Journal of Hazardous Materials 179 (2010) 318–322

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Chemical changes during vermicomposting of sago industry solid wastes

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ARTICLE INFO

Article history:
Received 25 August 2009
Received in revised form 2 March 2010
Accepted 3 March 2010
Available online 9 March 2010

Keywords:
Vermicompost
Sago industry waste
Nutritional changes
Poultry manure
Cow dung

ABSTRACT

A laboratory study was undertaken to examine the temporal changes in physico-chemical properties during vermicomposting of sago industry waste. The sago industry waste was blended with cow dung, poultry manure at various proportions, kept for pre-treatment for 21 days and subsequently vermicomposted for a period of 45 days under shade. Earthworm species (*Eisenia foetida*) was introduced at the rate of 50 g/kg of waste. The substrate moisture content and temperature were monitored regularly. The vermicomposts were sampled at 0, 15, 30 and 45 days for the assessment of temporal changes in physico-chemical properties. The data revealed vermicomposting of sago wastes, cow dung and poultry manure mixed at equal proportion (1:1:1) produced a superior quality manure with desirable C:N ratio and higher nutritional status than composting. *E. foetida* is an earthworm suitable for composting organic wastes such as poultry manure with extreme pH and high temperature and sago waste with high organic carbon in a shorter period of time. This study suggests that the sago industry solid waste could be effectively converted into highly valuable manure that can be exploited to promote crop production.

1. Introduction

Sago, a common edible starch in the form of globules is obtained by processing the tubers of tapioca (*Manihot esculenta* crantz). Sago industry is one of the major small scale sectors in India with more than 800 units located in Salem District of Tamil Nadu. The processing of sago generates huge quantities of biodegradable solid and liquid wastes which are highly organic, foul smelling and acidic in nature [1]. The sago industry is classified under orange category by the Tamil Nadu Pollution Control Board. Sago waste water is used in the production of biogas using a fluidized bed reactor [2] and by Hybrid Upflow Anaerobic Sludge Blanket Reactor (HUASB) [1]. Vermicomposting is a suitable technology to handle different types of organic and industrial solid wastes and make valuable manure from it [3]. Successful biomanagement of sago solid waste by vermicomposting using earthworm species *Eudrilus eugeniae* [4] and *Lampito mauritii* [5] has been reported recently. Sago waste has very low nitrogen and phosphorus content. The present study emphasizes the decomposition of sago waste along with cow dung and poultry manure in various combinations using the earthworm species *E. foetida* to produce good quality vermicompost.

Cow dung enhances the microbial activity in the initial decomposition process [6]. Poultry manure is a rich source of nitrogen and phosphorus [7] which can complement sago waste. Besides, the poultry units present in Salem District also face manure disposal problem due to their extremely high levels of nitrogen as ammonia, low pH, and heat generation when produced in large quantities [8]. The earthworm species *Eisenia foetida* was used in this study since it can tolerate wide pH range, temperature and moisture content [6]. *Eisenia andrei* has been used to compost poultry litter along with horse manure, pine saw dust, shredded paper and cotton industry waste [9]. During the vermicomposting process, the hemoglobin of earthworms is saturated with oxygen. This supports aerobic decomposition of organic wastes eaten by the worms by the microorganisms present in the mid gut [10]. Further, the earthworm casts contain calcium that buffers the pH of the substrate and facilitates rapid decomposition of organic waste [11]. Earthworms can also remove the harmful pathogens (by devouring them and also by discharge of antibacterial coelomic fluid) and heavy metals (by bio-accumulation) [12]. In this study, the temporal changes in physico-chemical properties of the vermicomposting made from various combinations of sago waste (SW), poultry manure (PM) and cow dung (CD) were investigated.

