POSSIBLE ROLE OF PHENOLIC COMPOUNDS ON VERMICOMPOSTING OF COIR PITH

Kanokwan Pundee[1], Saengchai Akeprathumchai[2] and Sudarut Tripetchkul[2]

[1]College of Multidisciplinary Sciences, [2]School of Bioresources and Technology, King Mongkut's University of Technology Thonburi, Bangkok, Thailand 10150
Contact: kanokwan.pun@mail.kmutt.ac.th

ABSTRACT

In coir fiber production process from coconut husk, large amount of coir pith is generally generated. Inefficient disposal of coir pith is one of the major causes of environmental problem since coir pith is recalcitrant in nature. Vermicomposting is an effective way to transform organic wastes into valuable plant nutrients by interaction between earthworm and microorganisms. This process not only accelerates organic waste decomposition but also improves the quality of final product. Therefore the present study aimed at evaluating the feasibility of producing vermicompost using coir pith as principle raw material. The mature earthworm, *Eudrilus eugeniae,* was introduced into a mixture of coir pith and cow manure. During vermicomposting, earthworm activities in terms of survival and weight gain, physical and chemical changes of vermicomposting material were determined. The significant earthworm mortality (90% mortality) and the worms' weight loss were found on day 14 of vermicomposting, whereas pH, electrical conductivity, organic matter, total carbon and nitrogen values of vermicompost were not significantly different from those of control. It is possible that phenolic compounds present in vermicomposting substrate may play an important role on worms' mortality since coir pith containing phenolic concentration (as gallic acid) at 230 mg/g dry weight led to significantly higher mortality and weight loss than those containing phenolic concentration at 150 mg/g dry weight. After one month of vermicomposting, C/N ratio, total carbon and nitrogen content of both treatments were not significantly different, approximately 25, 40% and 1.6%, respectively. The reproduction of earthworm was not observed in both treatments throughout 2 months of vermicomposting. The results suggested that total phenolic compounds in coir pith may affect the survival and weight gain of earthworm.

Keywords: Coir pith, Vermicomposting, Phenolic compounds, Earthworm survival

1. INTRODUCTION

Thailand is world's seventh largest coconut palm producer with more than 1 million tons of coconut produced annually (International Trade Center, 2012). Utilization of the coconuts for edible purposes and oil extraction generates a large amount of coconut husk which constitutes about 30% of coconut (Fuangworawong, 2008). Coconut husk, comprising 50 to 70% of coir pith and 30 to 50% of coir fiber (Prabhu and Thomas, 2002), has been utilized as a raw material for the production of coir fiber. All coir fiber has been utilized for mattress manufacturing while only 20% of coir pith has been used as planting material, particle board and fertilizer. However, coir pith, more than 80,000 tons, has been left nearby coir fiber industry every year (Fuangworawong, 2008) causing environmental problems, especially ground water pollution due to contamination of phenol present in leachate of coir pith during rainy season (Gopal and Gupta, 2001).

Coir pith, a lignocellulosic material, consists of 75 to 156 carbon to nitrogen (C/N) ratio and 30 to 50% lignin, 20 to 40% cellulose and 3 to 15% hemicellulose (Abad et al., 2002); therefore, coir pith is recalcitrant nature. Previous works applied composting, a thermophilic bio-oxidation process which transforms organic waste into stabilized humus like product through microorganisms activity (Dominguez et al., 1997), to accelerate coir pith decomposition. Coir pith was decomposed under different aeration rate (Fuangworawong, 2008) and low initial carbon to nitrogen ratio (Tripetchkul el al., 2012); nonetheless, the degradation of coir pith was still a long process. Therefore, problems associated with coir pith composting have to be taken into consideration.

Vermicomposting has been proven to be an effective way of organic waste treatment and vermicompost has been known as a good soil conditioner and fertilizer (Ndegwa and Thompson, 2001). It is a mesophilic bio-oxidation process of organic wastes by interaction of earthworms and microorganisms (Saha et al., 2012). Earthworms grind organic matter prior to ingestion, thus, increasing the substrates' surface area exposed to digestive enzymes produced by microorganisms present in earthworm's gut (Owa et al., 2013). In recent years, vermicomposting has been utilized to manage many types of substrate such as municipal solid waste, agricultural waste and sewage sludge (Giraddi, 2008; Ganesh et al., 2009). These results showed the possibility to convert coir pith into vermicompost. Objective of this study was to evaluate the influence of phenolic compounds on coir pith vermicomposting.

