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Biogas production potential of paneer whey, whey-cow dung and whey-poultry litter combinations

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Abstract

The research was conducted at University Livestock Farm and Fodder Research and Development Scheme, Mannuthy using portable floating drum biogas plants of 0.5 m^3 capacity, to study the biogas production potential of paneer whey alone and also in co-digestion with cow dung or poultry litter during monsoon season (25.95±0.160°C). In treatment I, five kg of paneer whey was used for biogas production. In treatment II, 2.5 kg whey was used along with 2.5 kg cow dung. In treatment III 2.5 kg whey was loaded along with 2.5 kg poultry litter. In all cases, biogas plants were loaded daily for 30 days. An adaptation period of ten days was provided before measuring the biogas volume. Composition of whey was analysed using different analytical methods. The various parameters of substrates and digesta along with the total methane content of biogas were determined. Biogas production potential of whey was compared with whey-cow dung and whey-poultry litter combinations. pH value of substrates were 3.89 ± 0.066, 5.90 ± 0.054 and 6.39 ± 0.061 while corresponding pH values of digesta were 6.44 ± 0.26, 5.074 ± 0.076 and 6.22 ± 0.067 for treatment I, II and III, respectively. The whey alone substrate showed highest biogas emission (0.2905±0.0099 m^3). Methane content of biogas were 57 per cent, 35 per cent and 15 per cent for treatment I, II and III, respectively. Suitable pretreatment of farm waste can improve methane content from co-digestion of whey.

Keywords: *Whey, farm waste, biogas, methane content*

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Disposal of dairy effluent without affecting the environment is a challenge for dairy processing industry. The quantity of effluent should be minimised because it involves not only the wastage of valuable nutrients but also the huge expenditure for treating it again. Whey is a byproduct of cheese (or paneer) and casein manufacture. It mainly consists of lactose, salts, lactic acid, proteins and fat. The biogas production from whey by anaerobic breakdown has been accepted as an effective tool for generation of bioenergy. Anaerobic digesters are small man-made ecosystems enclosed in a chamber where the parameters of anaerobic digestion are optimised to yield a steady outflow of biogas. Unlike fossil fuels, biogas by anaerobic digestion is permanently renewable, as it is produced from biomass, which is actually a storehouse of solar energy. Utilisation of biogas as an alternate source of energy is a good strategy to guard against depletion of fossil fuels. Moreover, farmers can utilise this resource for meeting the ever increasing energy needs in a dairy farm. Co-digestion of organic waste is a technology, frequently applied for simultaneous treatments of several solid and liquid organic wastes. In a co-digestion process the content of nutrients, as well as the negative effects of toxic compounds, can be balanced, increasing the gas yield. In this study efficiency of biogas production from paneer whey was compared with combinations of whey with cow dung or poultry litter.

Materials and methods

Collection of raw materials

Whey, was collected from University Dairy Plant, Mannuthy which was a byproduct of preparation of paneer from buffalo milk. Fresh cow dung was collected from University Livestock Farm and poultry litter was collected from All India Co-ordinated Research Project on Poultry for egg, Mannuthy.

Plan and design of experiments

Three portable floating drum biogas plants of 0.5 m^3 capacity, designed by Agro Biotechnology Agency for Rural Employment Development, Kerala Agricultural University were utilised for the study. In treatment I, five litres of whey were loaded daily into the biogas plant. In treatment II, 2.5 litres whey was mixed with 2.5 kg cow dung and mixture was loaded. In treatment III a mixture of 2.5 kg whey and 2.5 kg poultry litter was used. Ten days were provided as an adaptation period for each treatment. Observations were made each morning for the next 20 days.

Analysis of whey

The fat content of whey samples was determined according to the procedure laid out by the Bureau of Indian Standards (IS:1224, 1977). Lactose content of whey was determined using colorimetric method according to Teles *et al*. (1978). The Kjeldahl method (BIS, 1981) was used for estimation of total protein content of whey. The titratable acidity of whey samples was determined according to the procedure prescribed by the Bureau of Indian Standards (IS: 1479, 2016).

Analysis of substrate and digesta

The pH (pH meter) and temperature of the substrate and digesta were recorded daily before loading. The total solids of substrates and digesta samples were determined according to the procedure laid out by the Bureau of Indian Standards (IS: 12333, 1997).

