1.04	3.45±1.22
Exchangeable K(mg/kg)	4.95±2.01	5.10±1.98	5.92±2.49
C:N ratio	11.2±3.5	12.2±2.8	13.15±3.2
Conductivity (µs)	379±35.3	163±16.3	350±35.5

TB311=1:1(Banana Stem + spent tea + 311) TS311=1:1:1 (Sugar cane bagasse+ spent tea + 311) TSB311=1:1:1(Banana Stem + sugar cane bagasse+ spent tea+ 311)

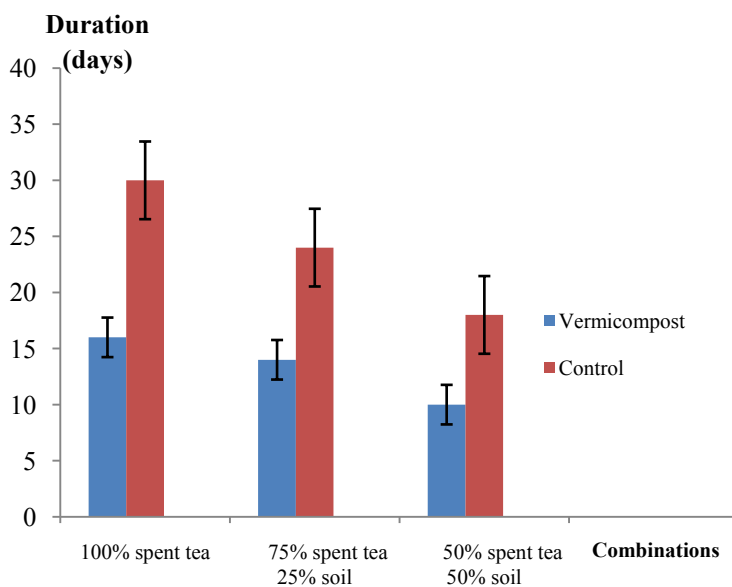
Table 12. Physico-chemical characteristics of final vermicompost (Introduction of consortium 313)

Parameters	TB313	TS313	TSB313
pH	8.27±2.6	8.40±3.9	8.42±2.2
Organic C (%)	8.01±3.2	6.20±4.2	14.1±5.2
Available P (mg/kg)	3.73±1.01	4.11±2.25	4.29±3.1
Exchangeable K(mg/kg)	5.21±1.67	5.63±3.54	5.49±3.8
C:N ratio	14.2±6.2	14.98±5.5	25.3±10.2
Conductivity (µs)	163±15.3	152±19.3	350±32.2

TB313=1:1(Banana Stem + spent tea + 313) TS313=1:1:1 (Sugar cane bagasse+ spent tea + 313) TSB313=1:1:1(Banana Stem + sugar cane bagasse+ spent tea+ 313)

3.2. Rate of Degradation

The combination of 1:1 spent tea and soil vermicomposting was the fastest to complete in just 10 days among the other organic waste selected in the individual vermicomposting setup (Figure 1). The average degradation rate via vermicomposting is 1.00×10^{-2} kg per day for the spent tea which produced nutrient-rich compost consist of 1.23 mg /kg P and 4.26 g/kg K. As for the sugar cane bagasse, the result was similar to spent tea waste that the combinations of 50 % waste and 50% soil via vermicomposting was the fastest to degrade in just 14 days (Figure 2) while for the banana stem, the result indicated that the 1:1 combinations were the fastest to degrade in 12 days (Figure 3). The combination ratio that was the fastest to degrade for all three combination of organic waste is 50:50. The vermicompost in combination of spent tea with banana stem degraded the fastest compared to other combinations. It took only 20 days and 16 days spent tea and sugar cane bagasse combination and spent tea, bagasse and banana stem respectively to completely degrade. The degradation rate via vermicomposting for mixture of spent tea and banana stem is 8.33×10^{-2} kg per day, 6.25×10^{-2} kg per day for all waste mixture and finally 5.00×10^{-2} kg per day for 50:50 combinations of sugar cane bagasse and spent tea (Figure 4).

