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Enhancing biogas production through anaerobic co-digestion

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Abstract
Alternative energy sources have become vital for future world stability and biogas production from organic wastes is gaining importance. Mono-digestion of animal manure is having limitations and co-digestion is an optimistic solution to overcome the bottlenecks. Study was conducted to evaluate co-digestion of livestock manures in different combinations *viz.*, T1 (cattle manure), T2 (cattle + goat manure), T3 (cattle + poultry), T4 (cattle + swine manure) in 1:1 ratio for estimating quantity and quality of biogas. An average daily yield (L) of 10.24 ± 0.11, 15.39 ± 0.86, 13.73 ± 0.64, and 16.41 ± 0.10 respectively for T1, T2, T3 and T4 with methane yield ranging between 54-62 percent. T4 substrate with cattle and swine manure had produced superior biogas in terms of quantity and quality when compared to other combinations.

Keywords: Co-digestion, livestock manure, biogas

1. Introduction
Alternative energy sources have become vital for future world stability. The most important attribute of alternative energy source is their environmental compatibility which had attracted the peer communities for its adoption [5]. Renewable energy sources like biogas produced from organic waste materials of intensified agricultural sector activities have become one of the most striking substitutes in the present scenario to meet global energy security.
Animal manure is nutrient rich agricultural fertilizers and is also a beneficial resource for the renewable energy production by anaerobic digestion (AD). AD will result in biogas production and significant reduction in volume of manure and the digested sludge can be used as a fertilizer for the agricultural fields [11]. The major advantage of utilizing manure as a source for biogas production is being available as a domestic resource in the rural areas and can reduce the dependency on fossil fuels. Hence, waste to energy (WTE) technologies like biogas technology should be widely employed for the utilization of animal manure and to mitigate the climate change arising due to the unscientific management of animal manure. It has also been recognized that using animal manure alone may not represent the most efficient way to produce biogas due to its low carbon/nitrogen ratio [12]. An attempt has been made to study the co-digestion of livestock manures for enhanced performance of the digester.

2. Materials and Methods
The study was conducted to evaluate co-digestion of livestock manures utilizing portable floating drum biogas plants of 0.5 m^3 capacity, designed by Agro Biotechnology Agency for Rural Employment Development (ABARD), Kerala Agricultural University (KAU), Vellanikara. Two Kg. fresh manure of the farm animals namely cattle, goat, poultry and swine in 1:1 ratio *viz.*, T1 (cattle manure), T2 (cattle + goat manure), T3 (cattle + poultry), T4 (cattle + swine manure) were used as substrate. Water is added in each treatment at 1:1 ratio on whole weight basis [9]. Before loading, fresh samples of the substrates from each treatment were collected and analyzed to determine TS and N content. Moisture free samples were analyzed for Volatile solids and C on DM basis [1]. Volume of gas produced in each treatment was measured daily in the morning (8 am). The increase in height of gas holder was recorded and volume was calculated using the formula, volume of the biogas, $V = \pi r^2 h$.Where, r denotes radius of gas holder and h denotes the increase in height after gas production.
Composition of biogas was determined using Multi Gas Analyzer [3]. The data obtained on various parameters during the course of study was statistically analyzed using SPSS Version 24.0.

3. Results and Discussion

Total solid (TS) content of different substrates was around 7 - 10 percent (Table. 1) and significant difference was noticed between the treatments. Ideal TS content for carrying out anaerobic digestion was below 10 percent [3]. Volatile solid (VS) content in different treatments was varying significantly and T1 is having more volatile solid content. C/N ratio was ranging from 18 – 27 in all the treatments.

Table 1: Chemical characteristics of substrate

Treatment	Total solids (TS)%	Volatile solids (VS)%	C/N ratio
T1	$7.53^{d} \pm 0.69$	$84.23^{a} \pm 0.34$	$18.42^{c} \pm 0.66$
T 2	$9.78^{b} \pm 0.69$	$81.66^{b} \pm 0.34$	$27.62^{a} \pm 0.66$
T3	$10.32^{a} \pm 0.69$	$61.52^{d} \pm 0.34$	$16.66^{d} \pm 0.66$
T4	$8.77^{c} \pm 0.69$	$72.84^{c} \pm 0.34$	$25.48^{b} \pm 0.66$

*means having different superscripts within same column differ significantly at 0.05 level.