Volume of biogas and methane content

The volume of gas produced in each treatment was measured daily. The increase in height of dome was recorded and volume was calculated from the following equation (Paudel, 2012).

Volume of the biogas, $V = \pi r^2 h$ where r = radius of gas dome; h= difference in height of the dome. The total methane content in percentage was measured using methane analyser (Jijo *et al.,* 2014) developed by Central Instrumentation Laboratory, College of Veterinary and Animal Sciences, Mannuthy

Statistical analysis

The statistical analysis was done using one way analysis of variance (ANOVA) (Snedecor and Cochran, 1994).

Table 1. Mean pH, Total solids content of substrates and digesta under different treatments

Sl. No.	Treatment	Substrate/ Digesta	pH	TS%
1	Whey alone	Whey	3.89 ± 0.066	5.53 ± 0.25
		Digesta	6.44 ± 0.26	6.67 ± 0.33
2	Whey-cow dung	Whey-Cow dung	5.90 ± 0.054	7.21 ± 0.114
		Digesta	5.074 ± 0.076	7.38 ± 0.14
3	Whey-poultry litter	Whey-Poultry liter	6.39 ± 0.061	9.86 ± 0.143
		Digesta	6.22 ± 0.067	9.79 ± 0.155

Results and discussion

The present study was carried out in monsoon season at an average ambient temperature of 25.95 ± 0.160°C. The mean temperature of digesta in three biogas plants were 28.80 ± 0.235, 26.18 ± 0.147 and 25.71 ± 0.61 for whey, whey-cow dung and whey-poultry litter, respectively. Wang *et al.* (2019) observed that moderate temperatures above 25°C were more conducive to high biogas production efficiency and microbial activity was inhibited towards 20°C. Temperatures used in our experiment were ideal for biogas production.

pH of substrate and digesta

The mean pH, total solids content of substrates and digesta under different treatments are depicted in Table 1. In treatment I substrate (whey) had a very low mean pH of 3.89±0.066 while in treatment II and III mean pH values of substrates were 5.90 ± 0.054 and 6.39 ± 0.061, respectively. The corresponding pH values of digesta were 6.44 ± 0.26, 5.074 ± 0.076 and 6.22 ± 0.067, respectively. Rugele *et al.* (2013) reported a higher pH of 4.54 for whey and they opined that the lactose, major solid in whey could be easily degraded into acid products mostly acetate and propionate. These workers used cheese whey for their research while in our study use of paneer whey, prepared by the addition of citric acid produced a lower pH than their findings. Lower pH of whey was also contributed by the rapid conversion of whey lactose into volatile fatty acids by acidogenic microorganisms (Ghaly *et al*., 2000).

Total solids content of whey and digesta

The total solids content of substrates and digesta under different treatments are given in Table 1. The average total solid content of whey (treatment I) was estimated as 5.53 ±0.25. This result agrees with Goyal and Gandhi (2009) who had observed a total solid percentage ranging from 5 to 6 for paneer whey. The mean total solid content of treatment II and III were 7.21 and 9.86, respectively. Rajendran *et al*. (2012) reported that the solid concentration in the household biogas digesters varied between five per cent and 10 per cent which is in accordance with present study. In the case of digesta, total solid content of treatment I, II and III were recorded as 6.67, 7.38 and 9.79 per cent, respectively.

Composition of whey

Mean lactose and protein contents (per cent) of whey in the present study were found to be 4.490±0.870 and 0.42±0.05, respectively. This result is very much comparable with the estimations of Goyal and Gandhi (2009) who had reported lactose and total protein content of whey as 4.5±0.89 and 0.41±0.89, respectively. A similar report on lactose content (4.5-5 per cent) in whey was given by Seesuriyachan *et al*. (2009). A higher lactose (4.85 per cent) and lower protein (0.30 per cent) content were observed by Rugele *et al.* (2013). The average total solid content (per cent) of whey was estimated as 5.53 ±0.25. Mean titratable acidity of paneer whey samples was estimated as 1.3490±0.0713 (per cent lactic acid). These results are in accordance with Shukla *et al*. (2013) who noticed that titratable acidity of whey ranged between 0.39 and 1.35 percentage.

