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Evaluation of fruit wastes as substrates for the production of biogas

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ABSTRACT

The present work is the study of fruit wastes for their potential in the production of biogas. Utilization of wastes for the production of biofuel can be a sustainable alternative to meet the energy challenge for the present and future generations. Wastes of Apple, Pineapple, Jackfruit, Orange, Banana as well as their mixture were taken as substrates and cowdung was used as the control. Laboratory scale digesters were designed and anaerobic digestion of the substrates was carried out. The amount of biogas produced from each substrate was measured by the water displacement method. The results revealed that the digestion of co substrates produced the highest amount of biogas (990 mL) at 3 weeks followed only by the control substrate (cowdung) which produced 980 mL at the same time. Among the individual substrates pineapple showed the highest potential producing 975 mL at the peak of production (3 weeks). Microbial load was also found to be in direct correlation with biogas production. The highest microbial load (6.2×10^4 cfu/mL) was recorded in co-substrates followed by cowdung (6×10^4 cfu/mL) at the peak of production period. Among the individual substrates, highest microbial load was recorded in pineapple (5.8×10^4 cfu/mL) followed by orange (5.6×10^4 cfu/mL) at the peak of production. The results of the study indicate the potential of anaerobic digestion of fruit wastes for biogas production.

Key words: Fruits, Biogas, Anaerobic digestion

INTRODUCTION

From the beginning of industrial revolution, global energy demand is rapidly increasing. In contrast, fossil fuel reserves are decreasing causing an increase in energy prices [1]. Today, one of the major challenges is energy supply for the future. Increase in population and unmonitored and uncontrolled urbanization is also creating problems of solid waste disposal. Furthermore, effects of global warming cannot be neglected anymore and carbon abatement policies have to be adhered to. In this context, anaerobic digestion of biomass is gaining importance as alternative to land filling practices and incineration. Using anaerobic digestion, biomass can biologically be converted into methane and hydrogen [2]. One of the benefits of using waste in digestion processes is that the produced methane can be used as a fuel. The rest product, the digested slurry, also contains a high amount of nutrients and can be used as a fertiliser. Some of the most common applications for biogas include lighting, electricity, cooking, and utilization as an alternative vehicle fuel [3]. The anaerobic digestion process and production of methane consists of bacterial hydrolysis, acidogenesis, acetogenesis and methanogenesis.

India produces 150 million tonnes of fruits and vegetables and generates 50 million tonnes of wastes per annum [4, 5]. Fruit wastes are created during harvesting, transportation, storage, marketing and processing. Due to their nature and composition, they deteriorate easily and cause foul smell. Therefore it becomes necessary to develop appropriate waste treatment technology for fruit wastes to produce biofuel and minimize green house gas emission. A complex microbiological process lies behind the efficient production of biogas. The organic waste treated in the biogas process represents the substrate for various microorganisms. The more varied the composition of the organic material, the more components are available for growth, and thus the greater diversity of organisms that can grow.

In the present work, wastes from five commonly consumed fruits viz. Orange, apple, pineapple, banana and Jackfruit, were evaluated for their potential in producing biogas by anaerobic digestion under laboratory conditions. The potential of fruit wastes to be used as substrates for biogas production can achieve the goals of developing a sustainable technology for waste management, producing renewable energy and reducing green house gas emissions.

Objectives

The objectives of this paper are as follows:

1) To evaluate wastes of five types of fruits viz. Orange, apple, pineapple, banana and Jackfruit as potential substrates for the production of biogas by anaerobic digestion.

2) To evaluate co digestion of five fruit waste types for its potential for the production of biogas.

3) To determine the microbial load at the point of charging, at the peak of production and at the end of retention time for each digester.

MATERIALS AND METHODS

- **Preparation of slurry**

The fruit waste samples were grounded in a kitchen blender to make it as a pulp for reduction of particle size and proposed to be used as feed to the reactor and kept at 4°C until use. 200 g of each of the five substrates was taken and mixed with 1L water and each transferred to a separate digester (S1 to S5). For the co-digestion, 40g of each of the five substrates were taken and mixed with 1L water (S6). For the control digester (S7), 200g of cowdung was mixed with 1 L water and added to it.

- **Startup of the digesters**

To each of the digesters, 400g inoculum consisting of pre-digested vegetable wastes from kitchen and cowdung collected from a biomethanation plant was added. To it was added the slurry of substrates. The digesters were placed in a constant temperature water bath and maintained at mesophilic conditions (35^0C) for start up 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 upto 9 weeks 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 cylinder. The volume of water displaced from the measuring cylinder was equivalent to the volume of gas generated. The digester was completely sealed and then connected to the gas delivery setup. 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.

- **Comparison of the quantity of biogas produced from the different substrates**

Comparison of the quantity of biogas produced after definite time intervals would be made from different substrates. The retention time of the substrates and the amount of biogas produced would be analysed in anaerobic batch digestion process.

