Research article

Vermicompost: Tool for Agro-industrial Waste Management and Sustainable Agriculture

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Abstract Rapid increasing of agro-industrial waste production has caused a serious environmental damage in Thailand. Thus, a proper management of agro-industrial waste has become an important issue. The objective of this study was to prove vermicompost as a suitable tool for agro-industrial waste management. The experiment of feasibility study of using vermicompost to reduce the cadmium contaminated in some typical Thai soil (Nampong (Sandy) and Phimai (Clay) soil series) were conducted by spike soil at various concentrations of Cd (0, 5, 50 mg/kg of Cd) as $CdCl_2$. The physical and chemical properties of soil were analyzed before and after compost and vermicompost. The results indicated that vermicompost could absorb the cadmium in sludge waste and subsequently reduce the cadmium contamination. Earthworm activity significantly increased the availability of soil pH, P, K, Na, Mg, Ca and decreased organic carbon as well as Cd contamination in soil. The production of earthworm was increased followed by the increasing of agro industrial waste. Thus vermicompost is a promising method for agro-industrial waste management that use locally available materials, enrich microorganism in soil and less impact on the environment.

Keywords vermicompost, agro-industrial waste, sustainable agriculture

INTRODUCTION

The increasing rate of agro-industrial waste due to the large scale of urbanization and a consequence of economic development has become a problem that produces the huge quantities of waste in Thailand and causes a serious environmental problem which is difficult for management. Among the available alternatives for disposing of sewage waste sludge, one of the most convenient ways is using the waste in agriculture purpose. Agro-industrial waste is one of the problems and difficult to manage as Thailand is an agricultural country. The increasing rate at which organic waste are generated has become a problem for disposal and/or management. Currently, the management and disposal of agro-industrial waste production is one of the most critical environmental issues. Therefore, the study related on the safe reuse and management of agro-industrial waste is important. According to Appelhof (1981), the appropriate disposal of waste should involve both maximum cost effective recovery of recyclable constituents and transformation of non-recoverable material into forms, which do not present environmental hazards.

Vermicomposting is the earthworm activity that turn the organic waste into the fertilizer. The process of vermicompost is broken down organic residues by earthworms and microorganisms (Aira and Dominguez, 2008). The stabilization process of organic waste materials involves the joint action between earthworms and microorganisms. Although microbes are responsible for biochemical degradation of organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering the biological activity (Suthar, 2007). Pimm (1982) reported that the dynamics of decomposition systems of vermicompost depend on the inputs of resources. There is a need of safe technology of disposal agro-industrial waste; the technologies must be ecologically sound, economically viable and socially acceptable. Therefore, vermicompost technologies fulfill all the conditions for suitable waste management. It is one of the common ways to decrease sludge volume. Cadmium is one of the main risk metals in soil and waste sludge (Alloway, 1995). Vermicompost may be used to assess the impact of cadmium contaminated soil and waste sludge on physiological state, reproduction and development of the animals and also reduce the cadmium residues in sludge and soil. The objective of this study was to determine the effect of earthworm (*Eudrillus eugeniae*) activity on suitable tool for Agro-industrial waste management and source of nutrients for plant production in sustainable agriculture.

MATERIALS AND METHODS

The earthworms (*Eudrillus eugeniae*) were collected from the meadow, which had no history of input of heavy metals. They were carefully brought to the laboratory along with the moist soil and culture in laboratory and acclimatized for 1 month under laboratory conditions in polyethylene buckets (culture pot) containing soil. Citric acid waste from ago-industrial waste was collected from Samutsakorn Province, Thailand. The citric acid waste was dried in direct sunlight for 1 month and passed through 2 mm of sieve. The chemical characteristics of citric acid waste are reported with its moisture to 50%. Cow manure was used as amendment material. The fresh cow manure used in this experiment was obtained from a local cow house. The investigation was carried out in a laboratory at the Faculty of Agriculture, Khon Kaen University, Thailand. The experimental units were conducted in polyethylene culture pots, which have four liters capacity of each. Nampong (Sandy) and Phimai (Clay) soil series were used in this experiment. Air-dried soil and farmyard manure were mixed in the ratio of 9:1 for the experiments. These mixtures at 400g were taken in each experimental pot to provide initial favorable environmental conditions for the worms.

The experiment was laid out in completely randomized design (CRD) with 3 replications. Two treatments were used: (i) vermicompost (soil + citric acid waste + cow manure + metal + earthworm), (ii) compost (soil + citric acid waste + cow manure + metal). To measure the normal activity of earthworms (*Eudrillus eugeniae*) in the prepared soil, 0, 5, 50 mg/kg of $CdCl_2$ were applied to each experimental beds containing ten earthworms. The moisture content was adjusted to 50% of WHC (Water Holding Capacity). The pH of soil was 6.08±0.08. Temperature was maintained at 30±2 $^{\circ}$C. The day of releasing the earthworms was marked at 0, 15, 30, 60 days.

