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Influences of Bedding Material in Vermicomposting Process

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Abstract

Rapid growth of urbanization and industrialization has led to generation of large quantities of wastes. Major portion of organic waste is dumped in landfill sites, creates the organic load on the ground water, and more emissions of landfill gases. The best possible alternative to reduce these potential pollutants is through vermicomposting. Vermicomposting is essentially composting with worms. This experiment was done to determine which bedding materials (either newspaper or sawdust) is more suitable for vermicomposting by using biological parameter which measured the growth rate (pH), number of worm, number of cocoons and worm biomass. The worms were breed in vermicomposter and the period of vermicomposting using *Perionyx excavatus* worm is six weeks. All of the four biological parameters showed that there are significant different between this two type of bedding using ANOVA test. The Duncan test demonstrated that newspaper bedding is more influential in worm biomass production and growth rate while sawdust bedding is better for cocoons production and number of worm. For pH analysis it reveals that the optimum pH for worm growth rate is near to neutral condition. As conclusion, different types of bedding material will influence the worm growth.

Keywords: Vermicomposting, Bedding materials, Biological parameters

1. Introduction

In recent years much attention has been paid to manage different organic waste resources at low-input as well as eco-friendly basis. Vermicomposting is one of the ways to reduce this organic waste and its have been practically used all over the world. Vermes is Latin word for worms and vermicomposting is essentially composting with worms (Ghatnekar *et al*., 1998). In nature, all organic matter eventually decomposes. But in vermicomposting, the worm speed up the process of decomposition and get a richer end product called "worm castings". On the other hand vermicomposting is a process of utilizing earthworms and it is an eco-biotechnological process that transforms energy rich and complex organic substances into a stabilized humus-like product (Benitez *et al.,* 2000). A wormery is a self-contained composting system that does not generate heat, retains most nutrients for reuse and properly maintained its odorless (Munroe, 2004). Vermicomposting is an easy way to make a positive environmental impact by reducing the amount of organic waste that finds its way into landfills, incinerators, and sometimes the ocean. Vermicomposting can be classified as an innovative and alternative technology that represents a technology that is environmentally sound and relatively new technology. In some countries mainly, Canada, United States, Australia, France, and some Southeast Asia countries, earthworms have been used for waste stabilization for many years (Martin *et al*., 1988).

Earthworms are one of the major soil macro invertebrates and are known for their contributions to soil formation and turnover with their widespread global distribution (Norbu, 2002). It plays a significant role in decomposition due to their symbiotic relationship with bacteria. As earthworms ingest and digest organic matter, they also take in microorganisms and metabolize them. When the organic material passes through the gut of the earthworm it again increases the surface area of the material so that the microorganisms can break it down further. The undigested materials, or castings, are fertile and rich in nutrients readily available to plants (Hansen, 2007). Organic manure and other agriculture organic wastes are essential sources for maintenance of soil organic matter and to sustain soil productivity. Usually there is a huge amount of animal excreta being generated in intensive livestock farming. Proper utilization of these wastes can enhance soil physical condition and environmental quality as well as provide nutrients for plant (Mishra *et al*., 1989; Bhardwaj, 1995). However if this organic manure are not been manage well it can pollute our environment especially river and groundwater by it runoff that contain lot of nitrates, phosphates, and ammonia. Horse manure is one of organic waste which regularly used in vermicomposting. Horse manure is suitable for the growth of earthworms and does not need any pretreatment and can be applied directly as a feed (Norbu, 2002). Ronald *et al*. (1978) reported that horse manure contains 0.7 % of nitrogen, 4.38 % of protein and 60% of organic matter and trace amounts of phosphoric acid and potassium oxide.

Any material that provides the worms with a relatively stable habitat is called bedding. This habitat must have the following characteristics such as high absorbency, good bulking potential and low protein and/or nitrogen content (high Carbon: Nitrogen ratio). Worms need bedding in addition to food. Shredded paper or newspaper, coir (coconut husk fiber), and shredded cardboard are common bedding materials used for worm composting. Normally, the bedding will soak well with clean water and then squeeze it to remove excess liquid. Selection of bedding materials is a key to successful of vermicomposting process. They provide protection from extremes in temperature, the necessary levels and consistency of moisture, and an adequate supply of oxygen (Munroe, 2004). Sawdust is a main organic waste in sawmill. It has a variety of practical uses including as mulch, an alternative to clay cat litter, a fuel, or for the manufacture of particleboard. Sawdust may collect in piles and add harmful leachates into local water systems, creating an environmental hazard. The biggest concern with sawdust are substances such as lignins and fatty acids which protect trees from predators while they are alive, can leach into water and poison wildlife (Canadian Geographic Online, 2008). Newspaper is a highly recyclable material in Malaysia. It will be contaminated when mix together with organic waste and will lower the grade. Newspaper consists of combination of fibers that are stick together. Sometimes wide variety of synthetic fibers, such as polypropylene and polyethylene, may be incorporated into paper as a way of imparting desirable physical properties. The aim of this study is mainly to determine the suitability of two type of bedding materials which are newspaper and sawdust for vermicomposting.

