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Investigation on paper cup waste degradation by bacterial consortium and *Eudrillus eugeinea* through vermicomposting

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ABSTRACT

Disposable Paper cups are a threat to the environment and are composed of 90% high strength paper with 5% thin coating of polyethylene. This polyethylene prevents the paper cup from undergoing degradation in the soil. Hence, in the present study two different approaches towards the management of paper cup waste through vermicomposting technology has been presented. The experimental setup includes 2 plastic reactors namely Vermicompost (VC) (Cow dung + Paper cup waste + Earthworm (*Eudrillus eugeinea*)) and Vermicompost with bacterial consortium (VCB) (Cow dung + Paper cup waste + *Eudrillus eugeinea* + Microbial consortia such as *Bacillus anthracis, B. endophyticus, B. funiculus*, *B. thuringiensis*, *B. cereus*, *B. toyonensis*, *Virigibacillius chiquenigi*, *Acinetobacter baumanni* and *Lactobacillus pantheries*). After treatment the physicochemical parameters were analysed. The results showed that the values of TOC (26.52 and 37.47%), TOM (36.01 and 33.13%) and C/N (15.02 and 11.92%) ratio are reduced in both VC and VCB whereas, the values of pH (8.01 and 7.56), EC (1.2–1.9 μs^{-1} and 1.4–1.9 μs^{-1}), TP (46.1 and 51%), TMg (50.52 and 64.3%), TCa (50 and 64%), TNa (1.39 and 1.75%) and TK (1.75 and 1.86%) have increased. This study substantiates the addition of the microbial consortia augmenting the degradation in VCB reactor by reducing the period of process from 19 to 12 weeks. Further the characterisation of the vermicompost prepared from paper cup with FT-IR shows high degradation of carboxylic and aliphatic group; SEM analysis shows the disaggregation of cellulose and lignin; XRD shows the degradation of cellulose. All these analyses endorse the degradation of the paper cup waste faster with microbes (VCB). Thus, this present study high lights management of the paper cup waste in a relatively short period of time.

1. Introduction

Disposal of solid waste is a major environmental issue all over the world. Particularly, urban India is facing this problem in a serious manner. India generates about 1, 88, 500 tonnes of municipal solid waste per day (Prashant, 2013). Without an effective and efficient solid waste management program, the waste generated from various human activities, both industrial and domestic could result in health hazards and could lead to the negative impact on the environment. Recently, post-consumer waste is seen to be a major component in many landfill sites, accounting for about 35% by weight of municipal solid waste (US-EPA, 2005). In order to overcome this problem, appropriate measure should be taken to minimize the waste generation. One of the best ways to reduce the generation of the waste is by recycling the discarded material in a safe, efficient, environmentally sound and cost effective manner.

Post consumer waste is a type of waste produced by the end consumer. In other words, the waste which gets generated does not involve in the production of another product (Karthika et al., 2014). Among the post consumer waste, paper cup becomes a widely used commodity all over the world. Though paper is recyclable, paper cups are coated with polyethylene plastic to prevent damage of the cups from hot beverages. A recent survey reveals that, consumption of paper cup in the country is around 1 Crore per day (Think beyond world, 2013). By this way paper cups generate about 253 million pounds of solid waste per year (Whirley, 2008). Unfortunately, these paper cups were reported to be very complicated to recycle. The polyethylene terephthalate (PET) coated inside the paper cups prevents the cups from being recycled or degraded (Bijayani et al., 2013). While trying to recycle the paper cup waste, it is true that the process will lead to several

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complications. Times of India, Bangalore, 2008 reported that for recycling 6000 paper cups, around 12 trees, 26,000 litres water, 1750 litres of oil were required which would create 250 kg of air pollutants thereby consuming 4100 kilo watts hours of energy. Moreover the recycling process was unable to separate the polyethylene lining. So, without proper disposal the paper cups end up in landfill and get eventually decomposed by releasing greenhouse gas. Hence, it is worthwhile for researches to pay attention on managing the paper cup waste generation.

To get control over the critical issue, we have opted vermicomposting technology for managing the paper cup waste generation. Vermicomposting involves the bio oxidation and stabilization of organic matter through joint action of earthworms and microorganisms to transform its physicochemical and biochemical properties (Dominguez, 2004). It is an ecofriendly, cheap and rapid technique suitable for Indian conditions (Amit et al., 2013). Nevertheless disposing the solid waste by land filling and open burning leads to air and soil pollution. Vermicomposting is an established field in waste management, converting the waste into high quality organic fertilizer. This process is performed in an aerobic environment with optimum biological activity and symbiotic interaction between earthworm and microorganism (Katrina et al., 2014). In a recent study, it was reported that vermicomposting of paper cup waste using earthworm required 19 weeks for conversion into a nutrient rich and stable product (Karthika et al., 2015). Vasanthy et al. (2017) results demonstrate that the microorganisms present in the vermicompost of paper cup wastes were effective in cellulase degradation and it can be used to reduce the period required for the degradation of paper cup waste. The focal theme of the present investigation is to enhance degradation by the addition of microbial consortia to the earthworm *Eudrillus eugenia* thereby reducing the period needed for the completion of the process.

