Journal of Scientific & Industrial Research
Vol. 71, March 2012, pp. 217-220

Biogas production through mixed fruit wastes biodegradation

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Received 13 July 2011; revised 17 January 2012; accepted 18 January 2012

This study presents biogas production from fruit wastes at ambient temperature using anaerobic batch digester (500 ml). Co-digestion of fruit wastes were carried out with rice bran and cow dung. Biogas production from different samples was as follows: Sample A (fruit waste), 363; sample B (fruit waste, 75% + cow dung, 25%), 405; sample C (fruit waste, 75% + rice bran, 25%), 315; and sample D (fruit waste, 50% + rice bran, 25% + cow dung, 25%), 381 ml. From chromatographic studies, sample B has maximum methane content (80%) and sample C has maximum carbon-di-oxide content (50%). Cow dung influences digestion of fruit wastes and showed highest yield (405 mg) of biogas production.

Keywords: Biogas, Biodegradation, Cow dung, Fruit wastes, Rice bran

Introduction

Only 0.5% of fruit wastes are converted into various useful products[1] and balance is disposed off. Fruit wastes can be treated chemically or biologically to yield useful by-products before final disposal. Anaerobic treatment is reported[2,3] of food processing wastes by products and wastes from agriculture based industries. Performance of an anaerobic digester depends on the type and composition of materials to be digested as well as pH and temperature[4]. Anaerobic fermentation of manure for biogas production does not reduce its value as a fertilizer supplement, as available nitrogen and other substances remain in treated sludge[5]. Advantages of co-digestion[6,7] include better digestibility, enhanced biogas production/ methane yield arising from availability of additional nutrients, as well as a more efficient utilization. Amount of carbon dioxide (CO_2) and volatile fatty acids produced during anaerobic process affects pH of contents in digester[8]. Regular use of fossil fuels as primary energy source has led to global climate change, environmental degradation, and human health problems[9]. Cattle dung is traditionally employed as a feedstock for biogas production in rural sectors. Many of the industrial wastes have been exploited for biogas production to compensate for electricity needs in industrial sectors[10].

This study presents biodegradation of mixed fruit wastes using different co-substrates to yield biogas by using anaerobic batch digester reactors made by using local materials to reduce production cost and simplifying its installation and operation.

Experimental Section

Fruit peel wastes from apple, pineapple, grapes, custard apple and sweet lime were collected from Anna University canteen, Chennai, India. Hand sorting was done to segregate unwanted materials (straw, plastic covers, packaging materials etc.). Then a composite sample was prepared and allowed to dry for two weeks and then dried samples were shredded manually into pieces for good uniformity. Samples (10 g each) had following compositions: sample A (fruit waste, 100%); sample B (fruit waste, 75% + cow dung, 25%); sample C (fruit waste, 75% + rice bran, 25%); and sample D (fruit waste, 50% + rice bran, 25% + cow dung, 25%). Then, these samples were analyzed[1] of preliminary characteristics (Table 1) for biogas production. Finally, amount of biogas produced was analyzed using gas chromatography (GC).

Experimental Set-up

A serum flask (500 ml) consists of sludge sample. A liquid displacement system (Marriott flask), consisting of a 500 ml serum flask with NaOH solution and plugged by a rubber stopper perforated by two hollow needles

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Table 1—Preliminary characterization

Characteristics	Samples				Sludge
	A	B	C	D	
pH	4.5	4.5	4.0	4.0	6.5
Total solids, %	20.5	79.8	75.6	75.6	83.14
Moisture content, %	79.5	20.62	24.4	24.4	16.86
Volatile solids, %	96.4	96.52	95.04	95.04	1.65

and placed upside down. Biogas produced by the sample in serum flask will accumulate in liquid displacement system, displacing NaOH solution. CO_2 will be absorbed by NaOH solution. Dispersed liquid therefore is considered to have the same volume as the produced biogas. Sample flask and NaOH flask are interconnected with a tube that is connected at both ends to syringes. Conic flasks or graduated cylinders covered with funnel are placed below the second hollow needle of NaOH flask. Displaced liquid is collected in flask or cylinder.

Experimental Procedure

A sample (1.0-1.5 g volatile solids) is taken in a serum flask (500 ml). Water is added to a level of 3 cm from the top of flask. Rubber stopper is placed and flask is connected to liquid displacement system. Top bottle is performed with both water and NaOH. Serum flask for blank, containing water + sludge sample, is loaded. Stock solution (5 ml) of acetic acid is added. First reading of biogas production is taken after one day as zero reading, after which, gas production is monitored on a daily basis. Sludge flasks should be mixed thoroughly before measuring biogas production. Blank sample measures biogas production, which should be subtracted from biogas production from different samples. Biogas produced is measured by water displacement method as amount of water displaced = amount of biogas produced.

Results and Discussion

Biogas Production from Blank Samples

Biogas production for different blank samples (A, B, C and D) implies (Fig. 1) that there is a slow increase in production initially and then production rate decreases and reaches to equilibrium state at the end. This is because it may consume minimum time for stabilization and after stabilization, biogas production is maximum, and after certain time, organisms need excess substrate for growth, hence rate decreases and production reaches almost constant.