Chemical analysis in soil and earthworm tissue samples

The pH was measured using digital pH meter in 1/ 2.5 (w/v) by deionizered water. Organic carbon was determined by the partially-oxidation method (Walkley and Black, 1934). Total N (Total nitrogen) was measured by micro Kjeldahl method (Jackson, 1973; Bremner and Mlvaney, 1982). Extractable phosphorous was determined by following BrayII extraction method (Schroth et.al, 2003) by spectrophotometer. Exchangeable elements (K, Ca and Mg) were determined after extracting the sample using ammonium acetate extractable method (Simard, 1993); analyzed by flame atomic absorption spectrophotometer (FAAS). C:N ratio was calculated from the measured value of C and N. To measure cadmium and total cadmium in soil and earthworm tissue; DTPA-Cd was determined after extracting using DTPA solution by analysis flame atomic absorption spectrophotometer (FAAS). To determine total metal concentrations, soil and earthworm tissue samples were digested by acid mixture 1:2 (HNO_3–$HClO_4$) (Tessier et al., 1979; Sparks, et al., 1996;; Maity et al., 2008; Suthar and Singh, 2008). 1 g dry sample was heated with 10 ml concentrated HNO_3–$HClO_4$ at 170°C for 3-4 hour; and analyzed by flame atomic absorption spectrophotometer (FAAS).

Statistical analysis

All results were analysed the means of three replicates. One-way ANOVA was used to analyze the significant difference between treatments and Turkey HSD test was used to compare the means by using Statistix 8.0 and Microsoft Excel.

RESULTS AND DISCUSSION

The pH values of the Nampong Soil (Ng) and Phimai Soil (Pm) on 0, 15, 30 and 60 days for the different concentrations of Cd treatments are represented in Table 1. The result clearly showed that there was significant difference in pH value among the treatments. However, Phimai soil has been found to have significantly higher soil pH in all cadmium treated vermicompost after 60 days. The comparison of two soil series (Nampong and Phimai soil series) indicated that there was no significant difference on pH values. The increasing pH were found in every treatments because of the ability of earthworm in releasing calcium compound and producing alkaline urine into the environments (Hu et al., 1998; Salmon, 2001) by calciferous glands. The pH of vermicompost beds may also be increased by the high activity of gut enzyme alkaline phosphates (Pramanik et al., 2007).

Table 1 pH value of Nampong soil and Phimai soil between vermicompost (VCP) and without earthworm (Compost: CP)

Time	Nampong Soil (Ng)				Phimai Soil (Pm)			
	5 mg/kg		50 mg/kg		5 mg/kg		50 mg/kg	
	CP	VCP	CP	VCP	CP	VCP	CP	VCP
0	6.06±0.01	6.06±0.01	6.13±0.01	6.13±0.01	5.57±0.02	5.57±0.02	5.75±0.05	5.75±0.05
15	7.06±0.01	7.26±0.01	7.13±0.01	7.03±0.01	6.57±0.02	6.76±0.01	6.75±0.05	6.53±0.06
30	7.22±0.03	7.42±0.03	7.3±0.05	7.16±0.05	7.36±0.01	7.31±0.02	7.18±0.03	7.22±0.03
60	7.16±0.02	7.55±0.05	7.25±0.02	7.42±0.03	7.26±0.01	7.87±0.06	7.15±0.02	7.88±0.04

In Namphong soil treatment, soil characteristic changes in the earthworm compost (Vermicompost) and without earthworm (Compost) found that after fermentation and maturing in 30 days, the organic carbon and C:N ratio were lower in both vermicompost and compost. The organic carbon and C:N ratio reduction was recorded that the ranges of the organic carbon were CP0,50 and VCP0,50 of 62-63% and 60-64%, respectively and the ranges of C:N ratio were 66-81% and 78-87%. The total nitrogen, exchangeable K, Ca, Mg and available P showed a significant ($P < 0.05$) increasing the percentage of different between VCP and CP that CP0 = 11.1, -26.2, 12.6, 23.1, 27% and CP50 = 0.6, 27.9, 53.3, 6.3,-2.7%, respectively. As the percentage of different after fermentation and maturing in 30 days in VCP0= 68.5, 58.7, 66.9, 55.9, 93.4 % and VCP50= 39.4, 78.3, 62.5, 69.0, 45.1, 93.2 % were recorded (Table 2).

