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Potential of domestic biogas digester slurry in vermitechnology

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A R T I C L E I N F O

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A B S T R A C T

This work illustrates the potential of domestic biogas digester slurry in vermicompost production. To achieve the objectives biogas plant slurry (BGS) was mixed with crop residues (CR) in different ratios to produce seven different feed mixtures for earthworm *Eisenia fetida*. After 15 weeks vermicomposted material was analyzed for different chemical parameters. In all waste mixtures, a decrease in pH, organic C and C:N ratio, but increase total N, available P and exchangeable K was recorded. C:N ratio of end material (vermicompost) was within the agronomic acceptable limit (<20). The reproduction biology of *E. fetida* in different waste mixture was also monitored and they showed excellent biomass gain as well as cocoon production in all waste mixtures. The results clearly suggested that vermitechnology could be a potential technology to convert byproducts of domestic biogas plant slurry into some value-added products.

1. Introduction

The decline in soil fertility and productivity due to excessive soil erosion, nutrient run-off, and loss of soil organic matter has stimulated interest in improving overall soil quality by the addition of organic matter (Bastian and Ryan, 1986). Soil fertility level and soil organic structure in natural systems are maintained over time through organic matter addition from litter fall and root mortality. However, in agro-ecosystems conventional seed-based practices such as tillage and crop biomass removal can result in deterioration of soil structure and the loss of soil organic matter. The application of organic matter in the form of plant residues has long been known to improve the properties of soils, especially soil organic matter. The organic matter accumulation in soils can be enhanced by such farming techniques including zero tillage, organic farming, maintenance of permanent grassland and cover crops, mulching, manuring with green legumes, application of farmyard manure, compost, vermicompost, strip cropping and contour farming (Roldan et al., 2005). Among these various techniques, the transformation of organic waste (sewage sludge, green waste, industrial sludge, urban community wastes and livestock excreta) to compost or vermicompost is becoming increasingly popular across the world, thus reducing the use of artificial fertilizers, and the amount of waste added to landfill sites (Suthar, 2008a). It is interesting that each year, human, livestock and crops produce approximately 38 billions metric tonnes of organic waste worldwide, which may be an efficient source of organic matter supply in soils.

This huge quantity of organic wastes, generated from different sources, can be converted into nutrient-rich bio-fertilizer (vermicompost) for sustainable land restoration practices. The vermicomposting is stabilization of organic material through the joint action of earthworms and microorganisms. While, 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. Earthworm's foregut acts as mechanical blenders and modifies the physical status of ingested organic wastes and consequently increases the surface area for digestive enzyme actions. In earthworm, the gut-associated-microbes provide several essential enzymes (exogenous) required for rapid digestions of ingested organic fractions. Moreover, the biological mutuality between earthworms and microflora produce a significant change in biological, physical and chemical characteristics of vermibeds. The egested material (worm cast or vermicompost) attracts detritus microbial communities (bacteria, fungi, actinomycetes, nematodes, microarthropods etc.) due to greater availability of forms of nutrients. The further mineralization of nutrients is carried out by microbial communities associated with freshly deposited worm casts. According to Loehr et al. (1985) in vermicomposting system earthworms maintain aerobic conditions in the organic wastes, ingest solids, convert a portion of the organics into worm biomass and respiration products, and expel the remaining partially stabilized product i.e. vermicompost. They suggested that the process is a function of (a) the portion of waste that is biodegradable, (b) maintenance of aerobic conditions and (c) the avoidance of toxic conditions. The vermicomposting produce a better quality product than traditional composting system in terms of nutrient availability (Vivas et al., 2009; Suthar, 2009a, 2010). On

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the other hand vermicomposting process often results in mass reduction, shorter time for processing and high levels of humus with reduced phytotoxicity in ready material than conventional composting systems. There are several successful examples of utilizing potential of earthworms in stabilizations of anthropogenic wastes generated from different industries (Loehr et al., 1985; Suthar, 2008a, 2010; Sangwan et al., 2008).

Biogas is produced by anaerobic digestion of animal wastes, which is used for domestic purposes. In agriculture-based countries around the world, biogas is produced in household reactors known as biogas digesters to provide energy for lighting and cooking. Millions of people, especially farmers, have benefited from this technology and its popularity is ever growing (Gautam et al., 2009). According to a rough estimation there are thought to be about 2.5 million household and community biogas plants installed around India. For commercial biogas production in India, cattle waste (dung) is the prime source. A considerable amount of biogas slurry is produced in biogas digesters. The spent biogas slurry (BGS) is a semi-liquid form of digested material in biogas digesters, which is, stabilized material with a variety of chemicals. In India, the majority of domestic biogas production units lack proper utilization of slurry from post methanation subunit. It is often deposited openly at nearby places of biogas unit, which later becomes an active breeding site for disease vector insects. The higher moisture content in freshly deposited slurry often attracts house flies to deposit eggs. In some cases dried or partially dried biogas slurry is used as manure for crop lands. Although, it can be utilized effectively as organic C pool in arable soils but low contents of NPK limits its potential use as bio-fertilizer in cropping system. On the other hand biogas slurry may be a potential source of earthworm culture due to containing easy digestible and assimilated carbohydrates and proteins. Nevertheless, the biogas slurry needs to be mixed with some plant nutrient-rich materials prior to using as substrate for vermiculture/vermicomposting. Crop residues appeared as potential source of earthworm feed and quality vermicompost production (Suthar, 2007, 2009b). In general, a great proportion of the crop nutrient input during cultivation returned in the form of the plant residues. Estimation showed that 30–35% of applied N and P and 70–80% for K remained in the crop residues of food crops (Suthar, 2008b). Such nutrient-rich crop residues must be processed biologically before they are used as a fertilizer and earthworm seems an appropriate candidate for this process.