2. Methodology

2.1 Collection and culturing of earthworm

The earthworms, *Perionyx excavatus*, were obtained from horses stable by digging up inside the composted horse manure (Figure 1). *P. excavatus* can be identified by its iridescent blue or violet sheen to its skin clearly visible under bright light. It is a very small worm, poorly suited as fishing bait, but has an impressive growth and reproductive rate far in excess of the other species grown in bin culture. This tropical worm species has very poor tolerance with low temperature fluctuations in the bin environment, handling or disruption to the system (Anphu Earthworm Farm, 2004).

<<Figure 1. *Perionyx excavatus* in vermicomposter>>

2.2 Collection of horse manure

The organic waste used to feed the earthworm is horses manure. It was collected from horses stable at Faculty of Veterinary, Universiti Putra Malaysia. The manure then air dried in the sun first before used. The main reason of using horses manure is because *P. excavatus* lived in the environment where the horses manure decomposed. Horse manure is used as feeding material to adapt *P. excavatus* to new environment. Another reason is it does not require addition of other material for moisture retention, aging, porosity and above all it does not require checking for the acidity of the bedding (Norbu, 2002).

2.3 Experimental Setup

The experiments were performed in small plastic aquarium with 1.5 liter of volume (Figure 2). The surface of aquarium was coated with paint to ensure that the light will not penetrate into the bins. A total of 10 earthworm bins were build where four bins for each treatment and each treatment has two bins for control. In this experiment, newspaper and sawdust are used as bedding materials. To prepare the bedding, sawdust and shredded newspaper were weighed for 50g for each boxes and mix with 40g of horse manure. The bedding was put on the base of bin and sprays with water to moist the bedding. A total of 10 of earthworms were placed into each of the boxes with their mean weight been recorded and fed with horse manure. An optimal feeding rate of 0.75 kg feed/kg worm/day (Ndegwa *et al*., 1999) was applied to all treatments. The experiment was conducted for six weeks in open but shaded area in Faculty of Environmental Studies, UPM.

<<Figure 2. Vermicomposter from coated plastic aquarium>>

2.4 Earthworm observation

The total biomass of the worms was determined by measuring the wet weight in each box at the beginning and end of the experiments and each week prior to feeding. To accomplish this, worms were removed from the bedding by hand, gently removed all of extraneous material, rinsed with distilled water to remove any bedding, briefly drained on a paper towel, and weighed on a scale. All of the worms within each box were weighed as a unit.

The formula below was used (Suthar, 2006) to determine worm growth response to the different bedding material:

Growth rate determination, $R = (N_2 - N_1) / T$ …………………………. (1)

Where, R= Growth rate

N_1= Initial earthworm biomass (mg)

N_2= End earthworm biomass achieved (mg)

T= Time period of the experiment day.

Meanwhile, the worms were removed manually and its population was count every week for each vermicomposter. The number of cocoons also will be counted as well as its mortality.

2.5 Parametesr measured

The manure and vermicompost were analyzed for the pH. The sample was mixed with distilled water at a weight ratio of 1:2.5 (10g compost and 25ml distilled water). The beaker was covered and left for 2 hours and shake occasionally. The pH was measured with a pH meter (Sundberg *et al*., 2004) and the sample solution was stir regularly. Temperature was measured daily to ensure the heat generated from decomposition process was not highly increasing

2.6 Statistical analysis

All of the reported data are recorded from four replicate samples of each treatment. Statistical Analysis of Science (SAS) were used to conduct an ANOVA and Duncan test on all of the biological parameter and Simple Linear Regression for relationship between pH and growth rate to determine any significant different amongst the measured parameters.

3. Results and discussion

3.1 Growth and reproduction in different types of bedding materials

The growth and reproduction of *P. excavatus* in different type of bedding materials is measured by using biological parameters. The parameters are worm biomass, growth rate, number of worm and number of cocoons.

During the experimental period of 6^{th} weeks, worms grew well in all of the vermicomposters except there was mortality observed in sawdust bedding in 1^{st} week. However increasing rate in biomass and growth was lower in those vermicomposters which using sawdust as bedding material (Table 1).