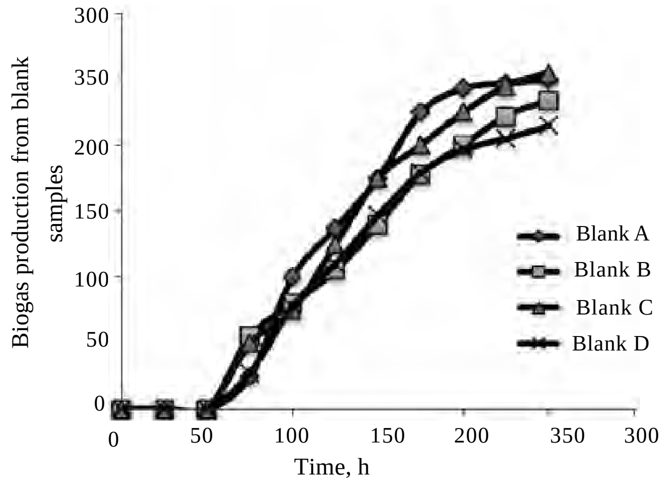

Fig. 1—Biogas production from blank samples

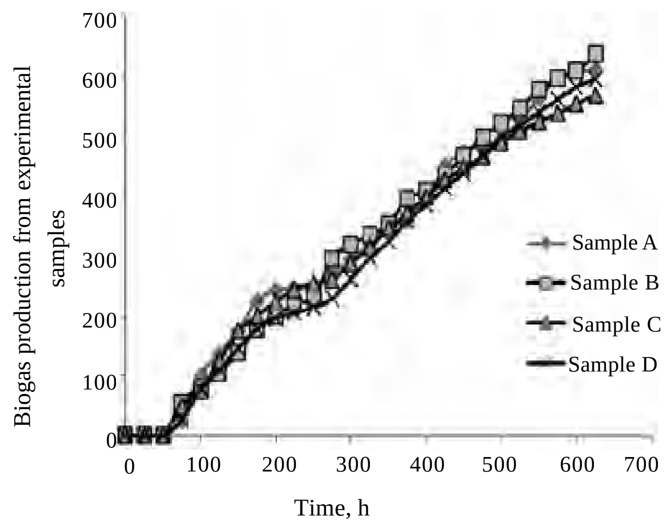

Fig. 2—Biogas production from experimental samples

Biogas Production from Experimental Samples

For sample A (Fig. 2), biogas production reached almost constant at 215 ml, indicating that all substrates in sludge bottle have been consumed and biogas production stops. After addition of fruit waste as substrate and cow dung, rice bran as co-substrates in respective sludge bottles, a steep increase was observed in biogas production after consumption of these substrates, once again the production rate falls and reaches constant above 613 ml[7]. For sample B (Fig. 2), at the end of the experiment, biogas yield was 405 ml. Using 100% cow dung under same conditions, cumulative biogas yield is reported to be 827 ml/g volatile solids[6]. Considering 25% cow dung of sample B, biogas yield was measured as 405 ml, which is only from cow dung

Table 2—Estimation of produced biogas

Experimental samples		Blank samples		Amount of biogas produced by experimental sample alone, ml x-y
Experimental sample	Amount of biogas produced by experimental sample, ml x	Sample	Amount of biogas produced by blank sample, ml y	
A	613	A	250	363
B	639	B	234	405
C	570	C	255	315
D	596	D	215	381