2. Materials and methods

The work was carried out at the Department of Biotechnology, PSG College of Technology, Coimbatore, Tamil Nadu (India). Sago industry waste and poultry manure were collected from a sago factory and a poultry farm in Salem, Tamil Nadu (India). The sago industry waste was mixed with cow dung or poul-

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doi:10.1016/j.jhazmat.2010.03.007

try manure in different proportions. Treatments consisted of T1, sago waste + cow dung (3:1); T2, sago waste + poultry manure (3:1); T3, sago waste + cow dung + poultry manure (1:1:1); T4, sago waste + cow dung (1:1); and T5, sago waste + poultry manure (1:1). Controls for the above treatments T1C, T2C, T3C, T4C and T5C were also included without the inoculation of worms. Besides the above controls, non-mixtures such as cow dung, C1; poultry manure, CII; and sago waste, CIII were also taken. The experiments were performed in four replicates in a completely randomized block design.

Mud pots measuring 30 cm height and 30 cm diameter were used. The pots were filled with 1.5 kg substrate per pot in various combinations and non-mixtures. The pots were kept under shade and irrigated with equal quantity of tap water on alternate days to ensure that the substrate moisture content was maintained at approximately 60%. After the completion of pre-inoculation period of 21 days, earthworm species (*E. foetida*) was introduced at 75 g per pot (50 g/kg of waste) into all the treatments and non-mixtures except in the treatment controls. The *E. foetida* worms were purchased from an organic farming society at Sathyamangalam in Erode District, Tamil Nadu. The sampling of the substrate was done at 0, 15, 30 and 45 days at a depth of 15 cm. Substrate samples drawn from all the treatment combinations were dried under shade and physico-chemical properties were analyzed.

2.1. Physico-chemical characterization

Moisture content of the initial waste materials and compost was measured gravimetrically. The pH was measured using a pH meter (LI 120 Elico India) in the filtrate obtained by dissolving the sample in double volume of distilled water. Total nitrogen was measured by microkjeldahl method [13]. Organic carbon content in the samples was measured by chromic acid oxidation method [14]. Hydrochloric acid extract of samples was prepared for the analysis of P, Ca, K, S, Na, and B. Total phosphorus was estimated by vanadomolybdo phosphoric acid yellow color method [15] using a colorimeter (Model 115, Systronics, India). Calcium was quantified by versenate titration method [16]. Potassium and sodium were estimated by the standard method of Jackson [15] using flame photometer (Model Mediflame124, Systronics, India). Sulphur and boron were estimated by gravimetric and colorimetric methods, respectively [15]. Standard deviation for each data set of the treatment was determined and presented.

3. Results and discussion

3.1. Physico-chemical properties of organic wastes

The organic wastes, cow dung, poultry manure and sago waste used in this study were analyzed prior to composting and their physico-chemical properties are given in Table 1. This table also provides the change in properties after vermicomposting for comparison. There was only a slight alteration in all the properties. The data given here was from the samples obtained on the 45th day after worm inoculation; however, the worms hardly survived after 20 days in these non-mixtures. The extremely high pH 10.4, in cow dung or low pH 5.0 in poultry manure may be detrimental for the growth of worms. The earthworm species *E. foetida* is supposed to tolerate extreme pH and temperature [6]; this justifies the survival of the worms at least for a short period. Among the three wastes, sago waste is found to be high in organic carbon 47.8%, but contains least amount of N (0.43%) and P (0.16%) compared with poultry manure which has the highest N (3.97%) and least carbon (30.0%) which were also observed by Banu et al. [5] and Omeira et al. [7], respectively. This suggests that blend of these wastes will complement each other. Cow dung had the highest amounts of P, K, S, Ca and good C:N ratio, hence this may facilitate the microbial growth and yield good quality vermicomposts. Addition of cow dung to kitchen waste [6] and textile mill sludge [17] has yielded good quality vermicomposts.