- **Microbial analysis**

Microbial analysis of each slurry was carried out at the point of feeding, at the peak of production and at the end of the retention time. Total Viable Count for the fruit waste slurries were done according to the modified Miles and Misra method [6] to determine the microbial load.

RESULTS AND DISCUSSION

Table 1: Average biogas production (in mL) from different substrates

Substrates	No. of weeks								
	1	2	3	4	5	6	7	8	9
Apple (S1)	615	625	655	640	628	618	600	590	580
Orange(S2)	655	665	700	690	688	650	645	635	615
Pineapple (S3)	765	878	975	900	850	820	765	700	655
Banana(S4)	590	610	620	615	600	596	584	570	555
Jackfruit(S5)	578	570	567	556	545	530	518	500	495
Co-substrates(S6)	800	877	990	975	900	860	848	800	792
Control(S7)	810	880	980	976	889	855	845	795	790

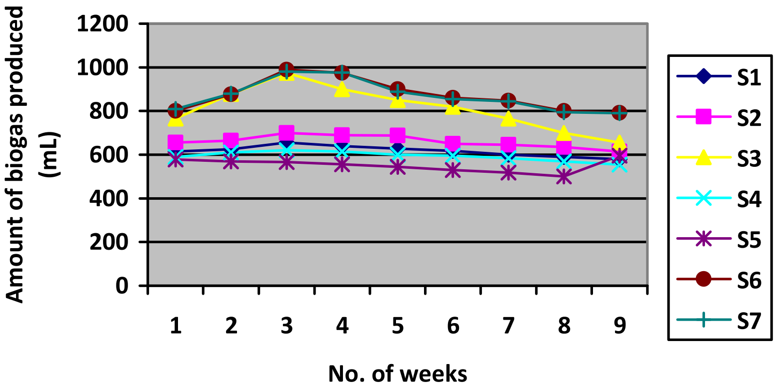

Figure 1: Average production of biogas by substrates Vs. No. of weeks

Biogas production from substrates:
The quantity of biogas produced (in mL) from the different substrates at different days is given in the Table 1 and Fig. 1

The biogas production recorded at 4 weeks was the highest for the control (976 mL) followed successively by the co-substrates and pineapple (975 mL and 900 mL) respectively. In all the substrates used, the peak of production was recorded at 4 weeks and then successively decreased upto 9 weeks. At 9 weeks Jackfruit recorded the lowest production of biogas (495 mL) while banana recorded the second lowest (555 mL).

Analysis of microbial load: The microbial total viable count revealed that the microbial load steadily increased from the point of charging upto the peak of production and then decreased towards the end of the retention period for each of the substrates (Table 2). The microbial load at the peak of production was highest for the control (6.2×10^4 cfu/ml) followed successively by co-substrates (6×10^4cfu/mL), pineapple (5.8×10^4 cfu/mL) and orange (5.6×10^4 cfu/mL). The lowest total viable count was found in jackfruit which recorded 4.9×10^4 cfu/mL at the peak of production and 3×10^4 cfu/mL at the end of retention period (Table 2).

Table 2: Microbial load of different substrates at the point of charging, peak of production and at the end of retention time

Substrates	Microbial load (cfu/mL)		
	At the point of charging	At the peak of Production	At the end Of retention period
Apple (S1)	3.6×10^3	5.4×10^4	3.8×10^4
Orange(S2)	3.7×10^3	5.6×10^4	4×10^4
Pineapple (S3)	3.8×10^3	5.8×10^4	4.2×10^4
Banana(S4)	3.8×10^3	5×10^4	3.6×10^4
Jackfruit(S5)	3.7×10^3	4.9×10^4	3×10^4
Co-substrates(S6)	3.8×10^3	6.2×10^4	4.6×10^4
Control(S7)	3.8×10^3	6.0×10^4	4.2×10^4

The fruit wastes could be potential substrates for the production of bioenergy possibly due to their high biodegradability and high moisture content (75%-90%) [7, 8]. The codigestion of the fruit wastes yielded higher biogas and showed higher total viable count of microbes than the individual fruit wastes. This is possibly due to the higher concentration of volatile solid contained in this feed. Higher yield of biogas was recorded in the co-digestion of fruit and vegetable fraction of municipal solid wastes with primary sludge than did the digestion of primary sludge [9]. Cowdung slurry performed better than the individual fruit substrates. This is in agreement with previous findings recording higher yield of biogas from cowdung than the fruit and vegetable wastes [10]. The microbial count has been found to be directly related to the biogas production. This could be due to the capability of bacteria, particularly Clostridia and Bacilli, for efficient hydrolysis of plant biomass rich in lignocellulose [11]. Finally, codigestion of the fruit wastes with cowdung and possibly, with substrates rich in proteins having good buffering capacity, can be suggested. Advantages of co-digestion processes include increase in waste organic load, dilution of potential toxic compounds, improvement of nutrient balance and increase in biogas yield [12].

CONCLUSION

The findings of this work indicate the potentiality of further research on the co-digestion of nitrogen-rich substrates with fruit and vegetable wastes for energy production and environmental protection.

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