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Mesophilic biodigestion of cowdung and mango peel in relation to bioenergy-batch study

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ABSTRACT

The objective of this study was to characterize the anaerobic biodegradability potential of mango processing solid waste and its methane potential (measured as methane yield) using different mass ratio of mango peel and cow dung. A maximum methane yield of 3.581 m^3 CH_4/Kg VS $_{degraded}$ was obtained at 8% TS and ratio of 1:10. Addition of cow dung led to faster onset of biogas production and higher methane productivity. The reductions in volatile solids in the entire BMP test were in the range of 96% to 98%. The specific gas production for mango peel was higher (5.3926 m^3biogas / Kg VS $_{added}$ and 5.5093 m^3 biogas / Kg VS $_{des}$) for the 1:10 ratio at 8% TS than for the 1:2 ratio 2.0342 m^3 biogas/Kg VS $_{added}$ and 2.4535 m^3 biogas/ Kg VS $_{des}$ at 4% TS. Consequently, the specific gas production for the mango peel, co-digestion with cow dung for the 1:10 at 8% TS was higher, compared to other values. This experimental result compared with anaerobic digestion potential of MP and cow dung alone. The organic waste available from the mango peel contains easily biodegradable organic matter and this contributed to a better biogas yield.

KEYWORDS

Anaerobic digestion;
Mango peel;
Methane yield;
Batch study.

INTRODUCTION

Large volumes of solid wastes are generated by the food processing industry annually and consequently these results in severe environmental impacts. Thus the solid wastes one of the serious problems in developing countries situations need eco-friendly treatment options. This has become a major environmental issue in India. The sustainable option thus lies in the reuse of these wastes by non-polluting and environmentally benign technologies while simultaneously deriving economic and material benefits in the process. One important option for energy recovery is anaerobic digestion. Anaerobic treatment consists of the decomposition of organic material in the absence of free oxygen and this process produces biogas enriched in methane, carbon dioxide, ammonia and traces of other gases within the reactor. The anaerobic process would be an economically attractive alternative for the treatment of different types of fruit wastes such as orange peel[1], fruit and vegetable solid wastes[2-5], pineapple processing wastes[6], apple processing waste[7], solid potato waste[8] and many of the fruit peels. Through anaerobic digestion and biogas production, these have great potential in catering for the energy demand, especially in the small-scale or local energy sector.

Fruit and vegetable wastes are highly biodegradable wastes which represent a potential energy resource for producing biogas by biological process[4,9]. Normally presence of cellulose in substrates such as garbage and waste paper are insoluble, but products of cellulose hydrolysis are available as carbon and energy sources for other microbes that inhibit environments in which cellulose is biodegraded and this availability forms the basis of many microbial interactions that occur in anaerobic environments and are a good source of Bioenergy[10]. Increasing the proportion of FVW from 20% to 50% improved the methane yield from 0.23 to 0.45 m^3 CH_4 Kg^{-1} VS_{added} and caused the volatile solid reduction to decrease slightly with the loading rate maintained in the range 3.19-5.01 kg volatile solid per cubic meter per day (kg VS m^{-3} D^{-1})[11]. The anaerobic digestion of different volatile solid mixtures of tomato-plant waste and rabbit waste shows that the methane production increases when the volatile solid concentration of tomato-plant waste increases in the mixture. The addition of the tomato plant waste to the latter in proportion higher than 40 percent improves the methane production obtained from the animal waste alone[12]. The thermophilic digestion of industrial orange waste mixed with municipal solid waste in a continuous stirred tank reactors can produce a methane yield up to 0.6 m^3CH_4/Kg VS for both mixtures of 30-70% and 20-80% OP and MSW respectively. This research was related to the utilization of animal and agricultural wastes for biogas production which is one of the alternative energy. The bio-methane from agro industry waste i.e. mango peel waste, a waste material of the mango pulp industry, is of great interest as a renewable energy carrier that could be used for heat and/or power generation[2].

In this context, this present work was to study the effect of different mixtures of solid wastes of mango processing industry with cow dung for an anaerobic batch digestion process at mesophilic temperatures and also find a mass ratio at which an effective methane production would be attributed and to obtain the data on the degradation rate in the mesophilic range.

