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A preliminary study on co-digestion of ossein industry waste for methane production

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Abstract

Sinews is a pasty proteinaceous by-product discharged from a primary bone clarification tank in the ossein industry, which was mixed with cattle dung in different proportions at ambient temperature. This study found that a mixture of sinews (40%) and cattle dung (60%) was more appropriate for enhanced methane yields with a high efficacy on anaerobic degradation. A maximum cumulative biogas production volume (18 L) with 71-77% methane content was obtained even with more parts of the sinews were used as a substrate. The best biogas production yield was 23.4 L biogas/Kg TVS added, revealed the suitability of the sinews mixture (40%) in the biomethanation process. In addition, the pH of each digester was not shifted to alkaline which was constantly maintained within optimal range during the course of digestion. Perhaps, this alternate strategy will be helpful for managing the odor produced from sinews during bulk storage.

Keywords: Biogas, co-digestion, methane, ossein industry waste, stickland pathway.

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INTRODUCTION

Anaerobic digestion systems have undergone many modifications in the last two decades, mainly as results of the energy crises. Major developments have been made with regard to anaerobic metabolism, physiological interactions among different microbial species, effect of toxic compounds and biomass accumulation. The anaerobic process would be an economically attractive alternative for the treatment of different types of industrial wastes including wastes of the collagenous (Lalitha et al. 1994), gelatin (Vieira et al. 2001), slaughterhouse (Braun et al. 2003) and meat processing industries (Resch et al. 2006). Nevertheless, a little attention has been made on the bioconversion of ossein industry waste into methane gas (Kalavathy et al. 2001).

During the process of raw gelatin production from cattle bones in the ossein (bone) industry, a huge quantity of sinews is discharged, as one of the by-products, from the primary clarification tank. Cattle bones are soaked in water and with alum in a clarification tank for at least 10 days. The bone waste collected from a discharging outlet seems to be fibrous and greases with a pasty matter containing little pieces of bones, and hairs. It is composed with a higher quantity of proteins and a small amount of lipids. This is thought as a major means to the origin of the odor around the ossein industry. Methanethiol, dimethyl sulfide and dimethyl disulfide are odor causing compounds produced from bio-solids (Chen et al. 2005). Though one of the odor control strategies is the preservation and enhancement of methanogenic populations during bio-solid storage (Lomans et al. 2002; Chen et al. 2005), the highly loaded and stable co-digestion of protein substrates would be a good technical and economic treatment alternative (Resch et al. 2006). In this context, this present work was to study the

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effect of different mixtures of sinews with cattle dung for an anaerobic batch digestion process at ambient temperature and also find a ratio at which an effective methane production would be attributed.

MATERIAL AND METHODS

Biomethanation process

A wet form of sinews was collected from the Pioneer-Myagi Indo-Japan Company at Cuddalore, India and preserved immediately in a plastic container at 4°C. Sinews and fresh cattle dung (final wet weight one kg, w/w) with an equal volume of tap water was loaded into a 2.4 L bottle digester in different proportions (20% to 80% sinews) and the contents mixed thoroughly by hand. The cattle dung served as both a substrate and microbial source. Each experiment was at ambient temperature in our field lab and the biogas production volume was recorded daily using the saline water (20% NaCl, w/v, pH 4.0) displacement method (Chellapandi 2004). All experiments were carried out in triplicate. Constituents of feed stocks and digested slurry were analyzed by the methods described by Anonymous (1989).

Gas chromatographic analysis

The methane content (%) in the produced biogas was measured (Kalavathy et al. 2001) by using a gas chromatograph (Hewlett Packard), connected with a flame ionization detector (FID) and data integrator. 100 μL of gas was injected into a 2m Porapak-T (80-100 mesh) steel column using a gas-tight syringe at a flow rate of 30 mL/min^{-1}. Nitrogen and hydrogen was used as carrier gas and fuel gas, respectively. The column, injector and detector temperatures were 75, 110 and 120°C, respectively.

RESULTS AND DISCUSSION

Cattle dung is traditionally employed as a feedstock for biogas production in rural sectors. We need to seek alternative biomasses from available bio-resources due to shortage of the cattle dung availability in the last two-decades. Many of the industrial wastes have been exploited for biogas production to compensate for the electricity needs in the industrial sectors. Thus, the ossein industry waste, particularly sinews, was selected as a substrate for biogas production in this study. It consisted of (in %) 42 ± 1 total solids, 78 ± 4 total volatile solids, 90 ± 4 protein and 7 ± 1 lipids in the dried matter. As proteins are a major part of the sinews, it was assumed to cause the probable ammonia toxicity to the methanogens involved in the biomethanation process at the late stage, suggesting either the use of cattle dung or other carbon sources are mandatory to establish the growth of the anaerobic consortia.