**Figure 1.** The duration of degradation of spent tea via vermicomposting

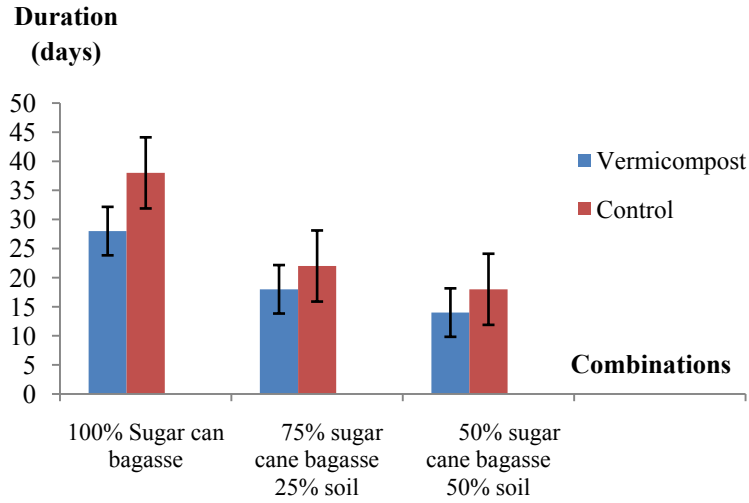


Figure 2. The duration of degradation of sugar cane bagasse via vermicomposting

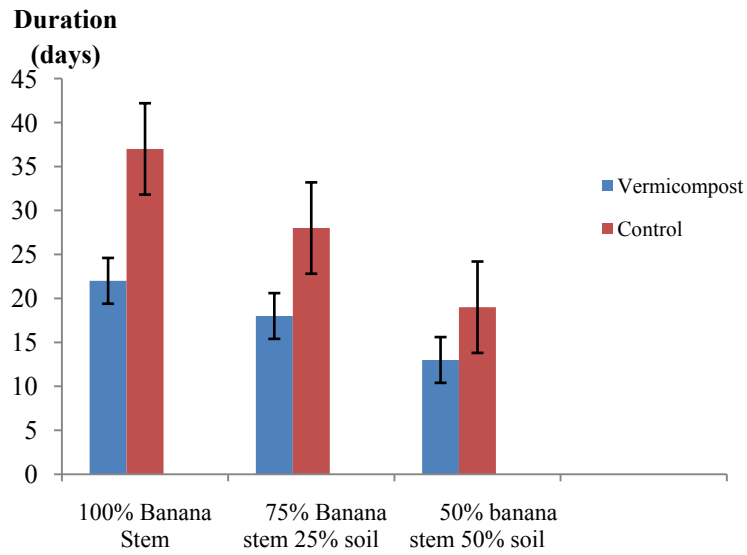


Figure 3. The duration of degradation of banana stem via vermicomposting

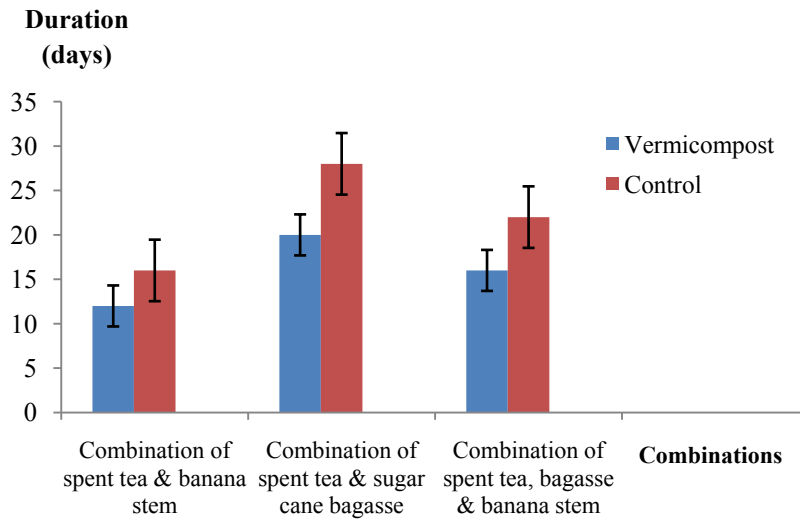


Figure 4. The duration of degradation of various combination of organic waste vermicomposting

After the introduction of microbial consortium at various combinations, the results indicate that the duration taken for a complete degradation of combination of banana stem and spent tea was only 8 days (Figure 5) compared to the other two combinations with the addition of microbial consortium M (Table 4). For the introduction of the other combination of microbial consortium (3I1 & 3I3), the results are shown in Figure 6&7. In overall, the combination of all waste with the addition of microbial consortium 3I3 was the fastest to degrade completely in 4 days.

