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Anaerobic Co-Digestion of Vegetable Waste with Cattle Dung and Fruit Waste for Biogas Generation

Patil V. S., Patil S.V., Bhide A.J.

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ABSTRACT

India is a developing country and its rate of energy consumption is increasing with economic and industrial development. Most of the countries are dependent on non-renewable energy sources that have many limitations and demerits. The use of renewable energy resources is beneficial from socioeconomic and ecological point of view that can help to achieve sustainable development goals. India is agro-based country and produces huge quantities of organic waste per day. The disposal of these wastes by unscientific treatment methods causes serious environmental pollution. Anaerobic digestion and co-digestion are considered as ecofriendly technology of energy generation and waste disposal. The co-digestion is more beneficial over anaerobic digestion and has several advantages. The present work was undertaken to study anaerobic co-digestion of vegetable waste with cattle dung and fruit waste with the objectives of treating the waste to generate biogas and to decrease its environmental pollution potential.

Patil V. S.[1]*, Patil S.V.[2], Bhide A.J.[3]
[1]Department of Microbiology, Lal Bahadur Shastri College of Arts, Science and Commerce, Satara 415002, Maharashtra, India
[2]Department of Botany, Lal Bahadur Shastri College of Arts, Science and Commerce, Satara 415002, Maharashtra, India
[3]Indian Institute of Science, Education and Research, Pune 411008, Maharashtra, India
Email : vishwasp15@yahoo.com
*Corresponding author

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INTRODUCTION

India has the world's largest population of 1.43 million which accounts for 17.76% of world's population (Worldometer 2023). India has achieved rapid and remarkable economic and industrial development in the past two decades and became the world's fifth largest economy in 2020. The commercial energy consumption has increased with high economic growth and industrial development.

The world's 85% energy comes from non-renewable supplies like coal, oil, natural gas and nuclear energy, indicating there is heavy dependence with respect to energy resources on non-renewable energy resources. The non-renewable energy reserves in India are very limited as compared to global scenario and hence come under a great threat with respect to futuristic energy requirements of the country. Non-renewable energy resources have limited reserves and are getting depleted every now and then with the current usage rate (Energy statistics 2019). Besides their limited reserves, the extensive use of non-renewable energy resources has caused environmental, social and economic problems globally (Srivastava *et al.* 2015).

Biomass is composed of organic matter from plants/animal origin, residue from agriculture or forestry and municipal and industrial waste (Guldhe *et al.* 2017). Biomass fuels contributed 90% energy in the rural areas and over 40% in the cities. Biomass may be converted to produce energy by thermal- chemical processes or bio-chemical processes. Organic waste is a main constituent of solid biomass. A huge amount of agricultural wastes are produced every year. The use of organic wastes as alternative energy resource offer several benefits. Agricultural wastes have been tested for their potential to use in manufacturing of biofuels, enzymes, vitamins, antioxidants, animal feed, antibiotics, and other chemicals through solid state fermentation by several researchers (Kumar *et al.* 2016).

Vegetable waste represents a major share of agricultural wastes. It is produced in during harvesting, poor and inadequate transportation, storage facilities and marketing practices of vegetables. They are perishable and voluminous. Disposal of vegetable wastes in unscientific manner cause an adverse impact on the environment and human health (Kumar *et al*. 2009).

India has the largest population of livestock of over 300 millions which produce about 980 million tonnes of dung. Most of the cattle dung are disposed in landfills or are applied to the land without treatment. These inappropriate disposal methods can cause adverse environmental and health problems (Harikrishnan and Sung 2003).

India is the second largest fruit producer in the World after China. About 12.6 % of fruit productions are from India. The losses in fruits along with vegetables are reached 30 to 40%. The current disposal methods-landfill and incineration cause serious environmental and health risks (Qdais *et al*. 2010).

Anaerobic digestion is an ecofriendly and technology wise simple method of energy generation and waste disposal. Anaerobic co-digestion is the simultaneous digestion of two or more substrates. Co-digestion has several merits like it can provide a better nutrient balance and therefore higher biogas yields, dilution of toxic substances, increasing OLR, synergistic effects on microorganisms, economic benefits (Meiramkulova *et al.* 2018). The present work has been undertaken to study co-digestion of vegetable waste with cattle dung slurry and fruit wastes with the objectives of treating the waste to generate biogas and to decrease its environmental pollution potential.

MATERIALS AND METHODS

Experimental setup

Vegetable wastes (VW) for the present studies were collected from the local vegetable market. Cattle dung (CD) was collected from a local. Fruit wastes (FW) were collected from local fruit market. The collected wastes were further segregated into individual fruit types and mixed in equal proportions, shredded and ground in a kitchen blender to make paste and kept in refrigerator at 4^0C until used. Inoculum was obtained from an active mesophilic digester of cattle dung based anaerobic digester. Anaerobic co-digestion studies were carried out in 1 liter capacity reactor-plastic carboys. The effective volume of each of the reactor was maintained at 600 mililiters. The reactors were provided with suitable arrangements for feeding, gas collection and draining of residues. The reactors were mixed manually by means of shaking and swirling once in a day to break the scum.

