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Biomanagement of sago bagasse with biogas plant slurry using an indigenous earthworms *Perionyx ceylanensis* Mich. and *Lampito mauritii* (Kinberg) for nutrients recovery

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ABSTRACT

This paper reports the recycling of nutrients by vermicomposting of sago bagasse (SB) and biogas plant slurry (BPS) using indigenous earthworms Perionyx ceylanensis Mich. and Lampito mauritii (Kinberg). A total of twelve vermicomposting treatments were established for both worms and dynamics of physic-chemical parameters has been studied for 84 days (12 weeks). The waste mixture containing VT4, VT5 and VT6 for P. ceylanensis and VT10, VT11 and VT12 for L. mauritii had better fertilizer value among studied treatments. At the end of experiment (after 84 day), vermicomposts showed significant decrease in pH and total organic C but increase in total Kjeldhal N, total P and total K, Ca, Mg and Na contents for both worms. The C: N ratio of final vermicomposts also reduced to 11.4±0.19 - 22.6±0.52 for P. ceylanensis and 14.4±0 .29 – 26.5±0.41 for L. mauritii from 63.4±5.2 – 87. 5±4.5 in different vermicomposting treatments. The results revealed that SB could be converted into good quality fertilizer by vermicomposting if mixed in proper ratio (up to 60%) with BPS. Among the two species of worms, P. ceylanensis exhibits better nutrients recovery rate than L. mauritii.

Key words: sago bagasse, nutrient changes, vermicomposting, *P. ceylanensis, L. mauritii.*

INTROUCTION

Biological management of organic solid waste have been widely recognized as the most efficient, sustainable and environmentally friendly methods for converting into hygienically safe and valuable products [1]. In terms of its economical costs and simple process, composting and vermicomposting was used widely, especially in developing countries and these technologies are emerging quickly valuable tools in pollution prevention and control. Moreover, with regard to the concerns on global warming, composting and vermicomposting is playing a major role. Nevertheless, the optimization of the biological methods for decentralized systems still needs to be investigated more [2]. Thus, what is need for the existing condition is an innovative method of recycling of organic wastes to produce organic manure at a minimum time in a minimum space and at minimum cost.

Sago is a common edible starch in the form of globules is obtained by processing the tubers of tapioca. India acquires significance in the universal tapioca scenario due to its highest productivity in the world. Similarly within India, Tamil Nadu stands first in respect of processing of tapioca into sago and starch throughout the nation, meeting about 80% of country's demand. Sago industry is one of the major small scale sectors in India with more than 800

sago starch units located in Salem District of Tamil Nadu and the processing of sago generates enormous quantities of biodegradable solid and liquid wastes which are highly organic, foul smelling and acidic in nature [3]. Sago waste is a rich fibrous residue and it is usually disposed of subsequent to the extraction of starch from the sago trunk. Cecil (2002) [4] reported that every 100kg of sago starch in pith, about 10kg of sago bagasse (hampas) is generated, and this sago bagasse are likely to be discarded into rivers or open dumps without any facilities for waste management and this practice may cause soil and water pollution. Therefore, appropriate technologies, which are environmentally viable and economically feasible, are needed for efficient management of sago bagasse. The proper handling and management of sago bagasse can supplement or replace purchased commercial fertilizers [5]. According to our knowledge, very limited information is available about the bioconversion of sago bagasse into nutrient rich manure in short period of time.

Biological stabilization of solid organic wastes through composting and vermicomposting are the best-known processes. Bioconversion of organic wastes using earthworms is as a bio-oxidative process in which earthworms interact intensively with bacteria, fungi, actinomycetes and other fauna within the decomposer community, accelerating the stabilization of organic residue and modifying its physico-chemical and biological properties. Therefore, there is a pressing need to find cost effective alternative method of shorter duration. In this regard, vermicomposting of organic wastes using earthworms is one of the latest techniques for the recycling of organic wastes and it is a viable, cost effective, eco-friendly and efficient method for waste management and manure production as suggested by many researchers [6, 7, 8]. Hence, vermicomposting constitutes a useful technique to convert organic wastes into valuable products with different applications, including the development of soil fertility and the suppression of certain phyto-pathogens [9]. With this background, in the present study were performed to investigate the role of epigeic species *Perionyx ceylanensis* Mich. and anecic species *Lampito mauritii* (Kinberg) in bioconversion of sago bagasse amended with biogas plant slurry and its utilization into nutrient rich fertilizer.