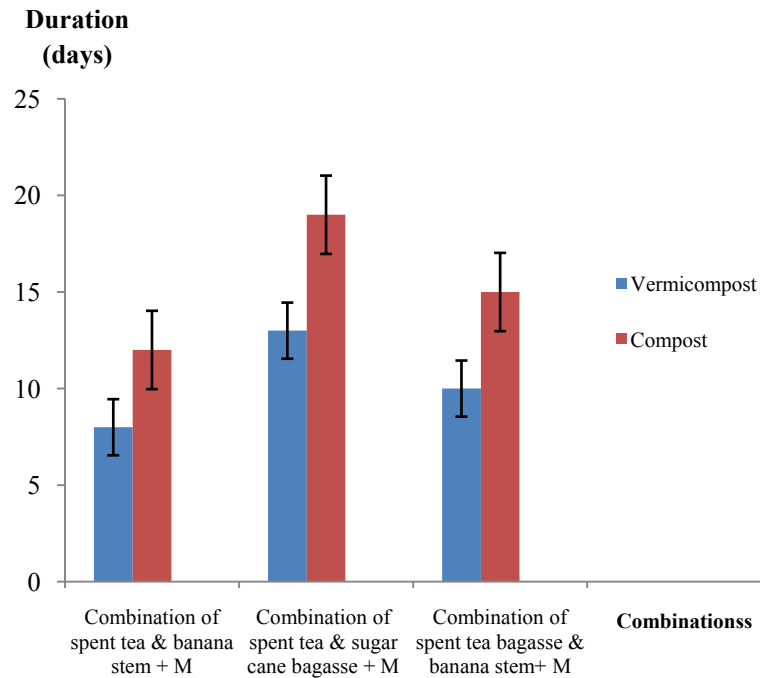


Figure 5. The duration of degradation of various combination of organic waste via vermicomposting with the addition of all mix microbial consortium (M)

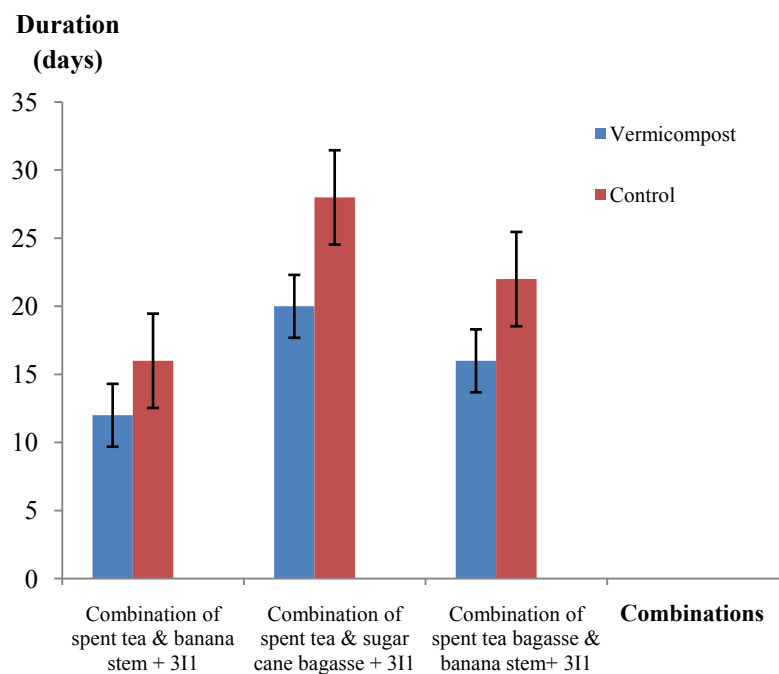


Figure 6. The duration of degradation of various combination of organic waste via Vermicomposting with the addition of microbial consortium 3I1