<<Table 1. Changes of biomass production and growth rate>>

The *P. excavatus* biomass production in two different types of bedding material with time is shown in Figure 3. The trend shows the mean individual biomass gradually increased from the 1^{st} week to 6^{th} week for two different bedding types. The mean individual biomass constantly increasing due to time but on the weeks 4^{th} onwards the increase in biomass becomes slower. The starting mean for newspaper as bedding material is 120 mg and for sawdust is 124 mg (Table 2). The final mean of worm individual biomass at the end of vermicomposting for newspaper bedding is 570.25 mg but for the sawdust bedding the achieved mean individual biomass is 432.5 mg (Table 2). There are differences between these two types of bedding materials where the mean individual biomass of worms in newspaper is higher than in sawdust at the end of composting period. The ANOVA test done on biomass production showed that there are significant different between newspaper bedding and sawdust bedding ($P<0.001$) at the 99% confidence level (Table 3). According to the Duncan test newspaper bedding with mean of 363.75 have more influence on worm biomass production compared to sawdust bedding with mean 269.14 (Table 3).

<<Figure 3. The mean individual biomass (mg) in different bedding>>

<<Table 2. Growth of *P. excavatus* in different type of bedding material>>

<<Table 3. ANOVA and Duncan test >>

The growth rate (mg biomass gained/worm/day) has been considered as a good comparative index to compare the growth of earthworms in different waste or food (Edwards *et al*., 1998). The vermicomposter with newspaper bedding material have the highest growth rate (10.72 mg weight gained/day/earthworm) compare to vermicomposter with sawdust as a bedding material (7.35 mg weight gained/day/earthworm) (Table 2). The P-value done by ANOVA for worm growth rate is ($P<0.001$). This showed that, there are significant different between newspaper bedding and sawdust bedding for worm growth rate at the 99% confidence level (Table 3). The difference could be due to the difference in species morphology and initial characteristics of the feed and bedding waste. Newspaper bedding gives more influence on growth rate of worm with mean of 9.68 contrast to sawdust with mean of 5.49 from the Duncan test that have been conducted (Table 3). It was observed that there is a lower growth rate in vermicomposter with sawdust, despite of attainment of more body weight than vermicomposter with newspaper. This was due to the fact that the time taken to achieve the maximum biomass was longer for sawdust than newspaper. Similar observations have been reported by Chaudhuri and Bhattacharjee (2002) for vermicomposting of cow dung and kitchen waste by *P. excavatus*. The other cause maybe due to the physical characteristic of sawdust that is taking time to decompose by microorganism making it was unable for worm to digest this bedding as food. For newspaper, because of its physical characteristic has been altered in the process of making paper cause it to form in more simple structure than the sawdust.

In general, the palatability of earthworms is influences directly or indirectly by chemical nature of the organic waste, which therefore affects earthworms' efficiency in decomposition system. However, for studied biological parameters, earthworm showed remarkable differences between beddings which illustrated that each of the bedding has it own advantages. Since this two type of bedding have different palatability, particle size, high protein and crude fiber content and even some concentration of special plant metabolites i.e. polyphenols and related substances. Therefore, it is hypothesized that earthworm growth patterns in this study were related to the chemical profile of the waste, although this needs experimental confirmation. Beside that, beddings, in which earthworm showed better growth patterns, were probably with supplying of easily metabolizable organic matter, non-assimilated carbohydrates, and even low concentration of growth-retarding substances, which favour earthworm growth in waste system. (Suthar, 2007)

3.2 Cocoon production

Earthworm in these two different types of beddings started to produce cocoons in 1st week (Figure 4). This is because of the worms that are chosen for this study, are in clitellates state that is the mature and adult worms. Clitellates have the potentials for reproduction, worms at this stage will appear bit darker in their colour due to the pigmentation of the epithelial cells (Ismail, 1997). The number of cocoons production increase proportionally due to time. Cocoons production in the sawdust bedding is rapidly increasing starting in week 2^{nd} to week 4^{th} and then decreasing in week 5^{th}. However, it then increases back in week 6^{th}. The maximum mean number of cocoons is in week 6^{th} (15.75). For number of cocoons in newspaper bedding it also increase proportionally in time but it started to decrease after week 5^{th}. The maximum number of cocoons in newspaper bedding is 9.0 in week 5^{th} and the number of cocoons in the end of vermicomposting is 8.0 (Table 1). The result analyzed by ANOVA showed that there are significant different between the use of newspaper and sawdust bedding in cocoons production of *P. exvacatus*, where ($P<0.001$) at 99% confidence interval. The mean in Duncan test showed that sawdust bedding influence the cocoons production more than newspaper bedding (Table 3).