3.2. Comparison of composting and vermicomposting of manure blends

In the present study, cow dung, poultry manure and sago waste were mixed in five different proportions in order to analyze the best combination for vermicomposting. The same combinations were also allowed for composting without worms for comparison. The physico-chemical properties of compost after 66 days and vermicompost after 21 days of precomposting followed by 45 days of vermicomposting are given in Table 2. The C:N ratio showed a drastic difference of 31.2 vs. 13.3 between vermicompost and compost in T3 which contains equal proportion of all three wastes. Conversion of organic wastes into compost with suitable C:N ratio has been observed earlier in different types of wastes, including kitchen waste and textile mill sludge [3,6,17]. In this study except T5 (SW:PM 1:1) all other treatments have a more favorable C:N ratio in vermicompost compared to compost. Vermicompost of T3 (CD:PM:SW 1:1:1) and T4 (SW:CD 1:1) combinations had higher macro- and micro-nutrients N, P, K, Ca, S and B than compost samples (Table 3). The treatments, T1, T3 and T4 having CD as a component showed a favorable reduction in Na levels. Earthworms survived for a longer period of >53 days in T3, whereas survival was <45 days in other treatments. Earlier reports by Tripathi and Bhardwaj [6] also indicated an increase of N, P, K amounts in the compost generated by *E. foetida* than that by microbes. Similarly, vermicomposting of sago waste also had shown a larger increase in N and P levels compared to composting [4]. Compost with C:N ratio less than 25 is considered as mature.

Table 1
Physico-chemical properties of individual wastes used in vermicomposting.

Properties	Cow dung CI		Poultry manure CII		Sago waste CIII	
	Initial	45*	Initial	45*	Initial	45*
Moisture (%)	60.10 (0.35)	57.90 (0.51)	25.70 (0.15)	26.00 (0.21)	55.00 (0.43)	60.90 (0.23)
pH	10.40 (0.11)	9.00 (0.04)	6.20 (0.01)	5.00 (0.10)	8.80 (0.09)	8.00 (0.15)
Total nitrogen (%)	2.56 (0.05)	2.50 (0.02)	3.96 (0.07)	3.97 (0.05)	0.43 (0.17)	0.34 (0.00)
Organic carbon (%)	40.20 (0.12)	40.30 (0.17)	30.00 (0.52)	30.10 (0.19)	47.80 (0.12)	47.30 (0.12)
C:N ratio	15.70 (0.34)	16.12 (0.23)	7.57 (0.62)	7.58 (0.26)	111.20 (0.27)	139.12 (0.03)
Total P (%)	2.05 (0.45)	2.12 (0.23)	1.67 (0.43)	1.70 (0.08)	0.16 (0.15)	0.11 (0.29)
Potassium (%)	2.70 (0.34)	2.90 (0.33)	1.70 (0.55)	2.20 (0.03)	1.10 (0.13)	1.70 (0.81)
Sodium (%)	0.55 (0.12)	0.45 (0.88)	0.72 (0.25)	0.65 (0.13)	0.42 (017)	0.31 (0.48)
Sulphur (mg/kg)	150 (0.23)	145 (0.48)	155 (0.85)	132 (0.22)	–	–
Calcium (%)	2.72 (0.05)	2.78 (0.08)	1.00 (0.12)	1.15 (0.23)	1.72 (0.15)	1.70 (0.08)
Boron (mg/kg)	220 (0.18)	232 (0.34)	222 (0.23)	217 (0.45)	54 (0.54)	55 (0.23)

45*: 45 days after the introduction of worms, worms could not be seen in the pots after 20 days. "–" refers to undetectable levels. Values in parentheses are standard deviation.

Table 2
Comparison of composting and vermicomposting of cow dung, sago waste and poultry manure blends.