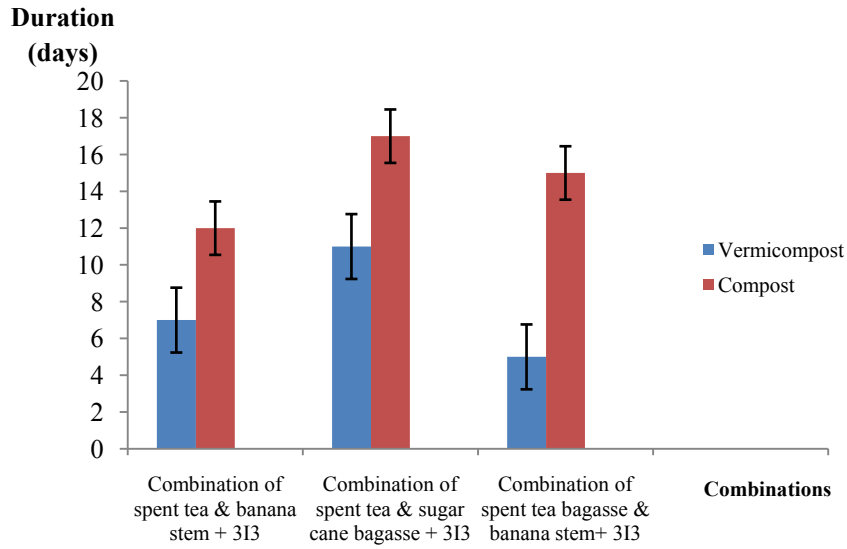
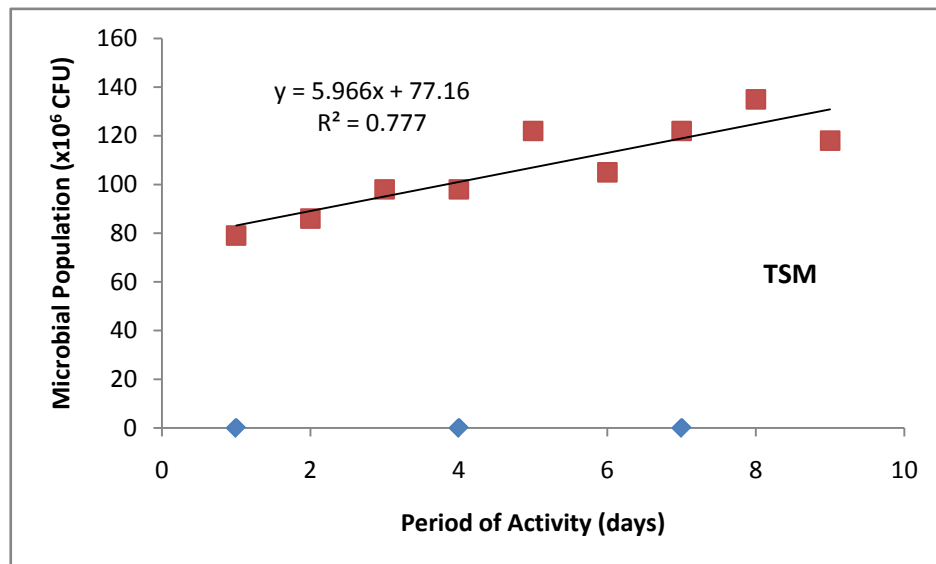
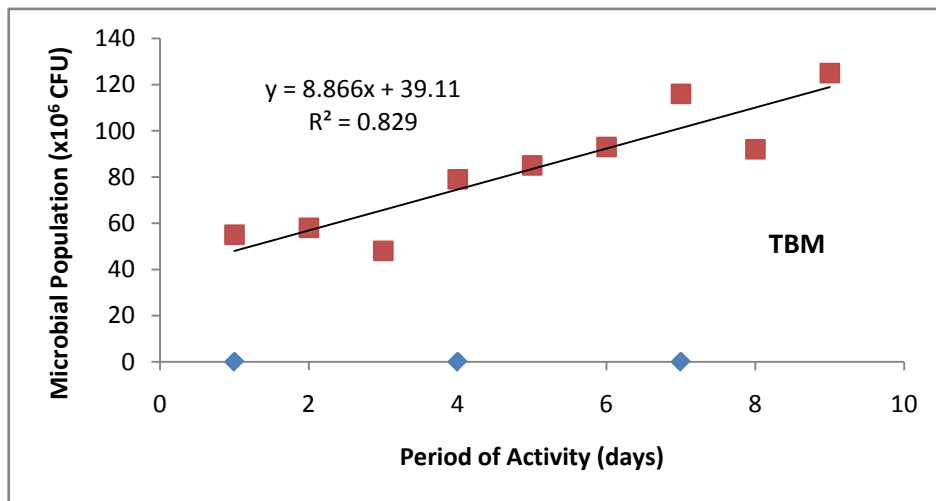


Figure 7. The duration of degradation of various combination of organic waste via vermicomposting with the addition of microbial consortium (3I3)

