Management of Fruit Wastes through Anaerobic Digestion and Utilization as Biofertilizer

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Abstract— One of the main environmental problems of today's society is the continuously increasing production of organic wastes. Sustainable waste management represents a step to reduce pollution and greenhouse gas emissions and to mitigate global climate changes. India is a major producer of fruits and fruit wastes are generated at each step of the food supply chain viz. agricultural production, post-harvest handling and storage, processing and packaging, distribution and consumption. In this study an attempt has been made to adopt anaerobic digestion as a technology to manage fruit wastes. Four fruit wastes viz. Pineapple, apple, banana and orange as well as their mixtures were studied for their potentiality as substrate or cosubstrate for the production of biogas. Cow dung was used as control. Biogas produced from each of them was measured on weekly basis for a period of 9 weeks. The study revealed that the average production of biogas was highest for the cosubstrate (510 mL) followed by cow dung (480 mL). Among the individual substrates, pineapple waste performed best producing 445 mL biogas on average basis while banana waste produced the least amount of biogas (310 mL). The digested sludge from each of the substrate was also studied for their effect on the yield and yield attributes on brinjal crop. The digested sludge from the cosubstrate performed best as a potential biofertilizer by recording highest no. of fruits/plant (15), plant height (75 cm), leaf area (190 cm2) and no. of branches/ plant (20). The study indicates fruit wastes as a potential alternative source of fuel and high value fertilizer.
Key words: Biogas, fruit wastes, Biofertilizer

I. Introduction

One of the main environmental problems of today's society is the continuously increasing production of organic wastes. Apart from food and land resource wastage, the carbon footprint of food waste is estimated to contribute to the greenhouse gas (GHG) emissions by accumulating approximately 3.3 billion tonnes of CO_2 into the atmosphere per year. India stands second in the production of Fruits and Vegetables in the world. It contributes about 10% of Fruits in the world production (Gautam and Guleria 2007). According to FAO (2011), the estimated Fruit waste percentage in each step of the food supply chain are 15, 9, 25, 10 and 7% in agricultural production, post-harvest handling and storage, processing and packaging, distribution and consumption respectively in South and South-East Asia. Traditional waste management practices such as incineration and composting have their limitations. Composting does not allow means to capture energy that is locked up in the waste. Incineration releases dioxins causing environmental problems and reduces the economic value of the substrate by hindering the recovery of nutrients and useful compounds from the incinerated substrate. In this context, anaerobic digestion can be used to strengthen energy security by employing food waste to generate biogas while addressing waste management and nutrient recycling. Anaerobic digestion (WRAP 2010) is "a process of controlled decomposition of biodegradable materials under managed conditions where free oxygen is absent, at temperatures suitable for naturally occurring mesophilic or thermophilic anaerobic and facultative bacteria and archaea species, that convert the inputs to biogas and whole digestate''. The main advantage in using anaerobic digestion is the biogas production, which can be used for steam heating; cooking and generation of electricity (Mata-Alvarez J et al. 1992; Verrier D et al. 1983; Ahring B K et al. 2002). The effluent produced can be used as a biofertiliser or soil conditioner (Ali R et al. 2000). Biogas can be generated from a large numbers of raw materials and can be used for variable energy services such as heat, power or as a vehicle fuel (Lantz M et al 2007).

II. Objectives

- Collection of different fruit wastes and pre-treatment for digestion
- Construction of digester at laboratory scale
- Comparison of the biogas yield from the different substrates
- To study the potentiality of digested sludge as soil conditioner by observation of morphological parameters of treated plant

III. Materials and methods

- Collection of feedstock: The wastes of four fruit samples viz. Pineapple (S1), apple (S2), banana(S3) and orange(S4) were collected from the grocery markets, municipal garbage dumps, and household kitchen as well as restaurants. Cow dung (S6) was also collected to be used as control.
- Pre-treatment of wastes and preparation of the slurry: 1.5 kg of each of the four fruit samples as well as cowdung were mixed with 2L of distilled water. The sample S5 was prepared as a cosubstrate by mixing 375 g of each of the four substrates with 2L distilled water. These mixtures were grounded in a kitchen blender to make it as a pulp for reduction of particle size.
- Fabrication of Digesters: Six digesters were fabricated at laboratory scale using 3L empty plastic gallons, valves, CPVC pipe, tank nipples, flexible rubber pipe and adhesives. Holes were bored on the cover of the digesters for input of feed and collection of biogas and at the bottom of the digester for collection of sludge for analysis. The inlets and outlets were sealed to maintain anaerobic condition.