Physico-chemical analysis of substrates and digester effluents

The physico-chemical analysis of substrates and effluent were determined according to standard methods (APHA 1998).

Anaerobic co-digestion of vegetable waste with agricultural wastes

The anaerobic co-digestion of vegetable waste with cattle dung and fruit waste were carried out at ambient temperature conditions. Acclimatization of inoculums was done before initiation of every experiment. Vegetable waste was mixed with cattle dung and fruit waste wastes separately in various proportions as 1:0, 0.75: 0.25, 0.5:0.5, 0.25:0.75 and 0:1. The reactors were fed with these combinations separately at 20 days HRT, pH 7.0 of the substrate and ambient temperature conditions. Biogas production from all the digesters was monitored daily. Water displacement method was used for measurement of biogas yield (APHA 1998). Quantitative analysis of biogas was carried on Michro 9100 Gas chromatograph.

Pollution abatement study

The reduction in pollution potential of agricultural wastes after co-digestion was studied with reference to % reduction of organic content in terms of total solids (TS) and volatile solids (VS).

RESULTS AND DISCUSSION

Vegetable waste used for co-digestion comprised equal mixture of potato (*Solanum tuberosum* L.), Onion (*Allium cepa* L.), Cabbage (*Brassica oleraceae* L. var. capitata), Cauliflower (*Brassica oleraceae* L. var. botrytis), Tomato (*Lycopersicon esculentum* Mill.) and Brinjal (*Solanum melongena* L.). Fruit waste used for co-digestion comprised equal mixture of Apple (*Malus pumila*), Banana (*Musa acuminata*), Grapes (*Vitis vinifera*), Pomegranate (*Punica granatum*) and Chiku (*Manilkara zapota*). The physico-chemical analysis of vegetable waste and other wastes is represented as per Fig.1 and Table 1. The results of physico-chemical analysis revealed that these wastes are highly amenable for anaerobic digestion.

The ambient temperature throughout the co-digestion studies ranged 30-35°C. The daily biogas yields in volume (ml) from the co-digestion of VW and cattle dung (CD) are represented in Fig. 2. The maximum biogas volume was obtained with the 0.5:0.5 (CD : VW) combination. The highest biogas volume (viz. 318 ml) was produced on 6th day of experiment. The minimum biogas volume was obtained with the 1:0 (CD: VW) combinations.

Table 1. Physico-chemical analysis of substrates used for co-digestion.

Sl. No.	Parameter	Unit	Mixed vegetable waste	Cattle dung	Mixed fruit waste
1	pH	-	6.80	7.49	4.61
2	Moisture	%	89.00	82.05	82.86
3	Total solids	%	4.43	17.95	17.14
4	Volatile solids	%	3.83	12.90	16.41
5	Total organic carbon	%	2.23	7.48	9.52
6	Total nitrogen	%	0.15	0.35	0.15
7	BOD	mg/L	97150	38500	58700
8	COD	mg/L	174000	83340	111530

The average daily biogas yield in terms of L/g VS degraded during co-digestion of VW and CD in 20 days experiment is represented in Fig. 3. The maximum biogas yield (viz. 0.503 L/g VSd) was obtained with 0.5:0.5 (CD: VW) combination and minimum biogas yield (viz.0.156 L/g VSd) was obtained with 1:0 (CD: VW) combination. The methane content in biogas collected from digester fed with VW: CD (0.5:0.5) was found to be 55.65 %. The reduction in TS and VS values for digester fed with VW: CD (0.5:0.5) were found to be 66.44% and 79.1% respectively.

The co-digestion of VW with CD gave better yield as compared to previous reports on anaerobic

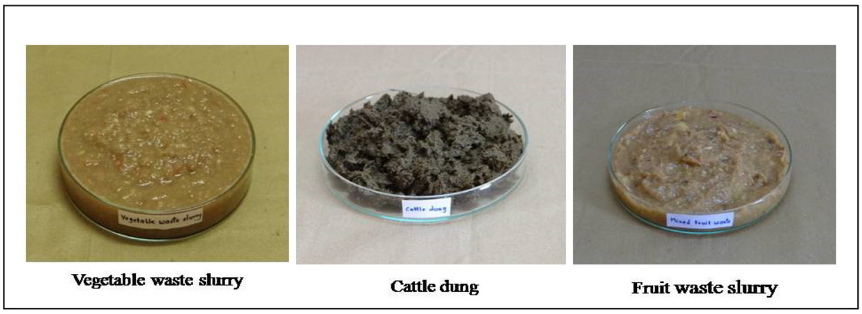

Fig.1. Agricultural wastes used for co-digestion experiment.