3.3. Microbial Population Count



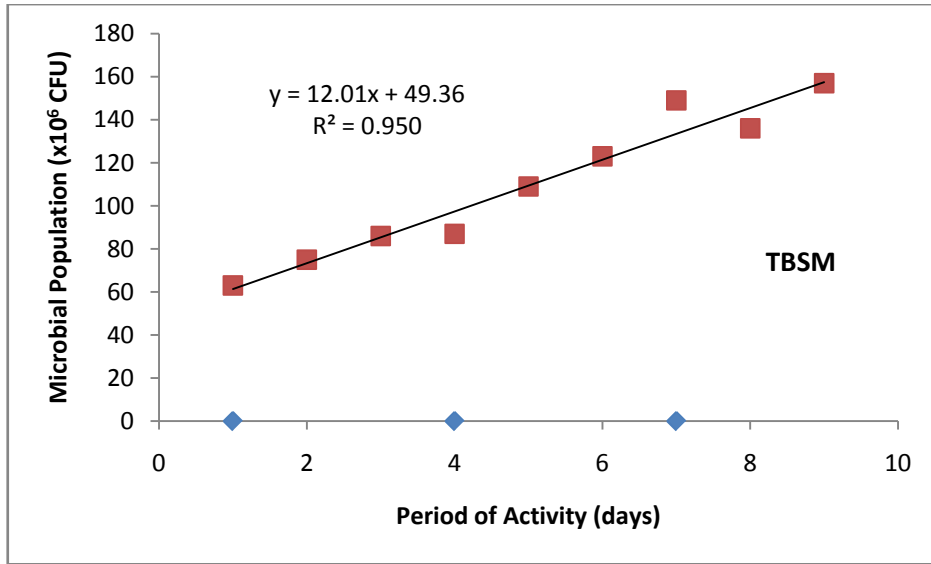
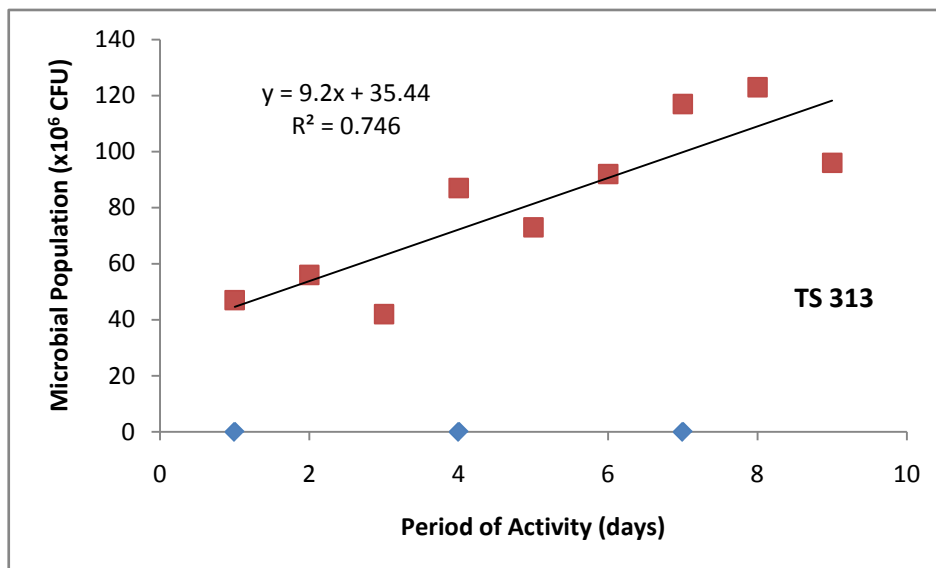
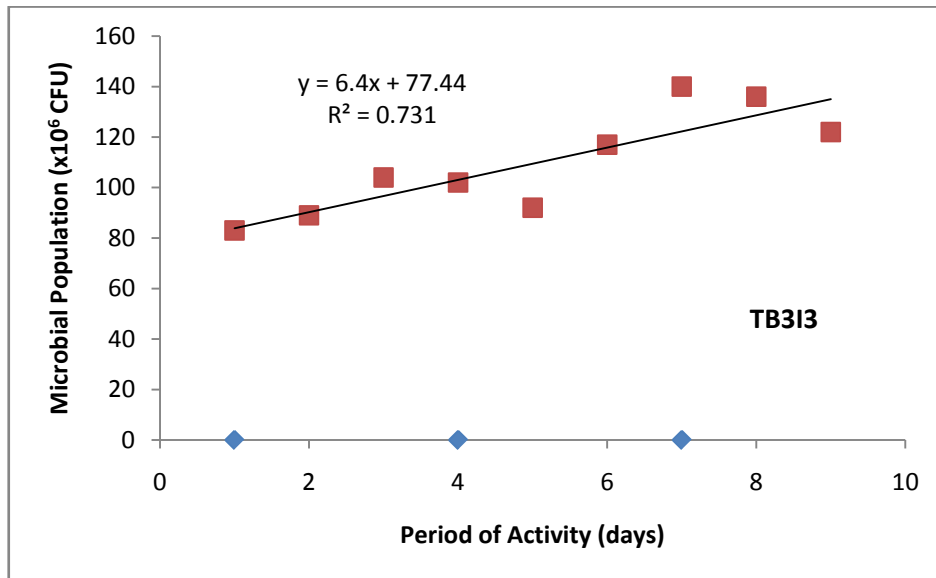


Figure 8. Microbial population for the vermicomposting after the introduction of M