2. EXPERIMENT

2.1 Materials

Materials employed for vermicomposting in this study were coir pith and cow manure. Coir pith was collected from coconut processing industry in Thungkru district and the cow manure was purchased from local pet shop in Bangkok, Thailand.

2.2 Earthworms

Earthworm, *Eudrilus eugeniae*, a commonly known as African night crawler used in this study was purchased from local worm breeder in Samutsakorn, Thailand. They were cultured in the plastic trays containing cow manure at room temperature. Moisture content was maintained at 70-80% using tap water. Earthworms whose weights range from 0.3 to 1 g were used for this study.

2.3 Preliminary study

In order to evaluate the feasibility of producing vermicompost from coir pith, the preliminary study was conducted using coir pith compost as substrate. The 1 month old coir pith compost, which consisted of coir pith, cow manure, rice bran and molasses at the ratio of 3:1:1:0.08 was used as substrate. Earthworm density was 25 earthworms per 1.5 kg substrate in 30×20×20 cm plastic container. Moisture content was maintained at 70-80% for the whole period of experiment.

2.4 Effect of pre-treatment coir pith on earthworm survivability

This study was to examine that phenolic compounds influence survival of earthworm. The experiments were divided into 2 treatments which are (i) untreated coir pith as a control and (ii) treated coir pith by soaking with water for 24 hours. Cow manure was mixed separately with untreated coir pith and treated coir pith in the ratio of 1:1 (by weight). The 50 earthworms were introduced to 4 kg substrate in 30×20×20 cm plastic container.

2.5 Analytical method

The physical and chemical parameters, namely temperature, pH, electrical conductivity, total carbon content and nitrogen content, were analyzed by standard method (AOAC, 1995) whereas earthworm population was observed in terms of worm number and worm weight once a week. Total phenolic content in coir pith was extracted and determined using Folin-Ciocalteu method (FAO, 2000).

2.6 Statistical analysis

Analysis of variance (ANOVA) and least significant digit (LSD) were accomplished using Minitab 14 (Minitab Inc., United States).

3. RESULTS AND DISCUSSION

Table 1 Physical and chemical characteristic of coir pith and the 1 month old coir pith compost

Characteristics	Coir pith	Coir pith compost
pH	6.75±0.03	7.71±0.02
EC (dS/m)	13.8±1.01	0.50±0.00
Organic matter (%)	84.06±1.97	68.88±1.65
Nitrogen (%)	0.81±0.06	1.90±0.17
Phosphorus (%)	0.24±0.003	0.37±0.00
Potassium (%)	0.51±0.003	3.30±0.05

Table 1 provides physical and chemical properties of both coir pith and composted coir pith. It is evident that organic matter and nitrogen contents of composted coir pith were, respectively, 69.0 and 2.0% whereas both pH and electrical conductivity (EC) were 7.7 and 0.50 dS/m, respectively.

Table 2 Physical and chemical changes during vermicomposting process

Physical and chemical characteristic	Vermicomposting		
	Day 0	Day 7	Day 14
Temperature	28.3±0.0	29.1±0.6	28.15±0.1
Moisture content (%)	76.00±0.02	78.47±0.01	71.55±0.03
pH	7.26±0.08	6.55±0.12	6.35±0.05
EC (dS/m)	0.40±0.03	0.47±0.04	0.64±0.06
Organic matter (%)	79.57±0.80	77.06±3.29	78.73±0.96
Total carbon (%)	44.21±0.45	43.45±0.67	43.74±0.54
Nitrogen (%)	2.18±0.003	2.30±0.088	2.46±0.05

The physical and chemical changes during vermicomposting of coir pith compost are presented in Table 2. The temperature of vermicompost pile remained rather constant, 28 to 29°C, which is accommmodable to earthworm. Dominguez (2004) reported that *E. eugeniae* could survive in the temperature ranging from 10 to 30°C given that 25°C was considered optimal. The fluctuation of temperature observed may be caused by changing of the ambient temperature. Moisture content of vermicompost pile decreased from 76% initially to 72% towards the end of experiment. pH at the beginning of vermicomposting was 7.26 and declined to the final value of approximately 6.35 on the 14th day of vermicomposting due to the activity of microorganism and earthworm. The total carbon content of vermicompost pile slightly decreased while the electrical conductivity and nitrogen content increased. Results indicated that vermicomposting rendered marginally changes in total carbon whilst could release the nutrient from substrate.