MATERIALS AND METHODS

Anaerobic digestion experiments

All the experiments were conducted in 0.5 l serum bottles incubated at 35±2°C. The active volume of reactor was 0.3 l. Anaerobic conditions were established by flushing the bottles with a N_2:CO_2 mixture 75:25 % for 3 to 4minutes and bottles were sealed immediately with rubber stoppers. The outlet in the stopper was used for collecting biogas by water displacement method. Every serum bottles was seeded with 20 ml of the inoculums. Alkali was added to the digester to maintain neutral pH which might drop due to VFA generation. The C/N weight ratio of the organic matter was adjusted to 25:1 using urea, as this is the optimum ratio for maximum microbial activity[9]. Since mango peel is deficient in nitrogen, the feed was always supplemented with 2% urea by weight of total solids. Methanogens have specific growth requirement for iron. Hence one gram of $Fecl_3$ was added to the each bottle. After the addition of substrates, water was added to the serum bottles to make the final % total solids.

Characteristics of feed stock

Solids waste (mango peel) was collected from the mango pulp processing industry located near Dharmapuri, Tamil Nadu. Mango peel was sundried for 30 days ground to fine particles using a grinding mill and screened through pore size of l mm. Fresh cow manure was procured from the local animal farms directly and always from the same cattle farm in order to ensure as uniform feed characteristics as practically possible. The samples were stored at room temperature until use. The properties of feed stock are shown in TABLE 1. The digesters were initially charged with cow-dung slurry diluted with water in the proportion of 4:5 together with a 10% inoculums obtained from predigested cow dung. It was added to the each reactor to initiate the digestion. The mass ratio of cow dung to mango peel in batch studies were 1:1,1:2, 1:5, 1:10,1:15 & 1:20. For each set of mass ratios the digestion mixtures had final concentrations ranging from 4%, 6%, 8%, 10% & 12%.

Analytical methods

Total solids, volatile solids, VFA (steam distillation

TABLE 1 : Characteristics of the mango peel, Cow dung and Inoculum (predigested cow dung) used in the experiments

Characteristics (%)	Mango peel	Cow dung
Moisture	08.2	84.68
Total Solids	91.8	15.32
Volatile Solids	92.3	77.5
Ash	07.7	22.5
Cellulose	6.0	25.0
Hemi cellulose	17.62	19.3
Protein	4.0	15.
Lignin	12	14.25

TABLE 2 : Properties of digestion mixtures at the end of experiments

Ratios of CD:MP	pH					Alkalinity (mg $CaCO_3$/L)				
	4%	6%	8%	10%	12%	4%	6%	8%	10%	12%
1:1	6.9	7.1	6.7	7.2	6.9	6200	6700	8600	6000	7600
1:2	6.8	4.6	6.4	6.3	6.4	8500	5350	8750	9150	9700
1:5	7	6.8	6.6	6.4	6.1	5600	6250	6600	7850	8600
1:10	7.5	7.2	6.5	7.1	7	3500	4600	5000	6000	8100
1:15	6.9	6.9	7.2	6.5	6.7	3200	3400	4000	4600	5000
1:20	7.2	6.7	7.2	7.3	6.8	4600	4600	4400	4600	5200

method) and pH, cellulose, Hemi cellulose, Ash was determined by standard methods as described in the methods of APHA[13]. The total volume of gas produced was measured at a fixed time in each day by water displacement method [9]. Gas samples were collected by gas sampling injector and a sample of 1 ml was used for each run. The biogas composition was determined using gas chromatograph with a packed column and thermal conductivity detector (TCD), using a Propak Q column.

RESULTS AND DISCUSSION

BMP results of mango peel used

Although there is not a single utilization process that can provide a complete solution to the mango peel disposal problems, anaerobic digestion of MP offers essentially a twofold benefit in solving the potential pollution problems. MP was considered to be a cheap source for the supplementation of some nutrients needed during the anaerobic digestion. BMP test in this part of the study were aimed at demonstrating the anaerobic digestion potential of MP and cow dung alone as a reference line. The Specific biogas production for mango peel alone at the end of the study in serum bottles having total concentrations of 6%, 8%, 10% and 12% were measured to 0.6487 $m^3/Kg\ VS_{added}$, 0.6563 $m^3/Kg\ VS_{added}$, 0.4718 $m^3/Kg\ VS_{added}$ and 0.3633 $m^3/KgVS_{added}$ respectively. The cumulative biogas production was almost complete in the first 15 days without any indication of lag time or inhibition. For highest total solid concentration, initially biogas production seemed to slow down for about 7 days, but afterwards biogas production continued with no sign of inhibition resulting to a total biogas production of about 921cm^3.