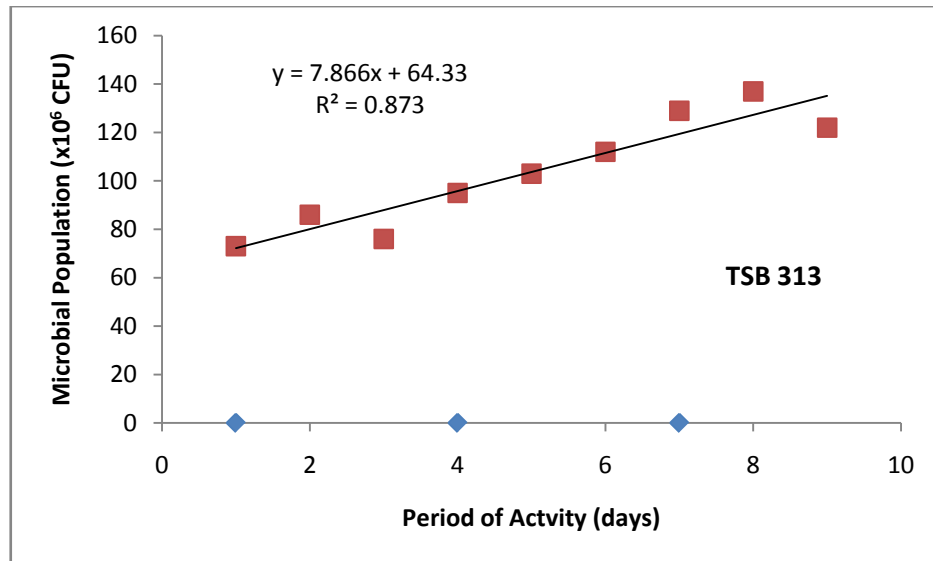


Figure 9. Microbial population for the vermicomposting after the introduction of 313

The microbial population of combinations of organic waste with different combination of microbial consortium are shown in Figure (8&9). The microbial population in the vermicomposting of banana stem waste combination with spent tea (all mix microbial consortium, M). The overall results indicate that the microbial population increases due to the introduction of the microbial consortium to each of the vermicomposting set-ups. The most active reaction can be observed in the set-up with the application of consortium 313 to the combination of all waste. This is proven when the same set-up degraded completely in just 5 days.

4. Discussion

The vermicomposting of the waste was faster compared to the control. That might have been due to higher initial N concentration present in the control which might have increased the microbial activity in the beginning, thus decreasing the C/N ratio (Eiland *et al.*, 2001). These results, however, support the observations from the earlier work of (Vincelas Apka, M *et al.*, 1997) who reported more rapid degradation of substrate during vermicomposting than composting. The result for C/N ratio indicates that spent tea has C/N ratio of below 15 that it can be utilized to replace soil (Morais and Queda, 2003). The nitrogen content decreased during subsequent vermicomposting which may have been due to ammonification, NH₃ volatilization and denitrification (Martins *et al.*, 1992 and Bernal *et al.*, 1996). Our results are also supported by (Benitez *et al.*, 1999) who observed a 36% loss of total nitrogen during vermicomposting of sewage sludge. The sugar cane bagasse set-up indicates the highest value of carbon to nitrogen ratio. This is probably due to the abundant cellulose compound in sugar cane bagasse. Thus, not all C was converted at the end of the process. This results supported by previous researches where it is said that vermicomposting reduce the C: N ratio and retains more N than the traditional methods of preparing

composts (Gandhi *et al.* 1997). It increases macropore space ranging from 50 to 500 µm, resulting in improved air-water relationship in the soil which favourably affects plant growth (Marinari *et al.* 2000). The most drastic reduction of carbon to nitrogen ratio can be observed in combination of all organic waste with the addition of inoculum 313 which reduced from 29.2 to 14.2 in just 5 days. Similar results were also reported by (Rasal *et al.*, 1988) who reported rapid decomposition of sugarcane trash with a mixture of cellulolytic fungi; *Trichoderma viride*, *Trichurus spiralis*, *Paecilomyces fusisporus* and *Aspergillus* sp. along with nitrogen fixing bacteria *Azotobacter* sp. The overall temperature changes were not too drastic for all the vermicomposting setups. Throughout this research, the optimum temperature has been maintained as it is generally considered necessary to keep the temperatures above 10°C (minimum) and preferably 15°C for vermicomposting efficiency and above 15°C (minimum) and preferably 20°C for productive vermiculture operations (Munroe, 2002). Available P and K in sugar cane bagasse recorded higher initial value compared to the other waste types. This maybe due to the higher activity of mineralization by the worms in the vermicomposting set-ups compared to the others. This research also supported by few similar studies that is related to the abundance of nutrient via vermicomposting like Muthukumaravel, 1996; Vasanthy *et al.*, 2005 that studied about the cow dung which give great influence to the rate of vermicomposition and increase the amount of macronutrients in the vermicompost. An increase in nitrogen concentration may be due to nitrogenous metabolic products of earthworms which are returned to the soil through casts, urine, mucus-proteins and earthworm tissue (Umamaheswari & Vijayalaxmi, 2003). Hence, it is clear that the mixture of vegetable waste and cow dung is suitable, converting the important plant nutrients into a more soluble state for plant to utilize (Nair *et al.*, 2005) and for the production of higher quality vermicompost. Padmavathamma, 2008 also