Properties	T1 (SW:CD 3:1)		T2 (SW:PM 3:1)		T3 (SW:CD:PM 1:1:1)		T4 (SW:CD 1:1)		T5 (SW:PM 1:1)	
	T1C	T1VC	T2C	T2 VC	T3C	T3VC	T4C	T4VC	T5C	T5VC
Moisture (%)	60.9 (0.48)	70.9 (0.57)	25.0 (0.28)	25.0 (0.40)	48.3 (0.18)	50.3 (0.06)	40.7 (0.18)	59.2 (0.14)	31.2 (0.28)	31.8 (0.35)
pH	7.19 (0.02)	7.08 (0.04)	8.0 (0.01)	7.60 (0.03)	8.0 (0.04)	7.79 (0.05)	8.56 (0.06)	7.27 (0.04)	7.88 (0.05)	7.70 (0.07)
C (%)	36.2 (0.04)	25.7 (0.17)	30.0 (1.08)	25.5 (1.68)	39.0 (0.31)	25.7 (0.33)	35.0 (0.51)	29.6 (0.23)	34.9 (0.33)	34.5 (0.15)
N (%)	0.96 (0.03)	1.86 (0.01)	1.26 (0.10)	2.14 (0.01)	1.25 (0.31)	1.94 (0.01)	1.40 (0.09)	2.27 (0.01)	1.64 (0.11)	1.62 (0.02)
C:N ratio	15.70 (0.19)	13.8 (0.14)	23.80 (0.42)	11.9 (0.74)	31.2 (0.84)	13.3 (0.12)	25.0 (0.11)	13.0 (0.09)	21.28 (0.21)	21.3 (0.16)
P (%)	0.85 (0.04)	1.05 (0.02)	0.70 (0.07)	0.82 (0.02)	0.90 (0.03)	1.50 (0.03)	1.30 (0.10)	2.12 (0.01)	1.10 (0.06)	1.09 (0.02)
K (%)	2.40 (0.03)	2.71 (0.01)	1.85 (0.04)	1.90 (0.02)	2.18 (0.06)	2.56 (0.02)	2.95 (0.10)	3.62 (0.04)	3.66 (0.01)	3.60 (0.03)
Na (%)	0.60 (0.02)	0.43 (0.00)	0.87 (0.08)	0.68 (0.02)	0.61 (0.14)	0.48 (0.01)	0.40 (0.07)	0.33 (0.00)	0.86 (0.00)	0.86 (0.00)
S (mg/kg)	66.0 (0.56)	68.3 (1.67)	97.0 (0.43)	73.3 (0.58)	79.0 (0.42)	55.3 (0.33)	87.0 (0.94)	75.7 (1.20)	88.0 (0.77)	88.3 (0.88)
Ca (%)	2.70 (0.04)	3.39 (0.05)	1.34 (0.07)	2.32 (0.02)	1.72 (0.12)	2.65 (0.04)	3.10 (0.07)	3.43 (0.03)	1.20 (0.01)	1.51 (0.01)
B (mg/kg)	105 (0.67)	125 (0.88)	211 (0.55)	218 (0.58)	216 (0.89)	241 (1.20)	218 (1.56)	233 (2.03)	217 (0.34)	216 (0.33)

SW, sago waste; CD, cow dung; PM, poultry manure; T1C, compost; T1VC, vermicompost. Values in parentheses are standard deviation.

3.3. Chemical changes during vermicomposting

3.3.1. Moisture content

The moisture content of sago waste blended with cow dung at 3:1 ratio or 1:1 ratio or sago waste + cow dung + poultry manure (1:1:1) increased progressively with the progression of vermicomposting (Table 3). The moisture content of the vermicompost made from sago waste + cow dung 3:1 and 1:1 combinations had increased remarkably from 46% to 72% and 36% to 59%, respectively, at 0 and 45 days of composting. The phenomenal increase in moisture content indicated the steady progression of decomposition. The cow dung is an ideal blend for vermicompost as it accentuates microbial growth and softens the sago waste that facilitates faster eating by earthworms [6,17]. As a result, the composting process becomes rapid and the substrate turns friable and retains higher moisture content than other combinations. Conversely, the moisture content of sago waste mixed with poultry manure at 3:1 or 1:1 ratio did not alter the moisture content throughout the course of experimentation. The data indicates that blending poultry manure has little or no effect on improving the friability of the substrate which decides the moisture retention capacity.