2. Materials and methods

The paper cup waste was collected from Bharathidasan University campus (10.6°N and 78.74°E), Trichy, India. The epigeic earthworm *Eudrillus eugeinea* was obtained from Periyar Maniyammai University, Thanjavur, Tamil Nadu, India.

2.1. Experimental set up

The experiments were carried out in 2 circular plastic containers (diameter 40 cm, depth 9 cm) with the capacity of 2 kg waste in each. The media was formulated as below (i) VC – Cow dung (500 g) + paper cup waste (500 g); (ii) VCB – Cow dung (500 g) + paper cup waste (500 g) + microbial consortium – (One ml of each bacterial culture (10^4 CFU/mL) were inoculated into 50 ml of nutrient broth. Then the 50 ml of overnight consortium was inoculated into the substrate). Initially, the medium alone was turned over manually every day for 15 days in order to make the paper cup waste suitable for earthworms after pre-decomposition period, 50 non-ciliated earthworms were introduced into VC and VCB. Based on cellulose degradation, 50 ml broth containing consortia of nine bacterial strains such as *Bacillus anthracis* (KM289159), *Bacillus endophyticus* (KM289167), *Bacillus funiculus* (KM289165), *Virigibacillius chiquenigi* (KM289163), *Bacillus thuringiensis* (KM289164), *Bacillus cereus* (KM289160), *Bacillus toyonensis* (KM289161), *Acinetobacter baumanni* (KM289162) and *Lactobacillus pantheries* (KM289166) (Karthika et al., 2015) were added to the VCB once in 15 days until the completion of experiment. The moisture content was maintained at 60–80% throughout the study period by periodic sprinkling of milli Q water. Sample triplicates were prepared for further analysis.

2.2. Chemical analysis

The experiment was conducted for 90 days; sample was taken once in 4 weeks for analysis. pH was determined by the digital pH meter (ELICO-L1162) and Electrical conductivity (EC) was studied by conductivity meter (ELICO-180). Total organic carbon (TOC) was analysed (Walkely and Black, 1934) and Total Kjeldahl nitrogen (TKN) by micro kjeldahl method. Total Potassium (TK), Total Phosphrous (TP), Total Calcium (TCa), Total Magnesium (TMg), Total Organic Matter (TOM) and Carbon and Nitrogen (C/N) ratio were analysed (Tandon, 2009).

2.3. Statistical analysis

The experiments were carried out in 2 circular plastic containers (diameter 40 cm, depth 9 cm) with the capacity of 2 kg waste in each. Three replicates of each container were used. Physico chemical data were obtained from three replicates. The data were subjected to statistical analysis such as one way ANOVA and Pearson correlation coefficient (SPSS Inc version 16.0). The significant difference between the parameter values of each sample groups was tested.

2.4. Fourier Transform-Infrared (FT-IR) spectroscopy

The vermicomposts samples are dried at room temperature for overnight. Accurately 2 mg of finely ground vermicompost sample was mixed with 400 mg of Potassium bromide (KBr) and was compressed under vacuum for 10 min. The FT-IR spectra were then recorded on KBr pellets between 4000 and 400 cm^{-1}, at a rate of 16 nm/s, using a PerkinElmer 1600 FT-IR spectrophotometer. Precautions were taken to avoid moisture uptake (Rajiv et al., 2013). The FT-IR spectra of paper cup (PC), Vermicompost (VC) and Vermicompost with microbial consortia (VCB) were compared.

2.5. X-ray diffraction method

X-ray diffraction patterns of the sample were analysed using X PERT PRO DIFRACTROMETER system (Sartaj, 2014). The molecular organization of samples such as C1 – cellulose, P1 – paper cup, VC and VCB were compared. The resulting diffraction patterns exhibited peaks with reference to 2θ (Scattering angle) from 10 to 4.

2.6. Scanning electron microscopy

The Paper cup and the final dried vermicompost samples of both VC and VCB were coated with gold for the clear visibility of the image, then the surface morphology was recorded using VEGAS 3 TESCAN electron microscope at 500× magnification (Eldho et al., 2012).

3. Result and discussion

The data represents the variation in physicochemical parameters pH, Electrical conductivity (EC), Total Organic Carbon (TOC), Total Organic Matter (TOM) and C/N ratio Total Phosphorus (TP), Total Magnesium (TMg), Total Calcium (TCa), Total Sodium (TNa) and Total Potassium (TK) of VC and VCB (Figs. 1–4).

3.1. Variation of pH

According to Lim et al. (2011), changes in the pH of the vermicompost are dynamic and substrate dependent. In our study, slight increase in the pH values was observed in both VC and VCB. pH ranged between 6.18 and 8.01 in VC and 6.14 and 7.56 in VCB