indicated that the application of vermicompost gives higher germination of the seeds and growth activities, thus enhancing the growth rate of a plant that uses the worm casting. The worm chosen for this research; *Eudrilus Eugeniae* (African nightcrawlers) was really active in degrading the waste especially in banana stem and in the combination of waste. This is supported by Rani *et al.* (2007) as she found that the *Eudriluseugeniae* is capable of ingesting and excreting organic materials at a high rate as they eat 10% soil and 90% organic waste materials. It converts the organic waste into vermicompost faster and has the ability to tolerate temperatures ranging from 0 to 40°C but the regeneration capacity is more at 25 to 30°C and 40–45% moisture level in the pile than the burrowing earthworms (Rani *et al.* (2007). Gaur (1982) found that the nutrients are richer in this particular worm's casts. As for the microbes isolated and used for the preparation of microbial consortium, it was proven that the combination of this particular species of bacteria were able to help to speed up the degradation process. One of the major observations from this research is that, upon the introduction of the microbial consortium, the waste started to shrink. This is probably due to reaction by the combination of microbes. Microbial activity during vermicomposting is stabilized by the interactions of microorganisms and the worm. This is agreeable with other findings which reported *Pseudomonas* sp. which are used in this research are capable of degrading organic compounds (Stainer *et al.*, 1998).

5. Conclusions

This research showed that the possibility to enhance vermicomposting of selected organic waste is higher with the application of formulated microbial consortium. This research also indicates that the rate of degradation of selected organic waste varies with the different combination ratio, type of waste being combined and the efficiency of the microbial consortium. Thus, the potential to convert sugar cane bagasse and banana stem mixed with spent tea and further addition of the selected microbial consortium into compost via vermicomposting is high that further research can be developed for continuous improvement for commercial viability. Research should be conducted in a larger scale to investigate the commercial viability for vermicomposting of organic waste.

ACKNOWLEDGMENTS

Authors would like to thank Institute of Research Management & Monitoring of University Malaya, Kuala Lumpur Malaysia for granting research grant to support this research financially.

REFERENCES

- [1] Agamuthu, P. (2004). Utilization and Management of Agricultural and Agro-Industrial Waste Workshop Manual, University of Malaya Press. Pp1-55.
- [2] Agamuthu, P. (2007). Solid Waste: Principles and Management. University of Malaya Press. pp 65-101.
- [3] Benitez, E., Nogales, R., Elvira, C., Masciandaro, G. and Ceccanti, B. (1999). Enzyme activities as indicators of the stabilization of sewage sludges composting with *Eisenia foetida*. *Bioresource Technol.* 67 (1999), pp. 297–303.
- [4] Bertran, E., Sort, X., Soliva, M., Trillas, I., 2004. Composting winery waste: sludges and grapes stalk. *Bioresource Technol.* 95, 203-208.
- [5] Eiland, F., Klamer, M., Lind, A.M., Leth, M and Baat.E. (2001). Influence of initial C/N ratio on chemical and microbial composition during long term composting of wheat straw. *Microbial Ecol.* 41 3 (2001), pp. 272–280.
- [6] Esther Rani D V, Perumalsamy K & Isaiarasu L (2007). *J Ecotoxicology Environment Monitoring.* 17(1), 37-41.
- [7] Garcia, C., Hernandez, T., Costa, F., 1991. The influence of composting on the fertilizing value of anaerobic sewage sludge. *Plant and soil*, 136(2):269-272.
- [8] Gandhi M, Sangwan V, Kapoor KK and Dilbaghi N. 1997. Composting of household wastes with and without earthworms. *Environment and Ecology* 15(2):432–434.
- [9] Gaur A C, (1982). *A Manual of Rural Composting* FAO/UNDP, Regional Project RAS/75/004. Field Document No.15. FAO, Home, 102.
- [10] Ghatnekar, S.D., Ghalsasi, D.S., Ghatnekar S.S. and Tamhane B.M. (2008) Vermiculture based solid waste treatment plants for biosafe vermicompost. *Green Farming*, 1 (10-11), 73-77.
- [11] Hachida, S., Chtourou, M., Medhioub, K., Ammar, E., 2006. Compost of poultry manure and olive mill wastes as an alternative fertilizer. *Agronomy for Sustainable Development*, 26(2): 135-142.
- [12] Fauziah, S.H. and P. Agamuthu. (2006). SWPlan Software Application for Malaysian Municipal Solid Waste Management. *Malaysian Journal of Science*, 26 (1), 17-22.
- [13] Lavelle, P. (1988). Earthworm activities and the soil system. *Biology Fertilizer Soils.* 6: 237 – 251.
- [14] Martins and Dewes, T. (1992) Loss of nitrogenous compounds during composting of animal wastes. *Bioresource Technol.* 42 (1992), pp. 103–111.
- [15] Martinez, C.E., Tabatabai, M.A., 1997. Decomposition of biotechnology by-products in soils. *Journal of Environmental Quality*, 26 (4):625-632.
- [16] Marinari S, Masciandaro G, Ceccanti B and Grego S. 2000. Influence of organic and mineral fertilisers on soil biological and physical properties. *Bioresource Technology* 72(1):9–17.
- [17] Maheswarappa HP, Nanjappa HV and Hegde MR. 1999. Influence of organic manures on yield of arrowroot, soil

