Renewable Biochemical Methane Potential through Anaerobic Co-digestion from Selective Feed Stocks

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Abstract: Biochemical Methane Potential (BMP) analysis provides a measure of the anaerobic biodegradability of a given substrate. BMP test is also used to evaluate the potential biogas (methane) production between various substrates. This test is also used to determine the amount of organic carbon in a given material that can be anaerobically converted to methane. Studies were carried out for the production of biogas from the leather solid waste. Co-digestion (simultaneous digestion of two or more substrates) studies were carried out in batch reactors using the fleshing (a solid waste generated during the processing of raw hides or skins into finished leather) along with the fruit and vegetable waste at mesophilic condition (35°C). The anaerobic methanogenic seed sludge prepared separately followed by standard BMP test, which was used as the seed inoculums. Recent research on this topic is reviewed in this current paper.

Keywords: BMP, Anaerobic digestion, Anaerobic Co-digestion, Methane, Mesophilic Condition

1. Introduction:
Anaerobic digestion is the multi-step biological process during which organic material is converted to a gas in the absence of oxygen which contains mainly CH₄ and CO₂. Methane could be a source of renewable energy producing electricity in combined heat and power plants. Anaerobic digestion (AD) technology is increasingly important for waste management as it generates renewable energy from industrial and municipal solid wastes in an environmentally benign way [1]. Anaerobic digestion of fleshing waste (LF) has been extensively researched and demonstrated. However based on investment returns from energy production, economics of fleshing digesters are not favorable due to the relatively low biodegradability of LF as compared to many other types of organic waste such as vegetable waste. One of the best approaches for improving the biogas production rate is Co-digestion of Leather Flesh (LF) with vegetable waste (VW).

Co-digestion of different materials may enhance the anaerobic digestion process due to the better carbon and nutrient balance [2, 3]. The use of co-substrates usually improves the biogas yields from anaerobic digester due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates [4]. The most common situation is when a major amount of a
main basic substrate (e.g. manure or sewage sludge) is mixed and digested together with minor amounts of a single, or a variety of additional substrate.

The tanning industry is one of the oldest and fastest growing industries in South and Southeast Asia. There are more than 3000 tanneries located in India with a total processing capacity of 700,000 tons of hides and skins per year [5]. Reuse of lime fleshing, rawhide and pelt trimmings in the production of valuable products, is frequently not feasible. Most of the leather solid wastes are currently land filled, resulting in air and water pollution, as well as emission of greenhouse gases like methane and carbon dioxide. The hide or skin consists of three layers, a top epidermal layer, middle corium layer (used to make actual leather) and bottom adipose tissue. The top and middle layer and bottom adipose tissue are the principal solid wastes generated from leather making and are termed fleshing (LF) and this waste is around 15% by weight of raw hide/skin processed to leather [6].

Anaerobic digestion (or) Biomethanation systems are nature and proven processes that have the potential to convert tannery wastes into energy efficiently, and achieve the goals of pollution reduction & elimination of uncontrolled methane emissions and on site recovery of energy potential as biogas, production of stabilized residue for use as low grade fertilizer, fleshing is characterized by moisture 870 g kg$^{-1}$; protein 40-50 g kg$^{-1}$; fat 10-20 g kg$^{-1}$; at a 1000 kg raw hide, nearly 850 kg is generated as solid wastes in leather processing[7]. Only 150 Kg of the raw material is converted into leather. Hence, obligatory measures must be undertaken for the innovative reuse of fleshing [8].

Fruit and vegetable waste (FVW) has also been evaluated as a digester feed-stock by a number of workers with a methane production of 0.37 m$^3$ kg$^{-1}$ VS being reported [9]. Vegetable wastes, due to high biodegradability nature and high moisture content (75 – 90%) seemed to be a good substrate for bio-energy recovery through anaerobic digestion process [10]. However, the operation of anaerobic digester fed with FW was not very effective and stable due to the accumulation of volatile fatty acids (VFAs) When the FVW is aerobically digested individually, sometimes low stability and low efficiency of operation may happen due to its low C/N ratio. Therefore, co-digestion of FW or FVW with other organic wastes, such as municipal sludge, animal manure, and agricultural biomass become more popular [11,12]. Co-digestion of FVW with LF may give an alternative solution for possible operational problems, but there is a limited research conducted on the co-digestion with FVW and LF. The main objective of the research was to evaluate the effect of biogas yield of LF and to assess the energy benefit gained from the co-digestion.