3.3.2. pH

The pH of the sago waste with cow dung or poultry manure decreased progressively with the progression of composting process regardless of types of combinations or proportions. However, the decrease in pH was more pronounced in sago waste + cow dung (3:1) combination where the pH declined from 8.87 to 7.08 during a period of 45 days of vermicomposting. Similar trend of response was observed in sago waste + cow dung with 1:1 ratio. The decomposition process releases organic acids that neutralizes the alkalinity of the substrate and brings down the pH close to the neutral at the end of the decomposition. Even in poultry manure blended sago waste, the pH decreased with the advancement of decomposition. The data suggests that the decomposition process neutralizes the alkalinity of the sago waste similar to any other organic materials compared in the study by Garg and Gupta [3].

3.3.3. C:N ratio

The C:N ratio is the most reliable indicator of the degree of decomposition providing data to support whether the compost is ready for field application. In general, C content decreased while N content increased during the progression of decomposition regardless of treatments. However, the C:N ratio varied widely depending on the rate of decomposition. Sago waste blended with cow dung at 3:1 or 1:1 or with poultry manure (1:1:1) decreased the C:N ratio from 59 to 14, 33 to 13 and 55 to 13, respectively, during the period of 45 days of vermicomposting. Similar observation was reported on improvement in C:N ratio when vermicomposting of poultry manure with pine saw dust was attempted by Castillo et al. [9]. Despite the fact that the reduction in C:N ratio is two-third in all the three cases, the C:N ratio of T1 and T3 was nearly double as that of sago waste and cow dung 1:1 (T4) blend at the beginning but were similar at the end of the experiment. This may be attributed to the rich carbon status of the sago waste which would have contributed for the higher initial C:N ratio in sago waste: cow dung (3:1). However, earthworms decomposed the carbonaceous wastes efficiently and the C:N ratio was brought down similar to that of 1:1 blend. Cow dung was found to be the best amendment in vermicomposting process since it increases the decomposition rate [18]. This was also observed in a comparative study of different materials such as cow dung and kitchen waste, cow dung and textile sludge, and cow dung + horse manure + peat coir [6,17,19]. In the present study in all the treatments, N content increased with the progression of composting while the reverse trend was observed for C content. These data suggest that decomposition in all treatment combina-

Table 3
Temporal changes in physico-chemical properties of vermicomposting of sago waste, cow dung and poultry manure.