- physico-chemical and biological properties when grown as intercrop in coconut garden. *Annals of Agricultural Research* 20(3):318-323.
- [18] Mitchell A and Edwards CA. 1997. The production of vermicompost using *Eisenia fetida* from cattle manure. *Soil Biology and Biochemistry* 29:3-4.
- [19] Muthukumaravel K, Vermicomposting of Solid Wastes, M. Sc., Dissertation, Bharathidasan University, Tiruchirappalli, 1996.
- [20] Montemurro, F., Maiorana, M., Convertini, G., Fornaro, F., 2005. Improvement of soil properties and nitrogen utilization of sunflower by amending municipal solid waste compost. *Agronomy of Sustainable Development*, 25(3): 369-375.
- [21] Nair, J, Vanja, S. and Martin A. (2005) Effect of pre-composting on vermicomposting of kitchen waste, *Bioresource Technology* 97: 2091-2095.
- [22] Ndegwa, P.M., & Thompson, S.A. (2001). Integrating composting and vermicomposting in the treatment of bioconservation of biosolids. *Biores. Technol.* 76, 107-112.
- [23] Padmavathamma, P.K., Li, L.Y., Kumari, U.R. 2008. An experimental study of vermi-biowaste composting for agricultural soil improvement. *Bioresource Technology* 99(6): 1672-1681.
- [24] Rasal, P.H. Kalbhar, H.B., Shingte, V.V., and Patil, P.L. (1988) Development of technology for rapid composting and enrichment. In: S.P. Sen and P. Palit, Editors, *Biofertilizers: Potentialities and Problems*, Plant Physiology Forum and Naya Prakash, Calcutta (1988), pp. 255-258.
- [25] Rodriguez, A.C. & I.R. Lapeire (1992). Increase in weight, length and number of segments of *Eudriluseugeniae* (*Oligochaeta*: *Eudrilidae*) at 24 C. *Rev. Biol.* 6: 215 - 221.
- [26] Senapati, B.K. and Julka, J.M. (1993). Selection of suitable vermicomposting species under Indian conditions. *Earthworm Resources and Vermiculture, Zoological Survey of India, Calcutta.* 113-115.
- [27] Sharma, S, Mathur, R.C., and Vasudevan, P. (1999). Composting silkworm culture waste. *Compost Sci. Util.* 7 2 (1999), pp. 74-81.
- [28] Stainer, A., Levi-Minzi, R. and Riffaldi, R. (1998). Maturity Evaluation of Organic Wastes. *Biocycle*, 29:54-56.
- [29] Tian, G., J.A. Olimah, G.O. Adeoye & B.T. Kangi. 2000. Regeneration of earthworm populations in a degraded soil by natural and planted fallows under humid tropical conditions. *Soil Science Society of America. J.* 64: 222 - 228.
- [30] Vincelas Apka, M and Loquet, M. (1997) Organic matter transformations in lignocellulosic waste products composted or vermicomposted (*Eisenia foetida* and *andrei*): Chemical Analysis and ¹³C CPMAS NMR Spectroscopy. *Soil Biol. Biochem.* 29 3/4 (1997), pp. 751-758.
- [31] Viljoen, S.A. & A.J. Reinecke. (1992). The temperature requirements of epigeic earthworm species *Eudriluseugeniae* (*Oligochaeta*); a laboratory study. *Soil Biology Biochemical.* 24: 1345 - 1350.
- [32] Umamaheswari S and Vijayalakshmi G S, *Poll Res.*, 2003, 22: 339-341.
- [33] Vasanthi M, Thamaraiselvi C and Ramadoss, A, *J Ecotoxicol Environ Monit*, 2005, 15, 207-211.
- [34] Vikineswary, S and Ravooof, A.A. (1991). Decomposition of oil palm empty fruit bunch in a sub-surface mulch. In: *Management and Utilisation of Agricultural and Industrial Wastes*, (ed.) Goh, S.H, Chuah, C.H., Tong, S.L., Phang, S.M. and Vikineswary, S. pp.206-210, Kuala Lumpur: Institute of Advanced Studies, University of Malaya.
- [35] World Bank (1999): *What a Waste: Solid Waste Management in Asia*. Urban Development Sector Unit, East Asia and Pacific region Online: www.worldbank.org/html/fpd/urban/publicat/whatawaste.pdf (23 August 2011).