2. Materials and methods:

2.1 Leather Fleshing (LF), Fruit and Vegetable Waste (FVW)

LF is collected from the Tanneries in and around Dindigul namely Pallapatti and Ponmandurai pudupatti, sludge was collected from the TALCO, Tamil Nadu, and India. FVW is collected from the Oddanchattram Market, Dindigul, India. Characterization of substrates was carried out using Standard methods (APHA) [13]. The characteristics of LF and FVW are shown in Table 1 &2 respectively.

| Table 1. Characteristics of LF |
|--------------------------------|
| Parameter | Value |
| pH | 12-12.5 |
| Moisture | 79-92% |
| VS | 0.6-0.75 |
| COD | 0.66-0.95 |
2.2 Inocula
Anaerobic sludge with good methanogenesis activity was used as inocula to the digester. The samples were collected from common effluent treatment plant, TALCO, Tamil Nadu, India. The required amount of sample for the experimental purpose is then taken and maintained in a closed airtight container and nutrients are added to the seed sludge. Enrichment solution is provided for the enrichment of microorganisms. This enriched population of microbes is called the seed sludge. Here the substrate used is, the leather fleshing and vegetable waste.

2.3 Analytical Method
PH was measured using digital pH meter. Total solids (TS), Volatile solids (VS), Alkalinity and Volatile fatty acids & Ammonia (steam distillation method) were estimated according to the procedures recommended in the Standard methods for examination of water and waste water

2.4 Biochemical methane potential Test
The BMP assay can be used as an index of the anaerobic biodegradation potential. The BMP is measured with BMP test, which consists in measuring the bio-methane or biogas produced by a known quantity of waste in an anaerobic condition.

Biochemical methane potential (BMP) tests were performed in 500 ml Erlenmeyer flask. Methane production rate is determined using the method of Batch system. It is the simplest form of digestion. Biomass is added to the reactor at the start of the process in a batch and is sealed for the duration of the process. The experimental setup for BMP test is shown in figure 1.

Table 2 Characteristics of FVW

| Ph         | 7.5-9.0 |
|------------|---------|
| VS %       | 80-85%  |
| TS%        | 8-12%   |
Substrates are added to the 500ml batch reactor. Anaerobic sludge is added to the serum bottle with a tube having its outlet end dipped in the water in the flask. This is done to minimize the contact of oxygen. The flask is tightly capped and connected to a fluid displacement system which containing NaOH. NaOH solution is chosen because it absorbs CO$_2$ and allows CH$_4$ to pass through it. This BMP test is conducted for Different substrate with different pH and Different ratio. The following figure (2.a) & (2.b) shows that the sealed Batch reactor and Water displacement system.
3. Result and Discussion:

The biogas and other process performance parameters were evaluated using Batch reactors at different feed stock to sludge ratios. The optimum \(\text{pH}\) used in the present study was 6.5. The setup was kept and analyzed for a period of 15 days. The supernatants were withdrawn and were subjected to analysis of the following parameters: \(\text{pH}\), alkalinity, daily gas production, volatile fatty acids (VFA), ammonia using standard methods for the examination of water and waste water [14].

In the methanogenesis process, the accumulation of VFA denotes the reduction of \(\text{pH}\). Supporting this, the biogas yield also decreases with decrease in \(\text{pH}\) due to hindrance of methanogenesis [15]. The optimum biogas production was observed at a \(\text{pH}\) of 6.5, consequently with \(\text{pH}\) value greater than 6.5, there exists a significant reduction in the biogas yield. Fig 3 shows the biogas production at different \(\text{pH}\).

![Cumulative Gas Production](image_url)
There are different ratios that were used to find out the optimum blend. The optimum biogas production was observed at the ratio of 1:0.5. Figure 4 shows the biogas production at different ratios.

In initial days there was a significant increase in VFA resulted in increase of methane production. But at the same time, after certain stage increase in VFA decreased the gas production. Figure 5 shows the VFA levels at different ratios.

Figure 4. Gas production at different ratio

Figure 5(a). VFA levels at different ratios.
The removal efficiency of total solids & volatile solids was 25% & 39 % respectively. The COD removal efficiency was 82%. The percentage of an aerobically digestible COD also provides a good estimate of the digester efficiency that could be achieved.

Figure 5(b). COD ratio

![COD Ratio Graph](image)

The ammoniacal nitrogen has a direct relationship with pH. During the digestion the free form of ammonia liberated, inhibits methane production due to the ammonical toxigenic effect. In this study the ammoniacal nitrogen decreased with increase in VFA. Hence there is a less possibility of ammoniacal toxicity.

Figure 5(c). Gas Production Relationship between VFA & NH₃

![Gas Production Graph](image)
4. CONCLUSION:
The biogas process was evaluated using pH, VFA, Alkalinity and Ammonia. Co-digesting improves nutrient balance and enhances pH buffer capacity. The pH plays an important role in anaerobic digestion. At pH around 6.5 maximum methane productions was observed when maximum conditions were found at a pH of 6.5 and the ratio of 1:0.5. Cumulative biogas yield increased from 560 ml to 1216 ml with optimum blend. Optimum blend observed from the study is 1:0.5. Blending of co-digested LF and vegetable waste helps to maximize the renewable energy recovery through the anaerobic co-digestion process.

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