The biogas yield was depicted in Fig.1. Gas production began from 2nd day after loading. But it was not considered as it was very low in quantity and rich in oxygen. Barik and Murugan [2] have observed a similar trend of low quantity and inferior quality of biogas till 10th day after loading. The observations were recorded from 8th day onwards as the gas is ignitable in nature and sufficient quantity is obtained to record. Initially, T1 and T2 have produced biogas more rapidly when compared to T3 and T4. Rico *et al.,* [12] has reported that ruminant manure was suitable for the initiation of anaerobic digestion due to the presence of more native micro flora. During the experimental period, a sudden cessation of biogas yield is noticed. A similar trend was observed by Liu *et al.,* [7] and he has opined that the drop in gas production was due to drop in the pH of the digester. Li *et al*., [6] reported that a decrease in the pH of the digester to below 6.5 will cease the gas production.

Average daily yield (L) was highest in T4 (16.41 ± 0.10) followed by T2 (15.39 ± 0.86), T3 (13.73 ± 0.64) and T1 (10.24 ± 0.11). A significant difference was observed between the treatments. Cumulative biogas yield (L) was 485.22, 650.57, 567.65, and 667.74 for T1, T2, T3 and T4 respectively (Fig. 1). Highest yield in T4 can be attributed to the presence of pig manure which is rich in fat and protein when compared to other substrates [8]. C/N ratio of T4 is 25.48 ± 0.66 which is the most optimized ratio for obtaining an enhanced biogas yield [2]. A shift in the C/N ratio from optimum was detrimental to the methanogens due to the decreased utilization of volatile fatty acids (VFA) [13]. Even though T1 is having higher VS content, the gas production was less when compared to other substrates due to the reduced efficiency of methanogens in utilizing the VFA's produced.

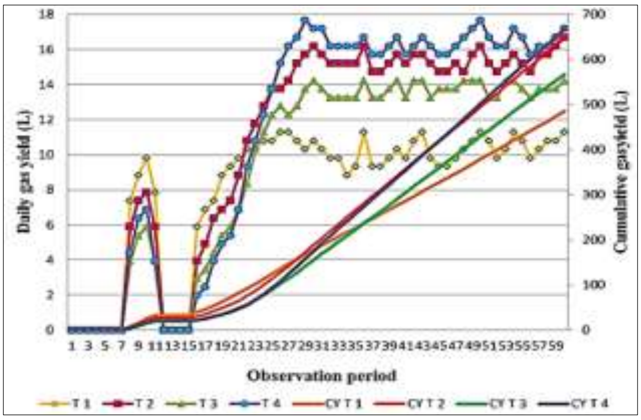

Fig 1: Biogas yield (l) from different livestock manures

Methane content was significantly different in all the treatments (Fig. 2) ranging between 54 to 62 percent. Highest methane yield was obtained in T4 followed by T3, T2 and T1. A shift in the C/N ratio from the optimum will cause a decreased efficiency of methanogens resulting in a reduced average methane yield [13]. In T3, C/N ratio was very low but the methane yield is high when compared to T1 and T2 because carbon-dioxide will be absorbed at alkaline pH [14] and pH turns towards alkaline in the digester with substrates containing more nitrogen content (less C/N ratio) [2].

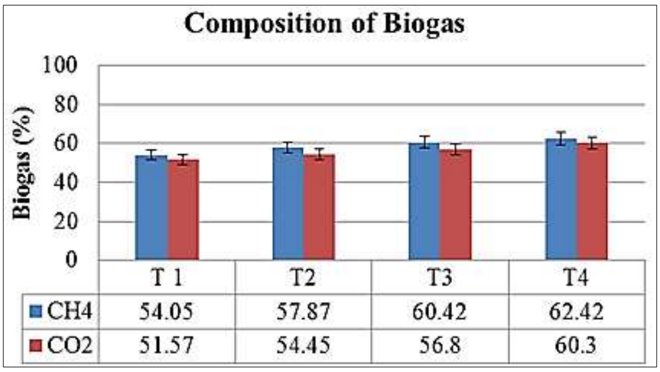

Fig 2: Composition of biogas from different livestock manures

4. Conclusion

Anaerobic co-digestion of livestock manures carried out for enhanced biogas production had an average daily yield (L) of 10.24 ± 0.11, 15.39 ± 0.86, 13.73 ± 0.64, and 16.41 ± 0.10 respectively for T1, T2, T3 and T4. Cumulative yield observed (L) was 485.22, 650.57, 567.65, and 667.74 for T1, T2, T3 and T4 respectively. It can be concluded that the substrate composition is one of the major factor which had a greater influence on the qualitative and quantitative attributes of biogas. Hence, the co-digestion of substrates with varied composition should be conducted for enhanced biogas production and better utilization of animal manure.

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