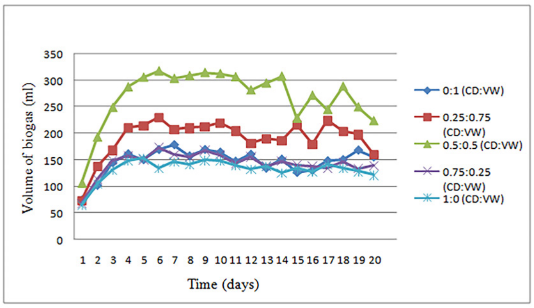

Fig. 2. Co-digestion of vegetable waste (VW) and cattle dung (CD) for biogas generation.

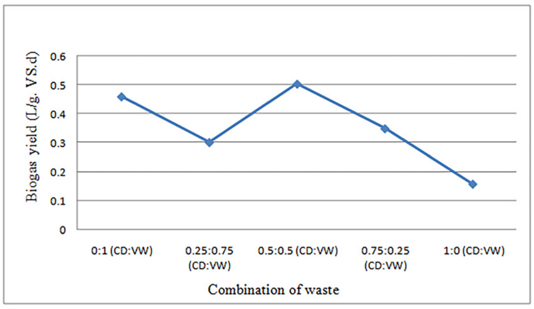

Fig. 3. Average biogas yield from mixture of vegetable waste (VW) and cattle dung (CD)

digestion of CD alone (Asikong *et al.* 2013, Desai *et al.* 2013) and co-digestion of CD with other industrial wastes (Patil *et al.* 2013, Chellapandi and Uma 2012).

The daily biogas yields in volume (ml) from the co-digestion of VW and fruit waste (FW) are represented in Fig. 4. The maximum biogas volume

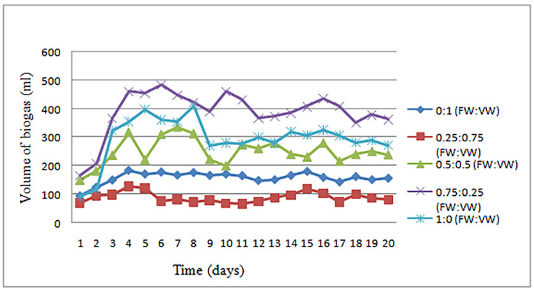

Fig. 4. Co-digestion of vegetable waste (VW) and fruit waste (FW) for biogas generation.

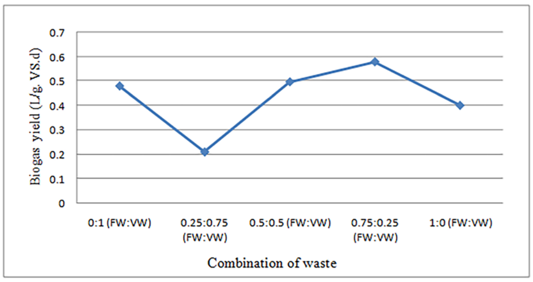

Fig. 5. Average biogas yield from mixture of vegetable waste (VW) and fruit waste (FW).

was obtained with the 0.75:0.25 (FW: VW) combination. The highest biogas volume (viz. 483 ml) was produced on 6th day of experiment. The minimum biogas volume was obtained with the 0.25:0.75 (FW: VW) combinations.

The average daily biogas yield in terms of L/g VS degraded during co-digestion of VW and FW in 20 days experiment is represented in Fig. 5. The maximum biogas yield (viz. 0.578 L/g VSd) was obtained with the 0.75:0.25 (FW: VW) combination and minimum biogas yield (viz.0.209 L/g VSd) was obtained with 0.25:0.75 (FW: VW) combination. The methane content in biogas collected from digester fed with 0.75:0.25 (FW: VW) was found to be 54.46 %. The reduction in TS VS values for digester fed with 0.75:0.25 (FW: VW) were found to be 60.79% and 73.17% respectively.

The co-digestion of VW with FW gave better yield as compared to previous reports on anaerobic digestion of FW alone (Banu *et al.* 2007), Co-digestion of VW with FW (Das and Mondal 2013, Sagagi *et al.* 2009) and Co-digestion of FW with other industrial wastes (Narayani and Priya 2012, Martin-Gonzalez *et al.* 2010).

CONCLUSION

The present study carried out at laboratory scale using 1 liter capacity digesters reveals that treatment of these wastes by anaerobic co-digestion generates considerable biogas yield and also decrease its environmental pollution potential as compared to individual wastes. With the further scale up of co-digestion studies these agricultural wastes can serve as potential source for energy which can be used to meet the energy needs of nation and subsequently there will be ecofriendly treatment of these waste meeting sustainable development goals of nation.

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