In this study mean fat percentage of whey was found to be 0.2700 ± 0.0105. This result is comparable with the observations of Goyal and Gandhi (2009) who had reported the fat percentage of whey as 0.10 to 0.26. Pinto *et al.* (2008) reported a fat percentage of 0.38±0.12 for whey probably because cheese whey was used for analysis. The low fat percentage obtained in the present study could be justified with the report by Masud *et al.* (1992) who had stated that paneer whey had very low amount of fat. Variations in composition of whey may result from variations in composition of milk, method of preparation, etc.

Analysis of biogas

The gas volume (m^3) was found to be highest for whey (0.29 ±.009) followed by whey-poultry litter (0.059±0.001) and whey-cow dung (0.025±.001) combinations (Fig. 1). There was significant difference ($p<0.05$) in biogas production between substrates. The increased gas production observed from whey in the present study is in agreement with the report by Ghaly and Ramkumar (1999) where they reported the high biogas production potential of whey in their research studies. Braun (2002) had also noticed that emission of gas from digestion of wastes with good fluid dynamics was found to be higher than solid wastes. The biogas production from whey was found to be greater than the gas production from whey- manure mixtures which is in agreement with finding by Al Imam *et al*. (2013) who had reported that cow dung had low gas production potential (0.46 m^3 biogas from 13.5 kg of cow dung).

Percentage of methane content of biogas produced from whey was 57 per cent which was higher than whey-cow dung (35per cent) and whey-poultry litter (15 per cent) combinations (Fig. 2). A similar result was reported by Rugele *et al*. (2013) where the estimated methane content of cheese whey was around 50 per cent. This high methane content found in whey is attributed to high lactose content of paneer whey (Gonzalez, 2006) which is rapidly broken down into energy yielding metabolites by anaerobic digestion (Ghaly and Ramkumar, 1999). Beszedes *et al*. (2010) opined that higher biodegradability of whey for the production of methane was also contributed by the enhanced hydrolysis of whey proteins. The co-digestion of whey with cow dung or poultry litter was less efficient in biogas production. A similar result (30.5 per cent) was noticed for whey-cow dung combination by Murto *et al*. (2004). Braun (2002) reported that, farm wastes with poor fluid dynamics