TABLE 3 : Properties of digestion mixtures at the end of experiments

Ratios of CD:MP	VFA (mg/L)				
	4%	6%	8%	10%	12%
1:1	288	344	376	428	456
1:2	368	388	420	448	500
1:5	480	620	688	716	744
1:10	472	516	612	736	868
1:15	488	516	540	552	568
1:20	496	528	544	512	560

Effect of co-digestion of mango peel with cow dung

The gas production by the various mass ratios of cow dung and mango peel is shown in figure 1. These show the degree of similarity that is achieved. Taken overall, the result suggest that, based purely on the gas production, MP is the most successful for co-digestion with cow dung which is easily available substrates in local area. MP with mass ratio of 1:10 & 1:15 and 6-8% TS can be thought of as materials which would give an appreciable enhancement in gas production. It is important to consider the rates at which the gas is produced. The digesters containing 6-8% TS mixtures produced gas at a higher rate than the cow dung control. These digestions exhibited lag periods. The digesters containing minimum % TS exhibits the lag period of 8days but the mass ratio of 1:10 has minimum lag periods of 4days. Although there is no apparent reason for the control sample having a lag period, it is reasonable to suppose that the additional lag times which occurred with co digestion were due to some characteristics of the mango peel waste.

As well as generating biogas, anaerobic digestion should reduce the VS concentration of the solids. A

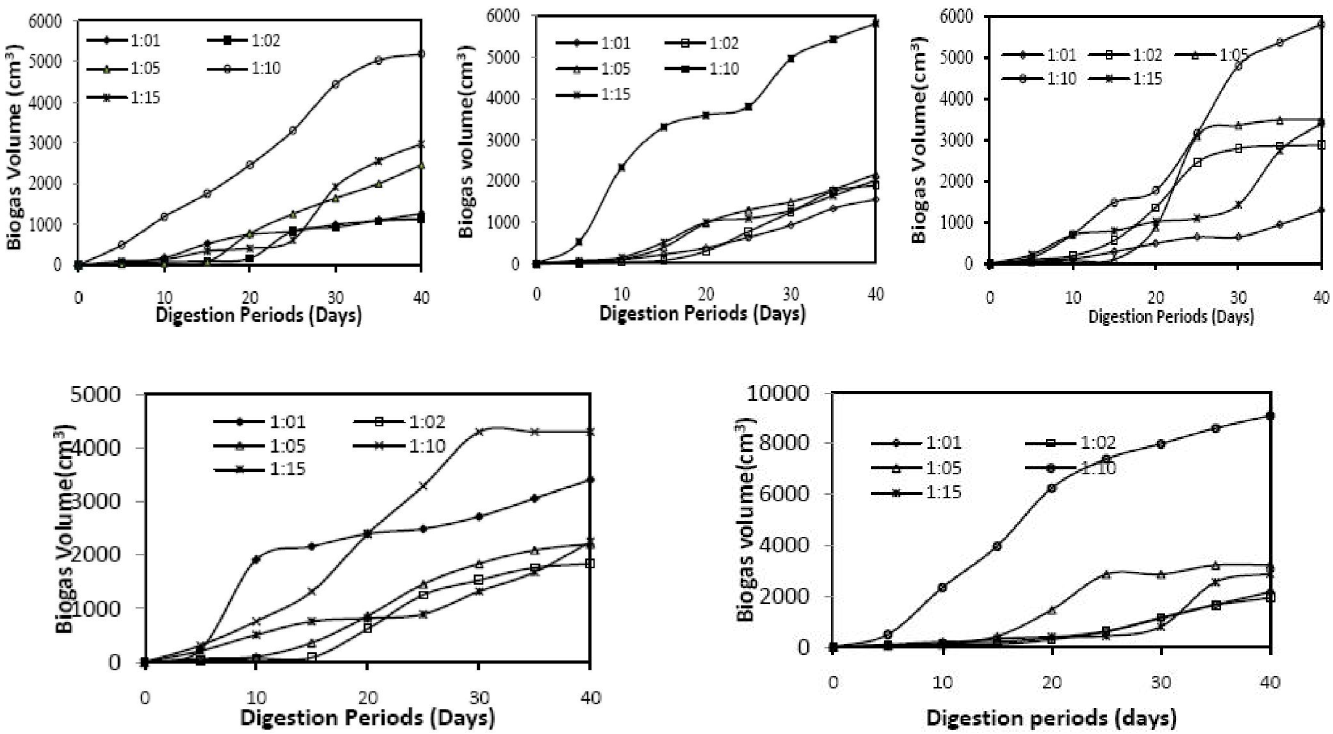

Figure 1 : Cumulative biogas production with digestion periods at different mixing ratios (1:1,1:2, 1:5, 1:10 & 1:15) of 4%, 6%, 8%, 10% & 12%TS