MATERIALS AND METHODS

Earthworm cultures: Two native species of earthworms *Perionyx ceylanensis* and *Lampito mauritii* were chosen for this experiment and both worms were cultured in the laboratory, department of zoology, Annamalai University, Tamilnadu, India and were randomly picked for experimentation.

Sago bagasse and biogas plant slurry: The sago bagasse (SB) was collected from a sago factory in Salem, Tamil Nadu (India). The digested biogas plant slurry (BPS) was obtained from the storage tank of an on-farm biogas plant in Faculty of Agriculture, Annamalai University. The SB was mixed with BPS in different proportions (Table 1). The initial properties of SB and BPS are reported in Table 2.

Treatment design: Cement tanks measuring 30cm height, 60cm length and 45cm width were used. Each vermicomposting treatment consisted of six replicates with 5kg of feed materials for both species of worms. The tank were kept under shade and irrigated with necessary quantity of water on alternate days to ensure that the substrate moisture content and was maintained at approximately 70% [8]. After the completion of pre-composting period of 14 days, 100 un-clitellated hatchlings of both worms were randomly picked from stock culture and introduced in each vermicomposting treatment. From vermicomposting treatments samples were drawn at 0 day (initial) and after 84 days (final) for the analysis of pH, total organic carbon, total Kjeldhal N, total P, total K, total Ca, Mg, Na and C: N ratio. 0 days refers to the day of inoculation of earthworms after pre-composting of 14 days.

Nutrient analysis: Double distilled water was used for analytical work. All the samples were analyzed in triplicate and results were averaged. The pH was determined using a double distilled water suspension of each sample in the ratio of 1:10 (w/v). Total organic carbon (TOC) was measured using the method of Walkley and Black [10], total Kjeldhal nitrogen (TN) by micro Kjeldahl digestion and total phosphorus (TP) using molybdenum blue method of Olsen et al, 1954 [11]. Total potassium (TK), calcium (Ca), sodium (Na) and magnesium (Mg) were measured by a Perkin Elmer 2380 Atomic Absorption Spectrophotometer and DR-3000 Spectrophotometer. One gram of the sample was digested with a mixture of nitric, sulphuric and precholric acid (3:1.5:2 by volume) at 100°C. The solution was filtered through Whatman filter paper (No.40) for further estimation. C: N ratio was calculated from the measured value of C and N. All the results reported in the text are the mean of six replicates. One-way ANOVA was used to analyze the significant differences among different vermicomposting treatments for studied parameters. The probability levels used for statistical significance were $P < 0.05$ for the tests.

RESULTS AND DISCUSSION

The native earthworm's *P. ceylanensis* and *L. mauritii* in vermicomposting process alter the physico-chemical properties of the waste materials. The final vermicomposts were granular, odour free, darker and homogeneous when compared to initial substrate. The nutrient value of obtained vermicompost depends on several factors viz., nature of feed substrate, aeration, moisture, temperature and earthworm species used in the experiment. Therefore, it is essential to specify various physico-chemical characteristics to measure the dynamics of vermicomposting process. The physico-chemical characteristics of the initial feed mixtures and vermicomposts of different vermicomposting treatments (after 84 day) are given in Table 3-11. In the present study, the total organic carbon (TOC) decreased in all the vermicomposting treatments including SB alone treatment after vermicomposting (Table 4) for both species of worms. However, maximum decrease in TOC was recorded in VT4, VT5 and VT6 for *P.ceylanensis* and VT10, VT11 and VT12 for *L. mauritii*, respectively. The loss in TOC during vermicomposting earthworms promoted suitable microclimatic conditions and combined action earthworms and microorganisms in the treatments that increased the loss of TOC from substrates through microbial respiration. Similar observations have been reported by Prakash and Karmegam (2010) [12] during vermicomposting of agro industry waste. In the present study, Total Kjeldhal nitrogen (TKN) content in the vermicomposts was higher than initial waste mixture and total nitrogen (TN) content of the substrates increased progressively during the development of degradation in VT4, VT5 and VT6 for *P. ceylanensis* and VT10, VT11 and VT12 for *L. mauritii*, than other treatments (Table 5). The difference in TKN content of vermicomposts was significantly different from each other *($P < 0.05$)*. The increase in TN content of the organic waste during decomposition is well recognized [13]. Mineralization of organic N to inorganic N during decomposition could have attributed to the increase of N content in the amendments [14].