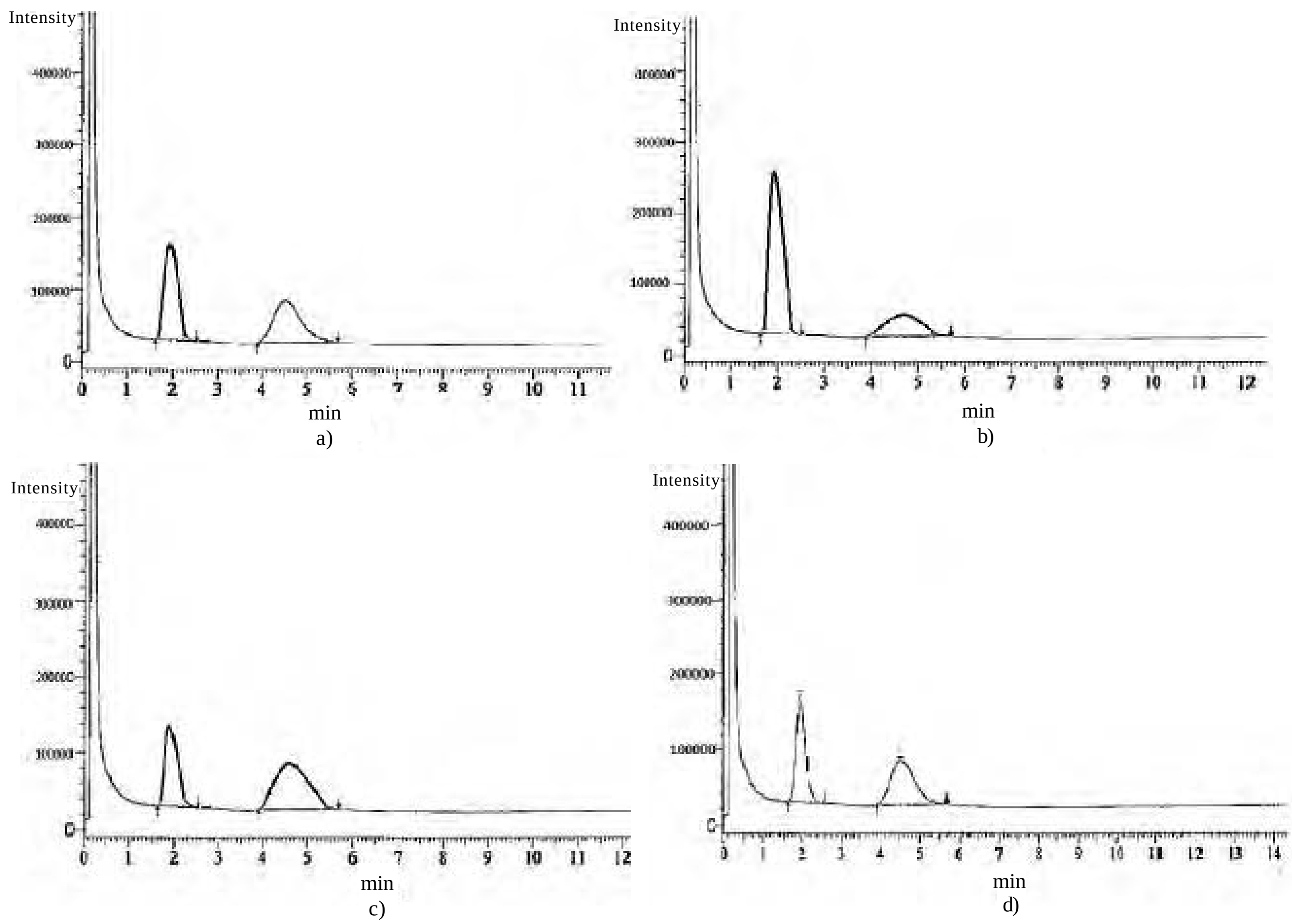

Fig. 3—Analysis of biogas composition by gas chromatography for: a) Sample A; b) Sample B; c) Sample C; and d) sample D

because cow dung has rich organic matter and presence of anaerobes facilitated biogas production. For sample C (Fig. 2), using same method, a total 315 ml of biogas was produced at the end of 25th day of experiment. Amount of biogas produced by this sample was less due to little contribution of rice bran in biogas production. For sample D (Fig. 2), yield of biogas was 381 ml, where cow dung leads to enhancement of biogas production but rice bran does not have greater potential for biogas production (Table 2) so that it does not cause efficient digestion[2].

Chromatographic Studies

Collected biogas was analyzed using GC studies (Fig. 3, Table 3). First and second peaks in all the four chromatograms (Fig. 3 a, b, c and d) were formed nearer to 2 min and 4.5 min respectively. From this retention time values, it has been confirmed as the first peak for

Table 3—Analysis of biogas composition by gas chromatography

S.No	Samples	Peaks	Compound name	Retention time	Theoretical plates	Resolution	Tailing factor
1	A	1	CH_4 -60%	1.939	286.36	0.00	1.202
		2	CO_2 -30%	4.516	255.78	3.25	1.347
2	B	1	CH_4 -80%	1.832	540.82	0.00	1.163
		2	CO_2 -10%	4.263	295.63	3.25	1.374
3	C	1	CH_4 -40%	1.762	261.34	0.00	1.79
		2	CO_2 -50%	4.459	265.91	3.25	1.168
4	D	1	CH_4 -70%	1.801	296.14	0.00	1.114
		2	CO_2 -20%	4.523	219.78	3.25	1.221

methane and second for CO_2. From the height of peaks, composition of biogas was quantitatively evaluated. Chromatogram obtained for sample B shows highest peak of methane as compared with others. Hence, it is inferred that sample B generated maximum methane content (80%). This is because of rich organic matter present in cow dung. Sample C (Fig. 3c) shows highest peak of CO_2 (50%), due to starch rich bran.

Conclusions

Four experiments with different kinds of feedstock were conducted under mesophilic condition in batch bioreactor for 25 days. Cumulative biogas production increased, when fruit waste with co-substrates were used. Highest biogas production (405 ml) was obtained for sample B (75% fruit waste and 25% cow dung), whereas lowest from sample C. GC studies implies that sample B can generate maximum methane content (80%) because of rich organic matter present in cow dung and sample D shows highest peak of CO_2 (50%) due to starch rich bran. Anaerobic co-digestion with cow dung has greater potential for biogas production because the presence of anaerobes that leads to enhancement of biogas production. Rice bran and fruit waste alone does not have greater potential for biogas production.

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