Parameters	T1 (SW:CD 3:1)				T2 (SW:PM 3:1)				T3 (SW:CD PM 3:1)				T4 (SW:CD 3:1)				T5 (SW:PM 3:1)			
Days	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
Moisture (%)	46.9 (0.55)	56.8 (1.21)	69.5(0.29)	70.9 (0.57)	25.3 (0.12)	26.6 (0.19)	25.4 (0.31)	25.0 (0.40)	44.7 (1.37)	47.5 (0.62)	49.6 (0.06)	50.3 (0.06)	35.7 (0.27)	42.8 (0.12)	51.7 (0.47)	59.2 (0.14)	30.9 (0.36)	31.9 (0.19)	32.6 (0.09)	31.8 (0.35)
pH	8.87 (0.11)	8.69 (0.06)	7.61 (0.33)	7.08 (0.04)	8.22 (0.04)	8.33 (0.11)	7.85 (0.03)	7.60 (0.03)	8.30 (0.13)	8.05 (0.05)	7.84 (0.04)	7.79 (0.05)	8.97 (0.07)	8.72 (0.04)	8.11 (0.06)	7.27 (0.04)	8.36 (0.13)	8.13 (0.07)	7.93 (0.03)	7.70 (0.07)
C (%)	41.5 (0.78)	38.4 (0.24)	30.4 (0.75)	25.7 (0.17)	30.4 (0.75)	29.5 (0.48)	27.8 (0.03)	25.5 (1.68)	41.9 (0.15)	36.6 (0.47)	30.7 (0.87)	25.7 (0.33)	38.7 (0.17)	36.1 (0.21)	32.6 (0.27)	29.6 (0.23)	36.1 (0.35)	35.0 (0.12)	34.6 (0.09)	34.5 (0.15)
N (%)	0.70 (0.01)	1.14 (0.01)	1.84 (0.02)	1.86 (0.01)	0.96 (0.03)	1.34 (0.02)	1.83 (0.02)	2.14 (0.01)	0.76 (0.01)	1.20 (0.01)	1.32 (0.01)	1.94 (0.01)	1.17 (0.01)	1.87 (0.01)	2.13 (0.04)	2.27 (0.01)	1.44 (0.02)	1.48 (0.01)	1.65 (0.03)	1.62 (0.02)
C:N ratio	58.8 (1.26)	33.8 (0.55)	16.6 (0.26)	13.8 (0.14)	31.7 (1.22)	22.0 (0.08)	15.2 (0.13)	11.9 (0.74)	55.3 (0.39)	30.4 (0.56)	23.2 (0.54)	13.3 (0.12)	33.2 (0.43)	19.3 (0.20)	15.3 (0.19)	13.0 (0.09)	25.1 (0.51)	23.7 (0.15)	21.0 (0.39)	21.3 (0.16)
P (%)	0.79 (0.00)	0.83 (0.01)	0.93 (0.01)	1.05 (0.02)	0.67 (0.02)	0.72 (0.01)	0.82 (0.02)	0.82 (0.02)	0.73 (0.02)	0.93 (0.01)	1.13 (0.05)	1.50 (0.03)	1.51 (0.02)	1.75 (0.03)	1.82 (0.02)	2.12 (0.01)	0.93 (0.01)	0.96 (0.00)	0.97 (0.00)	1.09 (0.02)
K (%)	2.19 (0.01)	2.20 (0.06)	2.69 (0.01)	2.71 (0.01)	1.63 (0.00)	1.69 (0.01)	1.75 (0.02)	1.90 (0.02)	1.91 (0.05)	2.19 (0.02)	2.37 (0.02)	2.56 (0.02)	2.81 (0.04)	3.30 (0.06)	3.47 (0.09)	3.62 (0.04)	3.34 (0.02)	3.41 (0.05)	3.56 (0.01)	3.60 (0.03)
Na (%)	0.69 (0.01)	0.63 (0.00)	0.55 (0.01)	0.43 (0.00)	0.90 (0.01)	0.87 (0.02)	0.79 (0.05)	0.68 (0.02)	0.60 (0.02)	0.59 (0.02)	0.53 (0.02)	0.48 (0.01)	0.47 (0.01)	0.44 (0.00)	0.41 (0.00)	0.33 (0.00)	0.90 (0.00)	0.89 (0.01)	0.86 (0.00)	0.86 (0.00)
S (mg/kg)	64.0 (1.53)	73.0 (3.00)	73.7 (2.73)	68.3 (1.67)	94.3 (2.33)	84.0 (1.15)	81.0 (0.58)	73.3 (0.88)	78.0 (0.58)	70.3 (0.88)	62.3 (1.45)	55.3 (0.33)	87.7 (1.20)	84.0 (1.15)	81.0 (0.58)	75.7 (1.20)	87.7 (0.33)	88.0 (0.58)	88.3 (0.67)	88.3 (0.88)
Ca (%)	2.32 (0.04)	2.80 (0.06)	3.10 (0.05)	3.39 (0.05)	1.82 (0.02)	1.94 (0.01)	2.13 (0.02)	2.32 (0.02)	1.61 (0.02)	1.85 (0.08)	2.53 (0.09)	2.65 (0.04)	2.87 (0.02)	3.22 (0.03)	3.47 (0.02)	3.43 (0.03)	1.36 (0.37)	1.49 (0.02)	1.31 (0.08)	1.51 (0.01)
B (mg/kg)	116 (0.88)	121 (1.76)	126 (1.15)	125 (0.88)	212 (0.33)	215 (0.33)	217 (0.33)	218 (0.58)	214 (0.33)	223 (0.88)	236 (0.88)	241 (1.20)	215 (0.33)	225 (1.45)	232 (1.45)	233 (2.03)	213 (0.33)	217 (0.67)	218 (0.33)	216 (0.33)