A notable biogas volume started to produce after 20 days, reached a maximum production at 30-33 days, and yielded up to 58 days steadily (Fig. 1). This delayed production of appreciable biogas is therefore probably due to the methanogens establishing their metamorphic growths by consuming methane precursors generated from the initial anaerobic digestion process, particularly through the hydrolytic and acetogenic phases (Lalitha et al. 1994, Bal and Dhagat 2001). A mixture of cattle dung (60%) and sinews (40%) gave the maximum biogas production (3.3 L/d) at 33 days. The biogas production rate slightly decreased with the increase in the addition of cattle dung to the sinews implying that a specific mixture of these biomasses is needed to optimize the anaerobic microorganisms.

The methane content (74%) in produced biogas increased with digestion time of 29 days and hence, was obviously maintained until 42 days as shown in Fig. 2. When a digester was fed with 20% cattle dung and 80% sinews, a poor yield in methane was reported due to ammonia accumulation (data not shown) exerted by a high protein content in the sinews. The Stickland pathway has already reported the concerns of the oxidation of amino acids (glycine and alanine) from biological wastes containing more proportions of protein to a volatile carboxylic acid (acetate) and one carbon atom shorter than the original amino acid, which can further be converted into methane. About 40% of amino acids can proceed coupled to other amino acid reactions and uncoupled degradation of the remaining amino acids must have relied on the uptake of hydrogen produced from these reactions by hydrogen consuming methanogens (Ramasamy and Pullammanappallil 2001). This suggested the

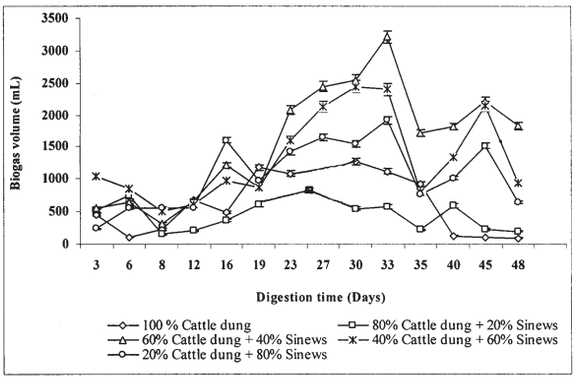

Fig. 1. Effect of different mixtures of sinews with cattle dung for biogas production in a batch digester.

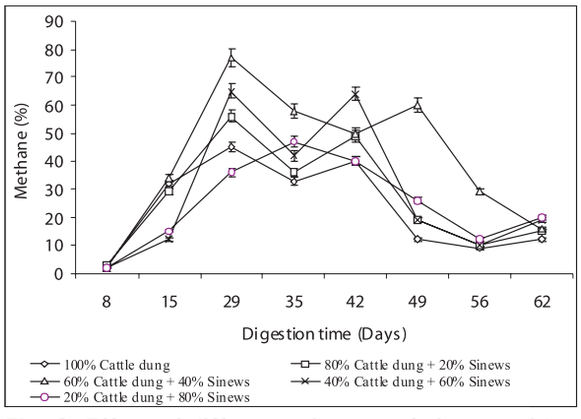

Fig. 2. Effect of different mixtures of sinews with cattle dung for methane production in a batch digester.

possible ways to utilize bone waste by anaerobic microorganisms for the biomethanation process.

An intensive and stable digestion of partly hydrolyzed organic wastes and protein rich slaughterhouse waste has been achieved in the balance of inconsistent pH and buffering NH4-N (Resch et al. 2006). Similarly, we found that the pH in all digesters was continuously maintained at optimal range (6.5-8.0) (data not shown). Considering the implication of pH optima until the course of digestion, this biomass has been suggested for a pilot-scale study.

The best biogas production yield (23.4 L biogas/kg TVS added) with 77 ± 6% methane content was obtained with a mixture containing 40% sinews and 60% cattle dung (Table 1). The high proportion of sinews did not diminish the methane production yield, but adding more cattle dung supported for an effective anaerobic digestion (82% after 49 days), not the methane yield. This is probably attributed due to the existence of greatly established and acclimatized hydrolytic consortia, and an inadequate magnitude of methanogenic populations. This also directly concerns the long acclimatization process of the methanogenic consortia required for more biogas yield in a batch digester (Chellapandi 2004).