<<Figure 4. Cocoons production/week in different type of bedding>>

Cocoons production per worm per day was also higher in sawdust compared to newspaper bedding. The difference between rates of cocoon production could be related to the biochemical quality of the feeds, which is an important factor in determining the time taken to reach sexual maturity and onset of reproduction (Flack and Hartenstein, 1984). Feeds which provide earthworms with sufficient amount of easily metabolizable organic matter and non-assimilated carbohydrates, favour growth and reproduction of earthworms. Edwards *et al*. (1998) concluded that the important difference between the rates of cocoon production in the two organic wastes must be related to the quality of the waste material, which is one of the important factors in determining onset of cocoon production. Suthar (2005) summarized that chemical nature of feeding stock may be of a primary importance for rearing of earthworms on organic waste resources. So, the difference in cocoon production could be due to variation in quality of the substrate.

Recently it has been reported that along with feed quality the microbial biomass and decomposition activities are also important (Suthar, 2005). The results indicated that the quality and palatability of food and bedding directly affect the survival, growth rate and reproduction potential of earthworms (Tripathi and Bhardwaj, 2004; Gajalakshmi *et al.*, 2005). From the observation the physical and chemical characteristic of this two bedding naturally effect cocoons production. Sawdust is commonly used in composting as a bulking agent to reduce the moisture content and that give more oxygen to the worm where no space in composting material does not fill with water. This condition favours the production of cocoons. A large proportion of the energy of mature worms is used in cocoon production. When cocoons are not produced, the energy is utilized for tissue growth (Chaudhari *et al*., 2002). The weight gain by the worm is more in newspaper bedding but cocoons production was lower than sawdust bedding. It indicates that newspaper bedding is a good biomass supporting medium but not good for reproduction.

3.3 Number of worms

There are different numbers of worm in different type of bedding material (Figure 5). For worm in newspaper bedding there is mortality in week 1^{st} where the number of worm is 8.75 (Table 1). It then increases back at week 3^{rd} and the increasing is proportional to time. The maximum number of worm in newspaper bedding is 16 at week 6^{th} which is end of vermicomposting period. The numbers of worm in sawdust bedding are not increasing until week 4^{th} but then are increasing constantly from week 4^{th} to week 6^{th}. The maximum mean number of worms in sawdust bedding is in week 6^{th} with 29 number of worm (Table 1). The ANOVA test shows that there are significant different between newspaper and sawdust bedding in influencing the number of worm. The P-value is less than 0.001 (Table 3) which means the confident interval is 99%. Besides that the Duncan test (Table 3) demonstrate sawdust bedding (14.14) seems give more affect to the number of worm compare to newspaper bedding (11.50).

The factor that influences the number of worm is related to the cocoons production. The mortality of worm in newspaper bedding is may be due to new environment that the worms are been located. The conducive environment in sawdust bedding for cocoons production will increase the number of worms also. So we can see the relationship between cocoons production and the number of worm. If the number of cocoons increases it will also increase the number of worms due to the hatchling of cocoons.

<<Figure 5. Number of worm in different type of bedding>>

3.4 pH and temperature measurement

Both pH and temperature seem to influence the growth of the worms. Growth rate of worm increase gradually due to time (Figure 6) compare to pH where it decrease proportional to time. The highest growth rate can be observed in newspaper bedding that is 13.14 mg/worm/day (Table 1) when the pH of the compost material is 7.43 (Table 4). For worm in sawdust bedding the highest growth rate is 7.47 mg/worm/day (Table 1) when the pH of the compost material is at 6.94 (Table 4). The best pH condition for the growth of the worm is pH that near to neutral. According to Hou *et al*. (2005) the optimum pH value was in the range of 6.5~8.6. If the pH value that outside this range, the earthworm numbers decreased greatly (died).

<<Figure 6. Worm growth rate with the pH of the bedding (NP= newspaper, SD= sawdust)>>