SW, sago waste; CD, cow dung; PM, poultry manure. Values in parentheses are standard deviation.

tions followed similar trends. C:N ratio of less than 25 is considered to be an indication of compost maturity.

3.4. Nutritional status of the vermicompost

Nitrogen content of the sago waste increased progressively during the advancement of decomposition process in all treatments except sago waste blended with poultry manure at equal proportion (1:1). The increase in N content of the organic waste during decomposition is well established [3]. Mineralization of organic N to inorganic N could have attributed to the increase of N content in all amendments. Among the combinations, sago waste blended with cow dung at 3:1 or 1:1 ratio increased the N content twice as much as that of the N content at the inception of the experiment. On the other hand, N content of poultry manure with sago waste at equal proportion (1:1) remained constant during the decomposition process which may be due to the low C:N ratio of poultry manure that favors microbial flare up.

Phosphorous content of the vermicompost increased with the advancement of decomposition [17]. The P content nearly doubled in treatment that had a combination of sago waste and cow dung under 3:1 and 1:1 ratios and 1:1:1 blend during a period of 45 days decomposition. Whereas P content showed a marginal increase in sago waste blended with poultry manure regardless of the proportions used. Potassium content increased slightly in all treatments. The K content was highest in sago waste blended with cow dung or poultry manure at equal proportions (3.3–3.6%). This observation is contradictory to the vermicomposting of the textile mill sludge mixed with cow dung [17], in which total K was lower in final cast than the initial feed mixture. However, vermiconversion of sugar mill sludge by *E. foetida* has shown increase of N, P and K when amended with biogas plant slurry [20]. Sodium content remained unchanged in all treatment combinations.

Sulphur content of vermicompost made out of sago waste, cow dung and poultry manure at 1:1:1 ratio linearly decreased from 78 to 53 mg/kg during 45 days decomposition. Such a conspicuous decline was also observed in sago waste + poultry manure (3:1). This may be associated with intensive microbial load and activity. On the other hand, sulphur content of the sago waste and cow dung at 3:1 ratio was unaltered during the process of vermicomposting.

Calcium content of treatments containing sago waste and cow dung at different proportions increased steadily during the composting process. The sago waste, cow dung (3:1), sago waste cow dung (1:1) sago waste cow dung and poultry manure (1:1:1) had increased Ca contents to the tune of 64%, 46% and 30%, respectively. This is obvious that the substrate blended with cow dung and poultry manure increased the feeding ability of the earthworms which favorably enhanced the Ca content of the vermicompost during decomposition [17]. In contrast, sago waste poultry manure (1:1) proportion showed a small increase in Ca content indicating a need for cow dung mixing to promote feeding behavior of earthworm [21].

Boron content of the vermicompost increased in all the treatments irrespective of the proportions of cow dung or poultry manure mixed with sago waste. The increase in boron content is pronounced in the 1:1:1 treatment of sago waste, poultry manure and cow dung than others.

4. Conclusion

The present study on the feasibility analysis of vermicomposting sago industry solid waste by *Eisenia foetida* has clearly indicated that sago waste could be converted to valuable manure with desirable C:N ratio and high nutritional status in a short period of time. Vermicomposting yielded better quality compost than composting.

Among the various amendment combinations, 1:1:1: ratio of sago waste, cow dung and poultry manure gave the best result in terms of macro- and micro-nutrients and C:N ratio.

Acknowledgement

The authors wish to thank the Management of PSG College of Technology, Coimbatore, India for providing all the facilities to complete this study successfully.

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