Table 1. Initial physico chemical properties of sago bagasse and biogas plant slurry

Property	Sago bagasse	Biogas plant slurry
pH	5.2±0.07	7.9±0.06
TOC (g kg^{-1})	472.7±32	407.5±21
TN (g kg^{-1})	5.4±0.13	6.9±0.21
TP (g kg^{-1})	4.7±0.11	5.8±0.15
TK (g kg^{-1})	3.2±0.21	4.3±0.11
Ca (g kg^{-1})	1.2±0.06	2.1±0.09
Mg (g kg^{-1})	1.5±0.04	1.1±0.05
Na (g kg^{-1})	1.5±0.06	1.4±0.03
C/N	87.5±4.5	59.1±2.5

All values are mean of six replicates

Table 2. Treatment proportion of sago bagasse and biogas plant slurry

Vermicomposting treatments	Substrate Proportion
P.ceylanensis	
VT1	SB (100%) + BPS (0%)
VT2	SB (0%) + BPS (100%)
VT3	SB (80%) + BPS (20%)
VT4	SB (60%) + BPS (40%)
VT5	SB (40%) + BPS (60%)
VT6	SB (20%) + BPS (80%)
L.mauritii	
VT7	SB (100%) + BPS (0%)
VT8	SB (0%) + BPS (100%)
VT9	SB (80%) + BPS (20%)
VT10	SB (60%) + BPS (40%)
VT11	SB (40%) + BPS (60%)
VT12	SB (20%) + BPS (80%)

VT-Vermicomposting treatment; SB- Sago bagasse; BPS - Biogas plant slurry. The figures in parenthesis indicate the percent content in the initial substrate.

Table 3: pH of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	6.1±0.05	5.6±0.03	5.6±0.07
VT2 andVT8	8.1±0.06	6.9±0.06	6.7±0.05
VT3 andVT9	7.5±0.03	6.2±0.02	6.0±0.05
VT4 and VT10	7.8±0.06	5.9±0.09	6.0±0.06
VT5 and VT11	7.9±0.04	6.9±0.05	6.8±0.07
VT6 and VT12	8.2±0.05	6.7±0.04	6.6±0.05

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 4: TOC (gkg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	472.7±15	319.5±17	331.6±11
VT2 andVT8	407.5±21	261.8±16	275.7±15
VT3 andVT9	461.4±18	305.7±24	321.3±12
VT4 and VT10	451.5±15	252.4±16	265.5±19
VT5 and VT11	430.8±27	245.8±22	258.3±23
VT6 and VT12	423.5±18	247.6±18	261.7±12

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 5: TN (gkg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE).

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	5.4±0.13	14.2±0.08	12.5±0.11
VT2 andVT8	6.9±0.21	18.5±0.22	16.8±0.31
VT3 andVT9	5.7±0.42	16.8±0.13	14.9±0.17
VT4 and VT10	6.1±0.37	20.4±0.23	18.4±0.20
VT5 and VT11	6.4±0.21	20.9±0.19	18.0±0.34
VT6 and VT12	6.8±0.19	21.7±0.28	18.1±0.19

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 6: C:N ratio of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	87.5±4.5	22.6±0.52	26.5±0.41
VT2 andVT8	59.1±2.5	14.5±0.33	16.5±0.27
VT3 andVT9	81.5±7.2	18.2±0.35	21.6±0.51
VT4 and VT10	74.9±3.4	12.4±0.29	14.4±0.34
VT5 and VT11	68.4±5.5	11.8±0.21	14.4±0.29
VT6 and VT12	63.3±5.2	11.4±0.19	14.5±0.42

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 7: TP (g kg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	5.4±0.13	9.1±0.15	8.2±0.06
VT2 andVT8	6.9±0.21	14.3±0.25	14.1±0.17
VT3 andVT9	5.1±0.17	12.7±0.27	12.2±0.19
VT4 and VT10	5.9±0.23	16.1±0.19	15.4±0.22
VT5 and VT11	6.2±0.31	16.3±0.41	15.4±0.31
VT6 and VT12	6.6±0.19	16.2±0.27	15.5±0.19

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

The decrease in C: N ratio was rapid and it showed a more or less stabilized pattern up to day 84 (Table 6). In the present study, decline of C:N ratio to less than 20 at the end in the treatments indicates an advanced degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes [15]. The decrease in C: N ratio and relative increase in the TKN of vermicomposts may also be due to the loss of dry mass in terms of CO_2 as well as moisture loss by evaporation during vermicomposting [16]. Similarly, after vermicomposting TP content was highest in VT4, VT5 and VT6 for *P.ceylanensis* and VT10, VT11 and VT12 for *L. mauritii*, respectively (Table