<<Table 4. Simple linear regression table>>

The simple linear regression test showed that there are significant different between pH and growth rate in newspaper bedding. The value of probability of T is 0.0296 (Table 4) that is less than 0.05 ($T<0.05$) at 95% confidence level. The R-square value (coefficient of determination) indicates that 17% of the variation in growth rate can be explained by the regression. For the sawdust bedding the test showed that there are no significant different between pH and growth rate. The values of T is 0.0720 that is more than 0.05 ($T>0.05$). The R-square value of sawdust is 12% showed that the relationship between pH and growth rate in sawdust bedding are not so strong. Munroe (2004) reported that earthworms absorb water and breathe through their skin. They are sensitive to pH value of the substrate. pH value is one of the most important factors affecting the survival of worms. Different pH value largely affected the activity of worms. There is a certain range of pH value for earthworms to survive. The substrate is unsuitable for worms if it is too acidic or too alkaline. Most experts feel that the worms prefer a pH of 7 or slightly higher. When pH value was below 6.5, the number of earthworm decreased significantly, implying that worms were sensitive to acidic conditions (Hou *et al.*, 2005). There was a decrease in pH of all the vermicomposter including the control vermicomposter during vermicomposting (Table 5). In general, the pH of worm beds tends to drop over time. Most of other reports on vermicomposting (Mitchell, 1997; Gunadi and Edwards, 2003; Garg and Kaushik, 2005) have also reported similar results. But pH decrease in all of the vermicomposter does not exceed below 6.5. The alteration of pH in the bedding is due to the fragmentation of the organic matter under series of chemical reaction. The decrease in pH may be due to mineralization of nitrogen and phosphorus into nitrites/nitrates and orthophosphates and bioconversion of the organic material into intermediate species of organic acids (Ndegwa and Thompson, 2000). It has been recorded by Edward *et al.* (1976) that different species of earthworms have their own pH sensitivity and generally most of them can survive at the pH range 4.5 to 9. They have also reported that different substrates could result in production of different intermediate species and different feed substrates show a different behavior in pH shift.

<<Table 5. pH analysis of different type of bedding>>

As for the temperature during vermicomposting period, it showed that the temperature is fluctuating between 28^{o}C to 30^{o}C. Worms are sensitive to variations in climate. Extreme temperatures and direct sunlight are not healthy for the worms. According to EPA (2007) the optimal temperatures for vermicomposting range from 13 °C to 25 °C. In hot, arid areas, the bin should be placed under the shade. There is no much different between temperatures although composting process is in running. The main reason for this is because the composted material are been sprayed with water to moist it. Beside that the high of composted material in vermicomposter are only 5 to 7 cm. This was done to avoid exposure of worms to high temperature during the initial thermophlic stage of microbial decomposition.

3.5 Influence of bedding material characteristic

In general, Carbon:Nitrogen (C:N) ratio is a factor related to the decomposition of the waste material and, even it is recognized as a factor related negatively with the growth of earthworms and reproduction activities. During present study, earthworm show expected relations with beddings initial C:N ratio. Thompson (2000) found that when C:N ratio of material is 25 (Ndewa *et al.*, 2000), earthworm can grow better. Some other researchers reported that 20 is the suitable C: N ratio (Liu *et al*., 2000). Different values of growth and reproduction rate were observed in bedding with high and low earthworm performance. In general, the chemical nature of the organic waste influences the palatability by earthworms directly or indirectly, which consequently affect earthworms' efficiency in decomposition system. However, for studied biological parameters, earthworm showed remarkable differences between newspaper beddings and sawdust bedding.

Absorbency is one of the require characteristic needed in bedding for vermicomposting. Newspaper is one of bedding material that high in absorbency whereas for the sawdust the level of absorbency is poor to medium. Worms breathe through their skins and therefore must have a moist environment in which to live. If a worm's skin dries out, it dies. The bedding must be able to absorb and retain water fairly well if the worms are to thrive. From the absorbency characteristic, its show that why the worm grew well in newspaper bedding. Bulking potential plays important role in vermicomposting. If the material is too dense to begin with, or packs too tightly, then the flow of air is reduced or eliminated. Worms require oxygen to live, just as we do. Different materials affect the overall porosity of the bedding through a variety of factors, including the range of particle size and shape, the texture, and the strength and rigidity of its structure. The overall effect is referred to in this document as the material's bulking potential. These two types of bedding newspaper have medium bulking potential where for sawdust the bulking potential is poor to medium (Table 6). Another characteristic for good bedding material is low protein and/or nitrogen content (high Carbon: Nitrogen ratio). Although the worms do consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels can result in rapid degradation and its associated heating, creating inhospitable, often fatal, conditions. Heating can occur safely in the food layers of the vermiculture or vermicomposting system, but not in the bedding (Munroe 2004). From the previous studies shows that newspaper have C:N ratio of 170 and for sawdust it is 142-750 (Table 6). However, this difference could be related to the quality of the bedding material. Since bedding material have different palatability, particle size, high protein and crude fiber content and even some concentration of special plant metabolites i.e. polyphenols and related substances. Therefore, it is hypothesized that earthworm growth patterns in this study were related to the chemical profile of the bedding, although this needs experimental confirmation. More so, beddings, in which earthworm showed better growth patterns, were probably with supplying of easily metabolizable organic matter, non-assimilated carbohydrates, and even low concentration of growth-retarding substances, which favour earthworm growth in waste system (Suthar 2007).