Our findings are thought to be more significant because of both improved methane and cumulative biogas yield achieved even at ambient temperature, which was fairly better than the control substrate. In addition, a digester with a suitable proportion of this biological waste showed a good working performance until the end of digestion, it suggested the possibility of use for bio-solid management in the ossein industry. Another noteworthy use of this waste is that due to the availability of more minerals from this substrate it can be considered for enhancing the growth of methanogens involved in the anaerobic digestion process. An enhanced biogas production has been reported earlier in the presence of cobalt, nickel, magnesium, calcium, iron and manganese in the digesters (Jarvis et al. 1991, Raju et al. 1994, Preeti and Seenayya 1994). Methanogens have proved to play a key role in the removing of volatile organic sulfur compounds (VOSC) through anaerobic methylation of H_2S,

Table 1. Effect of different mixtures of sinews with cattle dung on the biomethanation process after 40 days.

	To	T1	T2	T3	T4
Cumulative biogas volume (L)	7.5±0.8	4.5±0.4	18.0± 0.9	15.5±0.8	2.7± 0.4
Production yield (L biogas/kg TVS added)	9.98 ± 0.9	5.87 ± 0.5	23.47 ± 1.8	20.04 ± 1.2	16.39 ± 1.0
Specific production rate (L biogas/kg TVS added/days)	0.25 ± 0.01	0.14 ± 0.01	0.59 ± 0.1	0.50 ± 0.1	0.40 ± 0.1
Best methane content (%)	45 ± 3	56 ± 4	77 ± 6	65 ± 6	47 ± 5
Total solid reduction (%)#	82 ± 4	62 ± 6	56 ± 5	50 ± 3	68 ± 6

#Determined after 49 days (digester volume was 2.4 L)
To: 100% Cattle dung; T1: 80% Cattle dung + 20% Sinews; T2: 60% Cattle dung + 40% Sinews; T3: 40% Cattle dung + 60% Sinews; T4: 20 % Cattle dung + 80% Sinews

methanethiol and sulfur containing amino acids and reducing odors. Methane production is related to reduce VOSC production from which dimethyl sulfide and methanethiol are consumed by sulfur reducing bacteria and methanogens respectively under anoxic conditions (Lomans et al. 2002, Visscher et al. 2003, Chen et al. 2005).

CONCLUSION

Overall, an establishment of a methanogenic consortium in anaerobic digesters using sinews as a substrate could be one of the alternative ways for managing odor as well as solid waste management in the ossein industry. This present finding is comparatively better than the results obtained by Kalavathy et al. (2001) on sinews. Thus, only a selective proportion of sinews and cattle dung can be suggested to improve the efficacy of anaerobic digestion for methane generation with great extent. Besides, the odor emitted from the sinews in the ossein industry will be successfully managed by a co-digestion task in an eco-friendly manner and in an economic way.

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Metan Uretimi Icin Osein Endustrisi Atiginin Ko-sindirimi Uzerine Oncul Bir Calisma

Ozet

Kiris (tendon), kemik tutkali endustrisinde, birincil kemik temizleme tankindan atilan, macun kivaminda proteinimsi bir yan urundur. Cevre isisinda, parti halinde (toplu olarak) degisik oranlarda sigir diskisi ile degistirildi. Bu calismada, kiris (%40) ve sigir diskisi (%60) karisiminin, anaerobik parcalanmada buyuk bir etkinlikle, yuksek metan verimi icin daha uygun oldugu bulunmustur. Substrat olarak daha fazla kiris kisimlari kullanildiginda bile, %71-77 metan icerigi olan maksimum toplam biyogaz uretim hacmi (18 L) elde edildi. En iyi biyogaz uretim eldesi 23,4 L biyogaz/kg idi. Eklenen TVS biyometanlama surecinde kiris (%40) kullanilmasinin uygunlugunu ortaya cikarmistir. Buna ilaveten, herbir sindiricinin pH'si alkaline kaymadi ve sindirim boyunca surekli olarak optimal aralikta kaldi. Bu alternatif strateji, muhtemelen, endustrideki toplu kiris depolanmasindan kaynaklanan kokularin kontrol altina alinmasinda faydali olacaktir.

Anahtar Kelimeler: Biyogaz, ko-sindirim, metan, osein endustrisi atigi, stickland yolu.