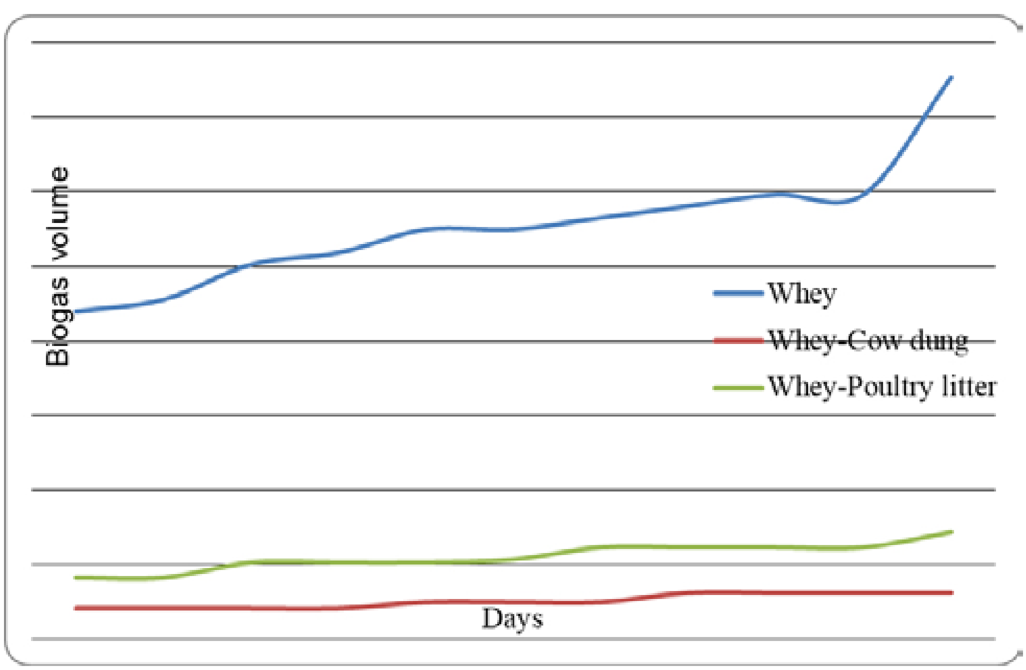

Fig. 1. Gas volume (m^3) observed with different treatments

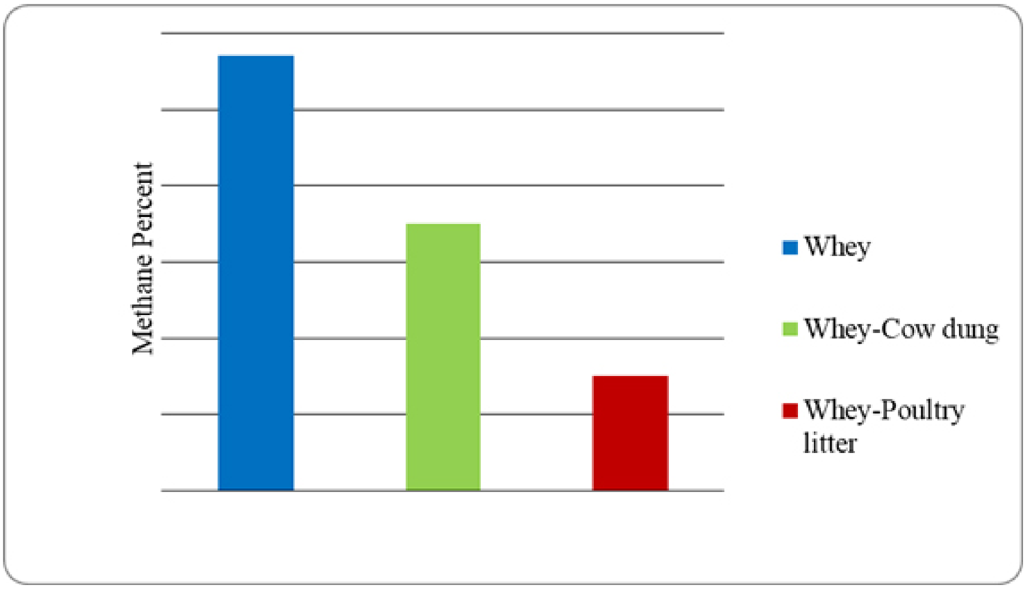

Fig.2. Comparison of methane content of different substrates

such as cow dung could not produce methane gas as liquid manure such as whey or sewage sludge. Carlini *et al.* (2015) noticed that biogas production from co-digestion of cheese whey and poultry manure was most efficient in the ratio 1:1, but findings of our study is contrary to that report. These authors diluted poultry manure for adjusting C/N ratio and for diluting uric acid. This modification reduced emission of ammonia and improved methane yield. Our experiment recorded better gas volume with poultry litter-whey combination than cow dung-whey combination but methane content was lower possibly due to ammonia emission. This prediction was further substantiated by Bojti *et al.* (2017) who found that water extraction from raw chicken manure elevated carbon to nitrogen ratio of the substrate and improved methane production.

Ellcuriaga *et al.* (2021) opined that co-digestion of livestock farm waste with agricultural waste will supply additional nutrients and equilibrate the feeding mixture and improve biogas production potential. Valenti *et al.* (2018) concluded from a trial conducted at southern Italy that a combination of Citrus pulp (42%), poultry litter (8%), cattle dung (4%), corn silage (17%) and whey (18%) was the most efficient in biogas production.

Conclusion

The results of our study revealed that paneer whey can be effectively used as a substrate for biofuel because it resulted in better biogas volume and higher methane yield. Since most of commercial farms have portable type biogas plants, utilisation of whey from the production of paneer will be an added advantage. It is also suggested that suitable modifications like dilution of farm waste so as to adjust C/N ratio of substrates will make co-digestion of whey with farm waste more effective for methane production by anaerobic digestion. Agricultural byproducts available in the state like pineapple waste, silage waste etc. could be tried along with whey and farm waste to improve the efficiency of reactors. Future studies are recommended in this direction.

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Conflicts of interest

The authors declare that there is no conflict of interest

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