<<Table 6. Bedding material characteristic>>

Most of the nitrogen in compostable materials is readily available. Some of the carbon, however, may be bound up in compounds that are highly resistant to biological degradation. Newspaper, for example, is slower than other types of paper to break down because it is made up of cellulose fibers sheathed in lignin, a highly resistant compound found in wood. Corn stalks and straw are similarly slow to break down because they are made up of a resistant form of cellulose. Although all of these materials can still be composted, their relatively slow rates of decomposition mean that not all of their carbon will be readily available to microorganisms, so a higher initial C:N ratio can be planned. Particle size also is a relevant consideration; although the same amount of carbon is contained in comparable masses of sawdust, the larger surface area in the sawdust makes its carbon more readily available for microbial use (Kourik, 1986).

4. Conclusion

It can be concluded that different type of bedding give different kind of result on selected biological parameters. Each of bedding material has its own characteristic that differ from one another and can influence the parameter that been studied. The result showed that newspaper bedding are better in term of growth rate and biomass production of worm compared to sawdust bedding that give better result in number of worm and cocoons production. Better results of biomass as well as growth rate potential of composting with earthworm can be observed using newspaper beddings according to Duncan test. The data demonstrated that using sawdust can achieve better result compared to newspaper bedding for the cocoons production and number of worm. From that we can specify the use of this bedding to achieve the desire objective. pH also affecting the growth rate of worm during composting period. It was stated that pH near the neutral state are the best pH for vermicomposting. So, using appropriate bedding and/or feeding material for earthworm culture could optimize vermicomposting practices. There are vast opportunities to study the influence of bedding interrelating with environmental variables in the field of earthworm biotechnology. The composting potential of *P. exvacatus* was influenced by the chemical nature of the substrate. *P. exvacatus* also showed good weight gain as well as reproduction performance in studied beddings. This also demonstrated that *P. exvacatus* could be used efficiency for composting organic waste especially with the studied material. Although still a great work is required to establish the optimal conditions for culturing of tropical earthworms for sustainable vermiculture operations. Further studies are required to explore the potential of utilization of newspaper and sawdust bedding in mixture with horses manure.

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Table 1. Changes of biomass production and growth rate

Weeks	Newspaper				Sawdust			
	Wt	GR	NW	NC	Wt	GR	NW	NC
0	120	0.00	10	0.00	124	0.00	10	0.00
1	180	8.67	8.75	0.75	154	4.21	10	0.25
2	287	11.36	8.75	1.50	202	5.56	10	1.25
3	371	11.94	11	3.00	270	6.95	10	4.75
4	488	13.14	12	5.75	317	6.89	12	14.00
5	538	11.93	14	9.00	386	7.47	18	12.75
6	570	10.72	16	8.00	433	7.35	29	15.75

Note:

Wt : mean weight of earthworm (mg)

GR : growth rate of earthworm

NW : mean number of earthworms

NC : mean number of cocoons

Table 2. Growth of P. excavatus in different type of bedding material

Type of bulking agent	Mean initial biomass (mg)	Mean end biomass achieved (mg)	Net biomass gain (mg)	Growth rate/worm/day (mg)
Newspaper	120	570.25	450.25	10.72
Sawdust	124	432.50	308.50	7.35

Table 3. ANOVA and Duncan test

	df[b]	F	P	Duncan test (mean)	
				Newspaper	**Sawdust**
Biomass production					
Treatments	1	102.63	<0.0001	363.75	269.14
Days	6	140.32	<0.0001		
Growth rate					
Treatments	1	181.99	<0.0001	9.68	5.49
Days	6	74.45	<0.0001		
Number of cocoons					
Treatments	1	24.31	<0.0001	4.00	6.96
Days	6	43.10	<0.0001		
Number of worm					
Treatments	1	12.87	0.0008	11.50	14.14
Days	6	24.83	<0.0001		

b Error; *df* = 45

Table 4. Simple linear regression table

Type of Bedding	Prob > T	R-Square (%)
Newspaper	0.0296	17
Sawdust	0.0720	12

Table 5. pH analysis of different type of bedding

Days	Newspaper		Sawdust	
	Experiment	Control	Experiment	Control
0	7.87	7.15	7.53	7.23
7	7.84	7.43	7.83	7.77
14	7.70	7.67	8.13	7.94
21	7.53	7.25	7.93	7.85
28	7.43	6.83	7.34	7.46
35	7.27	6.74	6.94	6.84
42	6.92	6.75	6.68	6.51