- Collection of inoculum and preparation of starter culture: The inoculum was collected from biomethanation plant and cultured on Nutrient Agar plates. Enrichment culture was done in Nutrient Broth. Morphological and biochemical testes for the isolated bacterial colonies were done according to K.R. Aneja (2005).
- Startup of the digesters: In each of the digesters, 1L of inoculum (starter culture) and 2L of the prepared feedstock substrate were added. The digesters were placed in a constant temperature water bath and maintained at mesophilic conditions (350C) for startup of the process. Mixing was done by manually shaking and swirling once in a day.
- Measurement of Biogas: Biogas production from the reactors was monitored daily by water displacement method. The gas collection was observed in an inverted measuring cylinder half immersed in water taken in a glass trough and a flexible tube connected to the gas outlet of the digester was passed into the measuring cylinder. The volume of water displaced from the measuring cylinder was equivalent to the volume of gas generated. The experimental setup was then left for monitoring for a specific time period at an ambient condition until a decline in gas production was observed.
- Application of digested sludge as soil conditioner and observation of morphological parameters of plants:

Weeks / Substrate	1	2	3	4	5	6	7	8	9	Average
Pineapple waste (S1)	390	425	540	690	609	450	383	260	258	445
Apple waste (S2)	331	380	530	663	500	440	262	240	254	400
Banana waste (S3)	240	250	316	400	540	335	258	236	215	310
Orange waste (S4)	250	300	412	475	575	420	315	295	243	365
Cosubstate (S5)	420	470	530	720	700	680	460	354	256	510
Cowdung (S6)	417	461	514	706	698	596	382	302	244	480

Table 1: Average production of biogas (mL/g) from different substrates

The digested wastes were applied to soil in pots at the time of sowing of seeds of brinjal cv. Pusa Kranti. The experiment was carried out in completely randomized block design and each of the six treatments was replicated thrice. The morphological parameters such as plant height, leaf area, no. of branches/plant and no. of fruits/plant were observed and recorded.

IV. Result and Discussion

The biogas produced from substrates is recorded in Table 1. The substrate S5 i.e. cosubstrates produced the highest amount of Biogas (510 mL/g on average) (Table 1 and Fig. 1). This could possibly be due to more varied composition of the organic material providing an effective substrate for a large variety of microbes to grow. It is followed by cowdung (S6) and pineapple waste (S1) where the average biogas produced was 480 mL/g and 445 mL/g respectively.

Among the individual fruit wastes, pineapple performed the best due to higher percentage of moisture content, total and volatile solids as compared to the other fruit substrates.

The retention period of all the substrates was same i.e. 9 weeks. The trend of production of biogas on weekly basis in each of the substrates is shown in Fig. 1. The biogas production increased from the first week and reached peak in the 4th week. It then showed a decreasing trend till the 9th week.

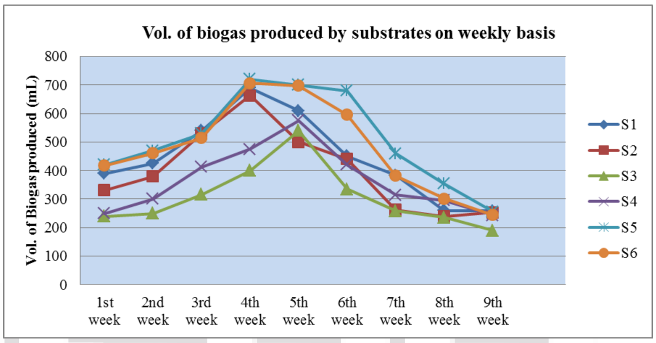

Fig. 1: Trend of biogas production from different substrates on weekly basis

However in banana waste (S3) and orange waste (S4) the peak reached was in the 5th week and showed sharp decline in the following four weeks. The effect of digested sludge on morphological parameters is recorded in Table 2.

Digested sludge of Substrates	No. of fruits/ plant	Plant height (cm)	Leaf Area (sq cm)	No. of branches/ plant
Pineapple digestate (S1)	13	69	168	14
Apple digestate (S2)	11	66	160	13
Banana digestate (S3)	08	62	145	09
Orange digestate (S4)	10	63	152	11
Cosubstrate digestate (S5)	15	75	190	20
Cowdung (S6)	15	72	180	18
Untreated plant	06	60	137	08

Table 2: Effect of digested sludge of different substrates on morphological parameters of plant

The no. of fruits/ plant was highest in the co-substrate digestate and cowdung followed by pineapple digestate. Similar trends were also recorded in the other parameters with the cosubstrate digestate performing best followed by cowdung and pineapple. The morphological parameters showed positive correlation with the amount of biogas produced. The substrate S5 with best morphological parameters also showed the highest amount of biogas production.

Due to the decomposition of its organic content, digested sludge provides fast-acting nutrients that easily enter into the soil solution, thus becoming immediately available to the plants. They simultaneously serve as primary nutrients for the development of soil organisms.

V. Conclusion

Thus through the adoption of green technology like anaerobic digestion-

- Pressure on finite resources such as coal can be minimized,
- Production of renewable energy from materials such as fruits that are readily and locally available is possible reducing the cost of its production and providing an alternative to cowdung as substrate
- Waste management and nutrient recycling is feasible by providing useful organic soil conditioner and fertilizer

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