The objective of the present paper is to produce nutrient-rich bio-fertilizer (vermicompost) and earthworm biomass from BGS spiked with different crop using earthworm *Eisenia fetida* (Savigny). The importance of bulky material types on waste minimizing and earthworm production rate was also monitored, which has not been studied extensively in previous studies.

2. Methods

2.1. Earthworm and organic waste collection

Composting earthworm *E. fetida* (Savigny) were obtained from stock culture maintained in the laboratory. Stock earthworms were cultured on partially decomposed cow dung.

The chopped straw of wheat, fresh sugarcane trash and dried and chopped guar bran were procured from a local agriculture farm, Sri Ganganagar, India. The bio-digested effluent (BGS) was obtained from a domestic cattle-dung-based biogas production unit situated in Sri Ganganagar, India. Fresh BGS (containing approximately 78% moisture) was collected in large-sized plastic containers and brought to the laboratory. BGS was slightly dried in air at room temperature 28 °C (SD = 0.4). The chemical characteristics of crop residues i.e. wheat straw, sugarcane trash and guar bran and fresh biogas slurry are given in Table 1.

2.2. Preparation of vermibeds and composting trial

Crop residues were air-dried and chopped. The air-dried BGS was thoroughly homogenized and mixed to obtain a powder form of it. Dried BGS was mixed with wheat straw (WS), sugarcane trash (SCT) and guar bran (GB) in different ratio (vol:vol) in order to produce following vermibeds:

(1) BGS – pure biogas slurry.
(2) BGS: WS-I – 1 part biogas slurry: 1 parts wheat straw.
(3) BGS: WS-II – 1 part biogas slurry: 2 parts wheat straw.
(4) BGS: SCT-I – 1 part biogas slurry: 1 part sugarcane trash.
(5) BGS: SCT-II – 1 part biogas slurry: 2 parts sugarcane trash.
(6) BGS: GB-I – 1 part biogas slurry: 1 part guar bran.
(7) BGS: GB-II – 1 part biogas slurry: 2 parts guar bran.
(8) Mixed-CR: BGS – 1 part mixed crop residues: 2 parts biogas slurry.

One treatment was composed of pure BGS (No. 1). Eight large-sized plastic containers (200 × 150 × 75 cm) were filled with bedding materials (one for each mixture). Ten kilogram of waste mixtures (dry weight basis) was put in container for 3 weeks for initial composting (thermal stabilization, initiation of microbial degradation and softening of waste mixture). Appropriate moisture (65%) was maintained during this period by periodically sprinkling of an adequate quantity of water. The waste mixture in different bedding was turned out periodically (after 3 days) for aeration and to remove odor from decomposing wastes. After 3-weeks composting, one kilogram (on dry weight basis) composted material was separated from each waste mixture type and filled in plastic circular containers of appropriate size (28 cm diameter and 30 cm in depth) for further vermicomposting experimentations. The experimental beddings were kept in triplicate for each treatment, and the control treatment had the same setup without earthworm. For laboratory screening earthworms (4-weeks old) having individual live weight of ≈256–278 mg were collected from the stock and 20 were released into each experimental container. The moisture content was maintained at 70–75%, throughout the study period by periodic sprinkling of adequate quantity of tap water. The containers were placed in a humid (70–80% humidity) and dark room at a temperature 27.0 °C (SD = 0.4). The earthworm mortality was observed for initial critical periods (for initial three weeks of experimental starting) and data of mortality were recorded for different experimental vermibeds. Homogenized samples of substrate material were drawn at 0, 15, 30, 45, 60, 75, 90 and 105 days from each experimental container. The samples were oven dried (48 h at 60 °C), ground in stainless steal blender and stored in sterilized plastic airtight containers for further physico-chemical analysis.

The biological productivity (biomass change, cocoon production etc.) was also monitored weekly in *E. fetida* during experimentations.

2.3. Chemical analysis

The pH was measured using a digital pH meter (Systronics made) in 1:10 (w/v) aqueous solution (deionized water). Organic carbon was determined by the partial-oxidation method (Walkley and Black, 1934). Total Kjeldahl nitrogen (TKN) was measured using the method described by Jackson (1975). Available phosphorous was measured using the method described by Anderson and Ingram (Olsen et al., 1954). Exchangeable K was determined after extracting the sample using ammonium acetate (Simard, 1993).