Table 6. Bedding material characteristic

Type of bedding	Absorbency	Bulking potential	C:N ratio
Newspaper	Good	Medium	170-812:1
Sawdust	Poor-medium	Poor-medium	142-750:1

Sources: Kourik, 1986; Munroe, 2004

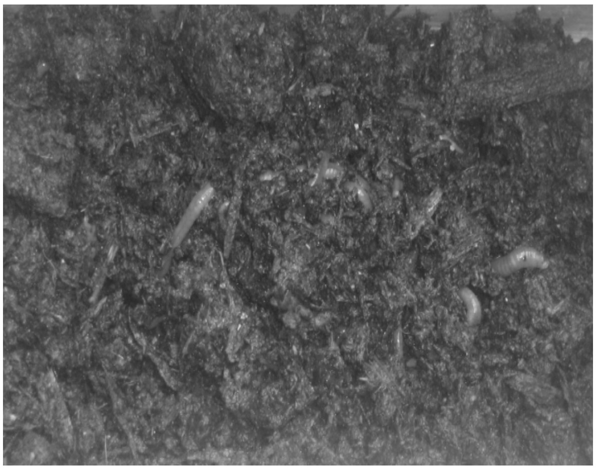

Figure 1. Perionyx excavatus in Vermicomposter

Figure 2. Vermicomposter from Coated Plastic Aquarium

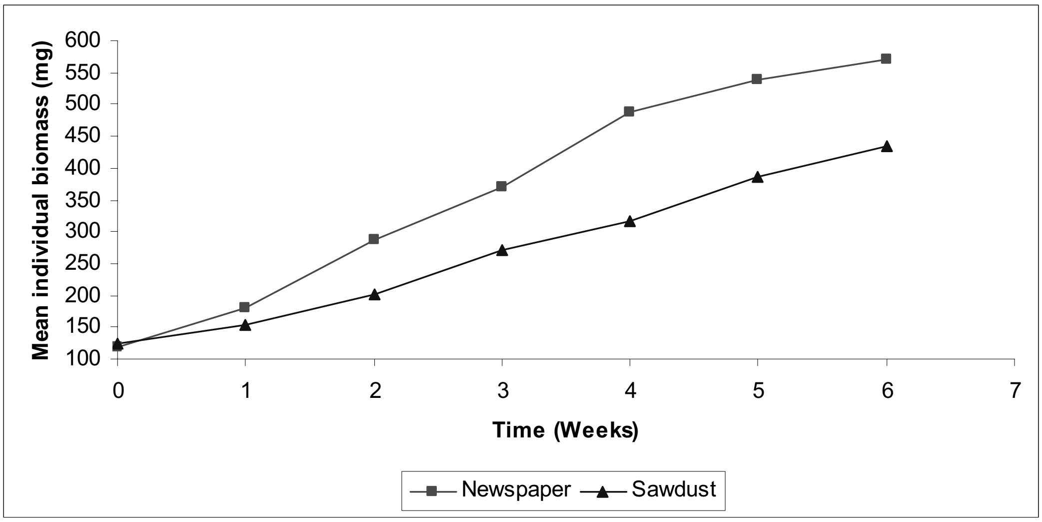