The initial worm number and average worm weight were 25 worms and 0.81±0.05 g, respectively. During 14 days of vermicomposting, over 90% of the worms died and worm weight decreased by 71% of the initial weight. It is surprising that composted coir pith could not sustain earthworm survival since both pH and EC of composted coir pith were nontoxic to earthworms; pH > 4.5 (Dominguez, 2004) and EC < 0.9 dS/m (Dayananda et al., 2008) given further that the moisture content was also maintained above 70% which is sufficient for earthworms' survival (Dominguez, 2004). Results found are in good agreement with that of Ganesh et al. (2009) who found the high rate of mortality and weight loss in earthworms during vermicomposting of the pre-composted leaf litter of acacia (*Acacia auriculiformis*). The authors offered that such high mortality rate may be responsible by the presence of high polyphenol and lignin content in substrate, approximately 12.5 and 14.7%, respectively. Israel et al. (2011) reported that, depending on extraction methods, 4.2-20.0 % of coir pith were extractable and that the extract contained significant amount of phenolic compounds such as tannins, flavonoids and other polyphenols. The difference in phenolic content of coir pith depended on source of coconut, the fiber removing method and the stock piling period of the coir pith (Abad et al., 2002). Therefore, it is palpable that decrease in the worm number and worm weight may be caused by some toxic components present substrate, composted coir pith.

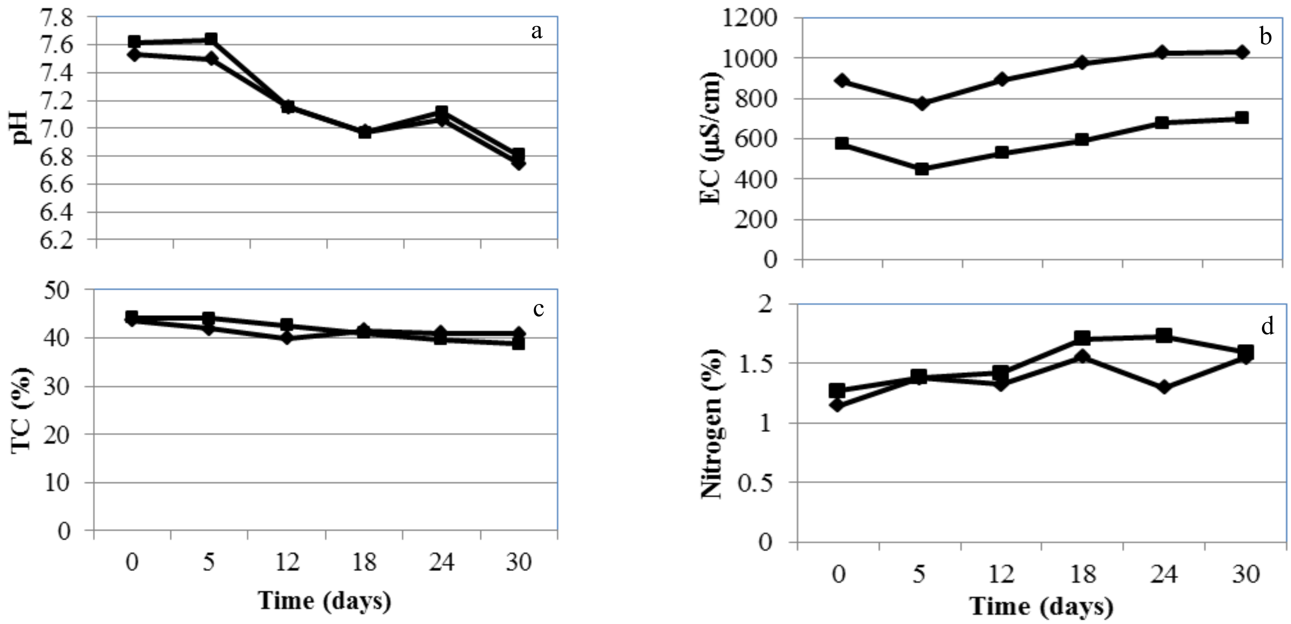

Fig. 1 Changes of pH (a), electrical conductivity (b), total carbon (c) and nitrogen (d) during vermicomposting of untreated coir pith (♦) and treated coir pith (■)