reduction in the volatile solids concentration did occur in all the digestions. Although there were some extremes in general, the reductions were in the range of 93% to 98%. But this shows the higher reductions in the volatile solids, when compared well with the VS reductions which have been reported by other workers examining digestion. From the result it is evident that when mango peel was mixed with cattle dung, it caused higher methane content in biogas from the batch biogas digester than that of cow dung alone, while lower quantity of gas evolved from the mango peel alone as a sole substrate. This is due to the non availability of cellulolytic and methanogenic microorganisms in the mango peel which is essential for biomethanation[14].

The cumulative methane production for different mass ratio digested as mixtures during co-digestion are shown in figure 1. The highest accumulated methane production was 4.4755 l CH_4 for 10% TS and 1:10 Mass ratio and the lowest methane production was 1.14 l CH_4 for 10%TS and 1:1 mass ratio. All the co-digested mixtures performed better than the mango peel digested separately in terms of methane yield. The methane yield ranged from 0.3789 to 4.8853 l CH_4/g VS added with the lowest in 10% TS and the highest in 8% TS. Compared with the methane yield of 0.3938 l CH_4/g VS added for the anaerobic digestion of Mango peel waste alone, co-digestion of mango peel waste with cow dung enhanced methane yield up to 90%. The gas composition reached a maximum of 94% CH_4 during co-digestion (data not shown). The properties of the co-digestion mixtures at the end of the experiments are given in TABLE 2. None of the co-digestion batches was acidified. There was no difference between the initial and final pH and PA values after 50 days of digestion. The pH and PA was in the range 6.4 - 7.0 and 3.5 - 8.7 g $CaCO_3$/l in all the combinations of mango peel waste and cow dung and similar to that of the control. The ammonium-nitrogen increased from the initial value of 0.7 to 1.1 g/l in all the experiments. The total VFA accumulation inside the system was low, i.e in the ranging from 344 mg/L to 736 mg/L (Table no.3). This particular phenomenon is a common indication of a good VFA utilization by the methanogens for methane production [15]. In addition, the available alkalinity is also adequate to buffer the total VFA accumulation in the system, as indicated by low VFA: Alk ratio of between 0.04-0.11. Negligible VFAs were detected at the end of the digestion period in any of the co-digestion or control runs. However no inhibition appeared in the co digestion studies.

The single wastes and mixtures of wastes were studied with regard to methane production in batch assays for a period of 50 days. Co-digestion of potato waste and sugar beet leaves improved the methane yield by 70-80% compared with that from batch digestion of mango peel waste alone and cow dung alone. The marked increase in the methane yield could be due to positive synergism established in the digestion liquor and the supply of additional nutrients by the co-substrates[16]. This is in agreement with an enhancement of about 60% in methane yield observed in studies on co-digestion of industrial confectionery waste with cow manure in a farm-scale biogas plant[17]. The increased methane yield could also be due to an improved C:N ratio and $FeCl_3$ in the co-digestion. The C:N ratios of the co-digested mango peel waste and cowdung, which ranged between 28 and 32, are within the values required for stable anaerobic digestion of organic waste[18,19]. The well-balanced anaerobic digestion in the co-digestion was also evidenced by the absence of VFAs, neutral pH and good PA, observed at the end of the digestion period. Jenkins et al.[20] reported that the PA should be above 1.2 g $CaCO_3$/l for stable operation. The high ammonium-nitrogen concentrations contributed to the high buffering capacity.

CONCLUSION

The use of mango peel as co-digestates with cattle slurry produced an increase in the methane yield, compared with that of a control digestion using cattle slurry alone. The periodic examination of the effluent also showed a characteristic pattern and the pH and VFA were always in the range of 6.4 to 7.20 and 700 to 1200mg/lit. respectively[4]. The concentration of VFA (as acetate) and the alkalinity (as $CaCO_3$) determined in the effluent were on an average 310 and 1220 mg/lit respectively, indicating stable anaerobic digestion conditions[2]. For stable digestion, it is imperative that a satisfactory ratio be maintained between VFA and alkalinity levels. The results of this trial suggest that mango waste is amenable to anaerobic digestion with cow dung at lab scale. This trial was short of duration (50 days) and mango waste material used may have been truly representative of material which would be used at full scale[21].

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