In Phimai soil treatment, soil characteristic changes in the soil earthworm compost and without earthworm found that after fermentation and maturing in 30 days the organic carbon and C:N ratio values were lower in vermicompost of than the compost material and a reduction was recorded every cadmium concentration. Organic carbon and C:N ratio values were showed significantly ($P < 0.05$) decrease the ranges of CP0 were 15.2% and 19.6%, CP50 were 21.7% and 34.4% when compare with earthworm compost (Vermicompost) as VCP0 were 38.8% and 75.4%, VCP50 were 40.8% and 61.0%. The total nitrogen, exchangeable K, Ca, Mg and available P showed significantly ($P < 0.05$) increase the percentage of different of between VCP and CP that CP0 = 5.4, 2.3, 12.1, 29.1, -135.8% and CP50 = 16.7, 40.8, 51.6, 43.3, 15.9 %, respectively. As the percentage of different after fermentation and maturing in 30 days in VCP0= 60.1, 54.7, 68.9, 14.0, 86.3% and VCP50= 34.6, 24.6, 43.1, 9.6, 82.8 % were also observed (Table 2).

Cadmium mitigation in soil

The results showed that the DTPA-Cd concentration in Nampong and Phimai soil after 60 days was decreased for each treatment beds (Fig. 1). The comparison between Vermicompost and Compost showed a significant DTPA-Cd decreasing trend ($P < 0.05$). In addition, waste treatment through vermicompost provided better cadmium absorptions as compared to the waste treatment without earthworm (Compost). This may be due to the absorption of cadmium in sludge waste and earthworm tissue which help to manage reduction cadmium in soil and decreased toxic cadmium to plant and micro organism (Suthar, 2008).

Table 2 Organic carbon (OC %), total nitrogen (TN), C:N ratio, exchangeable K, Ca and Mg and available phosphorous between vermicompost (VCP) and without earthworm (Compost: CP)

Parameter	Time	Nampong soil (Ng)				Phimai soil (Pm)			
		0 mg/kg		50 mg/kg		0 mg/kg		50 mg/kg	
		CP	VCP	CP	VCP	VCP	CP	CP	VCP
%OC	0d	3.12±0.01	3.12±0.01	3.1±0.0	3.1±0.0	2.76±0.01	2.76±0.01	3.36±0.02	3.36±0.02
	30d	1.17±0.06	1.23±0.03	1.12±0.05	1.1±0.11	2.34±0.09	1.69±0.01	2.63±0.04	1.99±0.08
Total N	0d	0.056±0.01	0.056±0.01	0.083±0.0	0.083±0.0	0.122±0.003	0.122±0.003	0.125±0.007	0.125±0.07
	30d	0.063±0.002	0.178±0.02	0.087±0.01	0.137±0.02	0.129±0.02	0.306±0.03	0.15±0.02	0.191±0.01
C:N ratio	0d	55.36±0.03	55.36±0.40	31.98±1.60	37.64±1.20	22.6±0.07	22.6±0.50	26.9±1.60	26.9±0.60
	30d	18.74±1.20	6.97±1.20	5.99±0.90	8.15±1.50	18.18±0.23	5.56±0.23	17.64±2.81	10.48±2.81
Exch.K	0d	640±10.0	640±10.0	665±28.0	665±28.0	850±10.0	850±10.0	942±37.0	942±37.0
	30d	507±16.0	1,550±10.0	922±11.0	1,775±34.0	870±10.0	1,875±41.0	1,592±19.0	1,250±23.0
Exch.Ca	0d	1,640±10.0	1,640±10.0	1,476±47.0	1,476±47.0	2,166±5.0	2,166±5.0	2,702±53.0	2,702±53.0
	30d	1,877±23.0	4,950±45.0	3,158±28.0	4,760±43.0	2,463±15.0	6,975±35.0	5,578±12.0	4,750±35.0
Exch.Mg	0d	50±1.0	60±1.0	74±3.0	84±3.0	244±2.0	344±2.0	267±4.0	367±5.0
	30d	65±4.0	136±5.0	79±1.0	153±3.0	344±5.0	400±6.0	472±12.0	406±11.0
Avail.P	0d	72±2.0	72±2.0	77±2.0	77±2.0	158±1.0	158±1.0	190±5.0	190±5.0
	30d	27±1.0	1,085±12.0	75±2.0	1,135±34.0	67±4.0	1,154±59.0	226±4.0	1,104±29.0