7). Increase in TP during vermicomposting is probably through mineralization and mobilization of phosphorus by bacterial and phosphatase activity of both earthworms [17]. The TK content was also greater in all the vermicompost at the end than initial mixture and SB alone treatment (Table 7). However, the maximum increase in TK was higher in VT4, VT5 and VT6 for *P. ceylanensis* and VT10, VT11 and VT12 for *L. mauritii*, respectively (Table 8). According to Barois and Lavelle [18] earthworm primes it's symbiotic gut microflora with secreted mucus and water to increase their degradation of ingested organic matter and the release of assailable metabolites. Therefore, directly or indirectly earthworm enriches the substrate material with exchangeable-K during vermicomposting. Likewise, Ca, Mg and Na content of vermicomposting treatments containing SB and BPS at different proportions increased steadily during the vermicomposting process than initial substrates (Table 9-11). This is obvious that the substrate (SB) blended with BPS increased the feeding ability of the both worms which favorably enhanced the Ca, Mg and Na content of the vermicompost during decomposition of SB [1]. The weight and volume reduction due to mineralization and decomposition of organic matter during vermicomposting may be the reasons for increase in Ca, Mg and Na concentrations in vermicomposts [19].

Table 8: TK (g kg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments using *P. ceylanensis* (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	3.2±0.21	6.5±0.23	5.7±0.22
VT2 andVT8	4.3±0.11	8.2±0.42	7.6±0.27
VT3 andVT9	3.5±0.24	8.9±0.35	8.5±0.08
VT4 and VT10	3.8±0.18	9.5±0.16	9.1±0.15
VT5 and VT11	3.9±0.19	10.1±0.41	9.6±0.22
VT6 and VT12	3.9±0.27	10.4±0.19	9.6±0.17

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 9: Ca (g kg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	1.2±0.06	1.9±0.02	1.6±0.02
VT2 andVT8	2.1±0.09	2.9±0.04	2.9±0.05
VT3 andVT9	1.3±0.05	2.3±0.05	2.2±0.03
VT4 and VT10	1.5±0.07	3.1±0.04	2.8±0.04
VT5 and VT11	1.3±0.05	3.1±0.06	2.8±0.05
VT6 and VT12	1.8±0.11	3.1±0.04	2.9±0.06

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 10: Mg (g kg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	1.5±0.04	2.0±0.09	1.8±0.05
VT2 andVT8	1.1±0.05	1.9±0.02	1.9±0.04
VT3 andVT9	1.4±0.07	2.2±0.08	2.0±0.06
VT4 and VT10	1.3±0.03	2.6±0.04	2.3±0.05
VT5 and VT11	1.2±0.05	2.7±0.07	2.5±0.06
VT6 and VT12	1.2±0.02	2.7±0.05	2.5±0.04

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

Table 11: Na (g kg^{-1}) of initial substrate and vermicompost obtained from different vermicomposting treatments (mean ± SE)

Vermicomposting treatments	Initial substrate (0 day)	Final Vermicompost (after 84 days)	
		P. ceylanensis	*L.mauritii*
VT1 and VT7	1.5±0.06	2.0±0.15	1.8±0.09
VT2 andVT8	1.4±0.03	2.3±0.11	2.0±0.06
VT3 andVT9	1.4±0.05	2.5±0.09	2.1±0.11
VT4 and VT10	1.1±0.03	2.7±0.17	2.3±0.23
VT5 and VT11	1.4±0.05	2.9±0.08	2.3±0.27
VT6 and VT12	1.4±0.02	3.0±0.21	2.5±0.19

VT1 to VT6 - P. ceylanensis; VT7to VT12- L.mauritii; All values are mean and standard deviation of six replicates.

CONCLUSION

This work was undertaken to explore the use of vermicomposting technology in sago factory waste (sago bagasse) management. Various combinations of SB with BPS were vermicomposted using native earthworm's *P. ceylanensis* and *L. mauritii* and the vermicompost quality were estimated in different vermicomposting treatments. The final vermicomposts was rich in important plant nutrients (nitrogen, phosphorus and potassium) and their C:N ratio was below 20 which indicate their agronomic importance. The quality of initial feed substrates determined the nutrient content of vermicomposts prepared after vermicomposting. The results revealed that vermicompost can be introduced as one of the technologies for converting SB into nutrient rich products. Among the two indigenous species of worms, *P. ceylanensis* exhibits better nutrients recovery rate than *L. mauritii*.

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