In order to assess the influence of phenolic compounds on survival of earthworms during vermicomposting, coir pith was soaked with water for 24 hrs. It was found that in subsequent to soaking with water the concentration of phenolic compounds was 150 $mg/g_{coir\ pith}$ which was approximately half of that of the untreated coir pith (230 $mg/g_{coir\ pith}$). Further, the pre-treatment of coir pith by soaking reduced one-third of the electrical conductivity of coir pith, namely, 0.6 dS/m for pre-treated coir pith and 0.9 dS/m for untreated one. It was found further that the initial pH of untreated and treated coir pith was approximately 7.5-7.6 which was suitable for survival of earthworm and decreased to the final value of approximately 6.8 on day 30 of vermicomposting. In addition, the total carbon and content decreased from 45 initially to 38%, while nitrogen content detected was increased from the initial value of 1.2 to 1.6% at one month of vermicomposting (Fig 1).

The earthworm population of untreated and treated coir pith was significantly different ($p<0.05$). The earthworm number present in the untreated coir pith (high phenolic content) and treated coir pith (low phenolic content) vermicompost decreased during the whole period vermicomposting, 3 weeks (Fig. 2). For untreated treatment, the number of earthworms declined more rapidly than that of low phenolic content (pre-treated) treatment. All of earthworms in high phenolic content treatment died within 24 days post vermicomposting while, for low phenolic content treatment, 60% of earthworms survived until day 60 (the end) of vermicomposting. The average weight of earthworm in high phenolic content treatment decreased over time while the average weight of earthworm in low phenolic content treatment increased sharply from 0.5 to 0.7 g during the first 12 days of vermicomposting, then declined to 0.5 g on day 18 and remained constant towards the end of vermicomposting (Fig. 3). It is suggested that mortality of earthworms maybe cause by an inability to acclimatize to new environment during transfer and rearing (Huang et al., 2014). Further, Kasurinen et al. (2007) reported when juvenile earthworm (*Lumbricus terrestris*) fed on leaf litter containing high phenolic compound concentration a decline in relative growth rates was observed. Additionally, Sabrina et al. (2012) investigated the influence of phenolic compounds present in oil palm empty fruit bunch (10% phenolic compounds as gallic acid) on survivability of earthworms, *Pontoscolex corethrurus* and *Amynthas rodoricensis,* native to oil palm plantation and reported that in subsequent to the introduction of substrate, significant earthworm mortality (20%) was observed. Results found in this study suggested that phenolic compounds present in coir pith are toxic to earthworms as evidence by the fact that vermicomposting of coir pith under low phenolic content led to higher percentage of survival of earthworms in comparison with that of high phenolic content. It has been reported that tannins, one of phenolic compounds present in coir pith, could form complexes with several organic compounds such as polysaccharides, proteins and minerals (Jansman, 1993). Therefore, it is probable that mortality of earthworms may be caused by such phenomenon since enzymes responsible for digesting organic compounds to nutrients necessary for survival might be inactivated by the presence of phenolic compounds, particularly tannins.

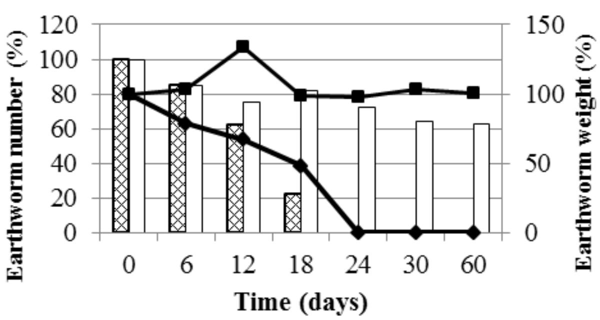

Fig. 3 Number (column) and weight (line) of earthworms during vermicomposting of untreated coir pith (,) and treated coir pith (,)

4. CONCLUSION

Coir pith *per se* appeared to be toxic to earthworms due to high phenolic compound content which in turn rendered vermicomposting ineffective. However, vermicomposting of coir pith became more feasible when suitable pre-treatment, i.e., soaking with water was adopted which could reduce the phenolic compound concentration and, thereby, lessen toxicity to earthworms.

5. ACKNOWLEDGEMENT

This study was financially supported by Petchra Pra Jom Klao Doctoral Scholarship.

6. REFERENCES

Abad, M., Noguera, P., Puchades, R., Maquieira, A., Noguera, V., Physicochemical and chemical properties of some coconut coir dust for use as a peat substitute for containerized ornamental plants., *Bioresource Technology*, vol. 82, pp. 241–245, 2002.