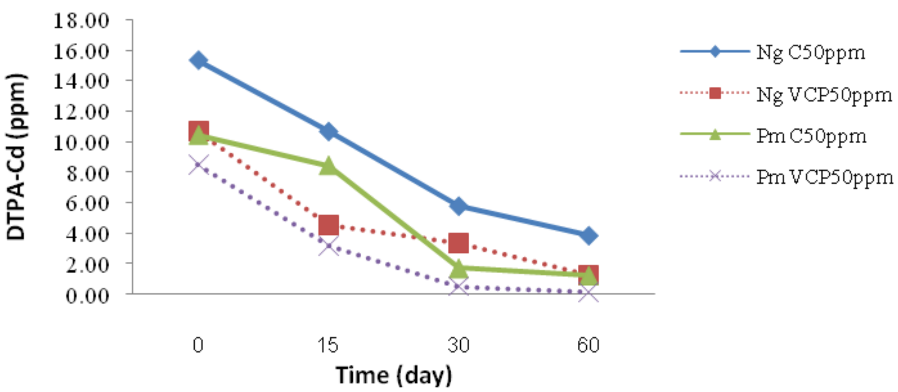

Fig. 1 DTPA-Cd in Nampong soil and Phimai between vermicompost (VCP) and without earthworm (Compost: CP)

Cadmium in earthworm tissue

The results showed that cadmium concentration in earthworm tissue after 60 days increased significantly with the increasing of cadmium concentration in earthworm ($P<0.05$) (Fig. 2). Thus, increasing of cadmium in earthworm tissue helped to reduce cadmium concentration in soil than without earthworm (Compost). The difference for tissues metal contents could be related to the feeding or feeding rate or/and amount of metals in ingesting materials by inoculated earthworms. Some earlier studies have revealed that earthworm can accumulate a considerable amount of metals in their tissues if reared for long periods in contaminated soil/substrates (Lukkari et al., 2006; Suthar, 2008; Suthar and Singh, 2008).

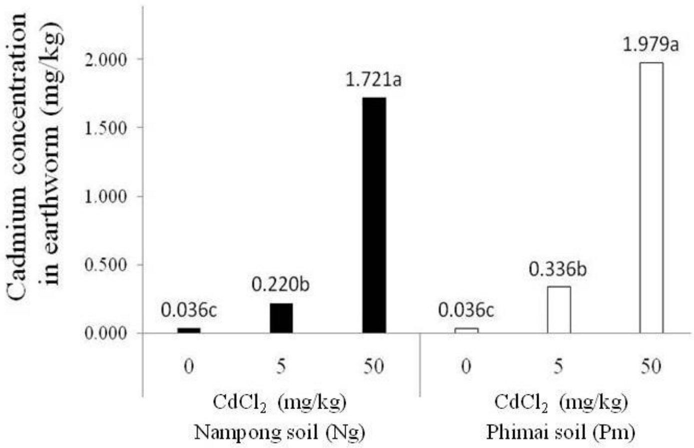

Fig. 2 Cadmium concentration in earthworm tissue

The results showed that vermicomposting of citric acid waste and cow manure were loss of organic carbon and C:N ratio. That means vermicomposting help to reduce organic waste and turn on the useful fertilizer. During the vermicomposting process, inoculated earthworms maintain aerobic condition in the wastes, convert a portion of the organic material into worm biomass and respiration products and expel the remaining partially stabilized product (vermicompost) (Suthar and Singh, 2008). Lee, (1992) and Le Bayon and Binet, (2006) suggested that the passage of organic matter through the gut of earthworm is converted to available P forms, which are more available to plants. Some previous studies also indicated the increasing of potassium content in vermicompost by the end of the experiment (Manna, et al., 2003; Suthar, 2007). The results obtained in this study demonstrated higher potassium concentration of the end product prepared from sewage sludge. The C:N ratio of the substrate material reflects the organic waste mineralization and stabilization during the process of composting or vermicomposting.

CONCLUSIONS

Agro-industrial waste (citric acid waste sludge and cow manure) has great agronomic and economic potentials as well as sustaining the environment. This study suggests that bio-stabilization of agro-industrial waste sludge using earthworm could be a potential technology to convert noxious agro-industrial and heavy metal in soil by-product into nutrient rich bio-fertilizer. The vermicomposting process showed a demonstrable impact on cadmium metal concentration of soil. The higher values of bio-concentration factors (BCFs) for different cadmium metals indicate that earthworm can accumulate a considerable amount of metals in their tissues. Earthworm biomass production and reproduction performance was excellent in bedding those contained lower proportions of agro-industrial waste sludge e.g., vermicompost which suggests that industrial sludge can retard the potentials of composting earthworms if applied at higher rate in vermibeds. Finally, agro industrial waste could be utilized as an efficient soil conditioner for sustainable land practices after processing by composting earthworms.

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