Figure 3. The Mean Individual Biomass (mg) in Different Bedding

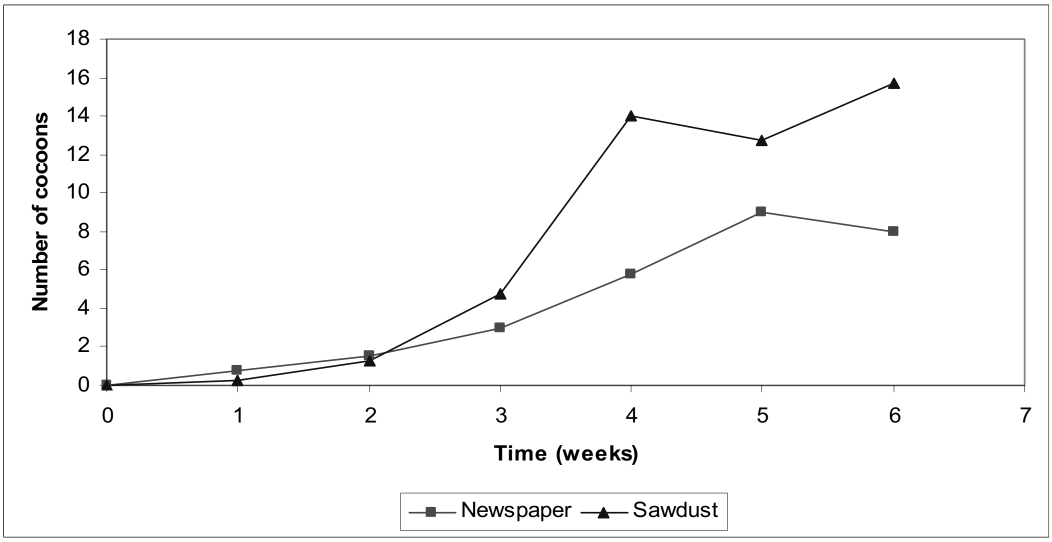

Figure 4. Cocoons Production/week in Different Types of Bedding

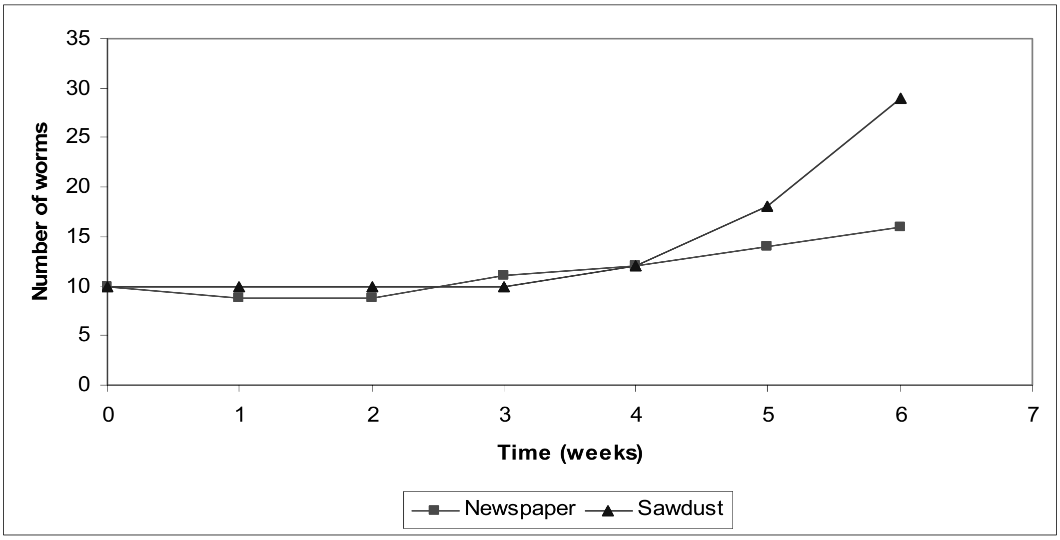

Figure 5. Number of Worms in Different Types of Bedding

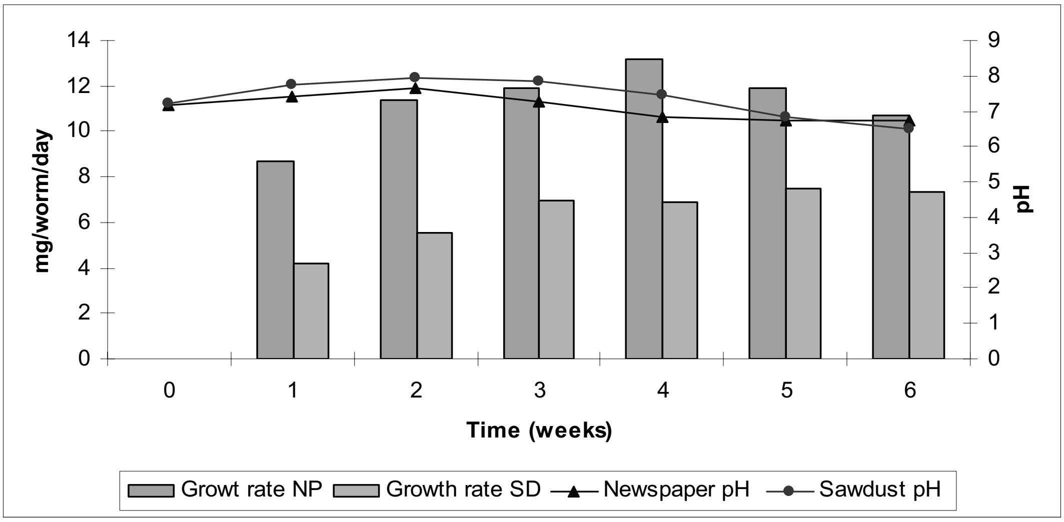

Figure 6. Worm Growth Rate with the pH of the Bedding (NP= newspaper, SD= sawdust)