Association Office Analytical Chemists International (AOAC), *Official Methods of Analysis*, 16th ed., The Association Office Agricultural Chemists, Verginia, pp. 5-24, 1995.

Dayananda, K., Giraddi, R. S. and Gali, S. K., Effect of salt and sewage water on the survival and reproduction of three earthworm species used in vermicomposting., *Karnataka J. Agric. Sci*.,vol. 21, no. 1, pp.52-54, 2008.

Dominguez, j, Edwards, C.A. and Subler, S., A comparison of vemicomposting and composting, *BioCycle April*, pp. 57-59, 1997.

Domínguez, J., *State-of-the-Art and New Perspectives on Vermicomposting*, Research. Departamento de Ecoloxía e Bioloxía Animal, Universidade de Vigo, Spain,pp. 404-407, 2004.

FAO, *Quantification of tannins in tree foliage*, FAO/IAEA Working Document, Vienna, 2000.

Fuangworawong, P., *Influence of Nitrogen Sources, Molasses Addition and Aeration Schemes on Composting of Coir Pith*. Dissertation, King Mongkut's University of Technology Thonburi (In Thai), 2008.

Giraddi, R. S., Effect of Stocking Rate of *Eudrilus eugeniae* (Kinberg) on Vermicompost Production, *Karnataka J. Agric. Sci*., vol. 21, no. 1, pp. 49-51, 2008.

Gopal, M. and Gupta, A., Coir waste for a scientific cause. *Indian Cocon.J.,* vol. 31, no. 12,pp. 13-15, 2001.

Huang, K., Li, F., Wei, Y., Fu, X., and Chen, X., Effects of earthworms on physicochemical properties and microbial profiles during vermicomposting of fresh fruit and vegetable wastes., *Bioresource technology*, vol. 170, pp. 45-52, 2014.

International Trade Center, Competitiveness of Thailand coconut, Available online: http://tpso.moc.go.th/img/news/1064-img.pdf, 2012.

Israel, A. U., Ogali, R. E., Akaranta, O. and Obot, I. B., Extraction and characterization of coconut (Cocos nucifera L.) coir dust. Songklanakarin Journal Science Technology, Vol. 33, No. 6, pp. 717-724, 2011.

Jansman, A. J. M., Tannins in feedstuffs for simple-stomached animals.*Nutrition Research Reviews*, vol. *6*, no. 01, pp. 209-236, 1993.

Kasurinen, A., Peltonen, P.A., Julkunen-Tiitto, R., Vapaavuori, E., Nuutinen, V., Holopainen, T. and Holopainen, J.K., Effects of elevated CO_2 and O_3 on leaf litter phenolics and subsequent performance of litterfeeding soil macrofauna. *Plant Soil*, vol. 292, pp.25-43, 2007.

Ndegwa, P. and Thompson, S., Intergating composting and vermicomposting in the treatment and bioconversion of biosolids., *Bioresource Technology*, pp. 107-112, 2001.

Owa, S. O., Olowoparija, S. B., Aladesida, A. and Dedeke, G. A., Enteric bacteria and fungi of the Eudrilid earthworm *Libyodrilus violaceus*. *African Journal of Agricultural Research*, vol. 8, no. 17, 1760-1766, 2013.

Prabhu, S.R. and Thomas, G.V., Biological conversion of coir pith into a value-added organic resource and its application in agri-horticulture: current status, prospects and perspective. *Journal of Plantation*, vol. 30, no. 1, pp. 1-17, 2002.

Sabrina, D.T., Gandahi, A.W., Hanafi, M.M., Mahmud, M.M. and Nor Azwady, A.A., Oil palm empty-fruit bunch application effects on the earthworm population and phenol contents under field conditions. *African Journal of Biotechnology*, vol. 11, no. 9, pp. 4396-4406, 2012.

Saha, S., Dutta, D., Ray, D.P. and Karmakar, R., Vermicompost and soil quality, Farming for food and water security, vol. 10, 2012.

Tripetchkul, S., Pundee, K., Koonsrisuk, S., & Akeprathumchai, S., Co-composting of coir pith and cow manure: initial C/N ratio vs physico-chemical changes. *International Journal of Recycling of Organic Waste in Agriculture*, vol. 1, no.1,pp.1-8, 2012.