CHAPTER 4

EXPERIMENTAL INVESTIGATION ON BIOGAS GENERATION

Mitigation of green house gas emissions through renewable energy production is of increasing importance. Biogas production is a key technology for the sustainable use of agrarian biomass. Utilization of biogas has gained importance in recent years due to its renewable, environmental compatible and cheap nature. Further, with an increase in the cost of petroleum products, biogas can be an effective alternative source of energy for cooking, lighting, food processing, irrigation, rural electrification, and several other requirements.

Anaerobic digestion has been used for many years to treat strong organic wastes, primarily of domestic origin. Digestion seemed a possible method for reducing the pollution caused by farm slurries and also to be a method by pollution control, which could give energy. Biogas technology contributes the following.

- It provides a better and cheaper fuel for cooking, lighting, and power generation.
- It provides good quality, enriched manure to improve soil fertility.
- It provides an effective and convenient way for sanitary disposal.
• It generates social benefits such as reducing burden on forest for fuel wood, reduction in the drudgery of women and children etc.

• As a smokeless domestic fuel it reduces the incidence of eye and lung diseases.

Biogas plants can be classified in several ways depending upon the design and mode of operation. One common way of classification is to categorise these as movable drum type and fixed dome type. The plants can also be classified as batch type, semi-continuous and continuous fed type. The batch type digester gives less average gas production and has high hydraulic residence time (HRT). It is suitable for crop and forest wastes, agro-industrial wastes and the same has been considered in the present work.

The de-oiled cakes have been traditionally used as a fertilizer to meet the requirements of the soil. The de-oiled cake of Pongamia pinnata, remaining after the extraction of oil from the seeds is rich in carbon and hydrogen contents and has no particular value as a fertilizer, but has high potential to yield biogas. The objective of the present experimental work is to investigate the anaerobic treatability and methane generation potential of the de-oiled cake of Pongamia pinnata by performing biochemical methane potential (BMP) test in a batch type digester with out provision to control the parameters affecting biogas generation. In addition, the work includes the study of the variation of different parameters that affect the anaerobic digestion such as pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia nitrogen and total nitrogen during the various stages of biogas generation.
4.1 EXPERIMENTAL SET UP

The experimental set up consists of a digester with a stirrer and a provision to collect and measure the amount of biogas generated during the anaerobic digestion process. The schematic representation of the experimental set up is shown in Figure 4.1.

![Diagram of experimental set up]

**Figure 4.1 Schematic representation of the experimental set up**

4.1.1 Digester

A batch digester of capacity 20 liters with a stirrer is fabricated from a stainless steel drum with necessary feeding and sampling arrangements. The dimensions of the digester are as given below.

\[
\begin{align*}
D &: 0.24 \text{ m} \\
H &: 0.45 \text{ m} \\
V &: 0.020 \text{ m}^3
\end{align*}
\]
Stainless steel is chosen to avoid corrosion and the possible reaction between the digester material and the sludge. The lid is permanently sealed and is brazed to the body to avoid any possible gas leakage. A pressure gauge is attached to the lid to indicate the pressure inside the digester. A ball valve is provided in the side of the digester to regulate the flow of the generated biogas and to route it to the gas collector. Another bigger ball valve is provided at the bottom of the digester to take slurry samples for testing and also to feed the feedstock during repeated trials. The drum is clamped to the worktable. A photographic view of the laboratory scale digester for the batch process employed is shown in Figure 2.2.

4.1.2 Stirrer

A stirrer is provided inside the digester to achieve proper mixing of the digester contents and also to enhance the fermentation process. It consists of a stainless steel rod (shaft) with blades and is powered by an electric motor of capacity 0.25 HP capable of revolving at 500-5000 rpm. The shaft is enclosed in a mild steel bush. O-rings are provided to arrest the possible gas leak through the stirrer arrangement. The O-rings get compressed and are fixed to the shaft rigidly inside the bush.

4.1.3 Gas measurement

The gas measurement is based on downward water displacement technique. Biogas generated from the digester tank passes through a one-way valve into the gasholder. A graduated glass tube of 10-liter capacity is used as the gasholder and is kept in the inverted position in the water reservoir.
Initially, this gasholder is filled with water to the brim. As the biogas enters continuously, water is displaced into the water reservoir tank due to the biogas pressure. This procedure is a water-displacement technique. The water reservoir can be kept at an appropriate elevation to provide a desirable pressure to the outlet gas by water displacement. This technique also increases the solubility of carbon dioxide in the water.

4.2 EXPERIMENTATION

The oil cake was crushed and sieved to the required fineness and was added with the required quantity of water and inoculum to maintain 8% total solids. In order to maintain the C : N ratio, a small quantity of cow dung was added. Digested slurry from a well established cow dung digester was added as the source of microbial inoculum. The slurry inside the digester was
periodically stirred. The daily gas output was recorded. Periodically, slurry sample was collected through the bottom gate valve in a small euro bag to measure the various parameter values. The pressure inside the digester was closely monitored. A series of experiments was carried out. As there was slight deviation among the values of different trials, the average value of the trials has been taken into consideration. The error associated with the measurement of gas collection in the collector tank is indicated in the Appendix 1.

4.3 RESULTS AND DISCUSSION

In this study biochemical methane potential (BMP) test was performed in order to investigate the biogas generation potential of the de-oiled cake of Pongamia pinnata. The daily gas generation, cumulative gas generation, variation of pH, COD, BOD, ammonia nitrogen and total nitrogen during the gas generation period are discussed in this section. As a result of anaerobic digestion process, biogas to the tune of 185 liters was generated over a period of 21 days with 66% CH₄, 33% CO₂ by volume and negligible amount of traces of other hydrocarbons.

4.3.1 Cumulative gas generation

The daily and the cumulative biogas generated are illustrated in Figure 4.3. Most of the gas generation in the digester was completed within 21 days, which is in agreement with Isci et al (2007). They reported 23 days for fermentation of caster cakes. Gas generation started in the 3rd day, dropped suddenly and then a gradual increase in production rate was observed till 9th day. Majority of the gas collection was recorded between 5th and 15th day. The cumulative gas production was 185 liters where as in the literature, it is reported that 400 liters would be possible per kg per day on a continuous daily
Figure 4.3 Daily and cumulative gas generation

4.3.2 pH variation

The variation of pH during the gas generation period along with the cumulative gas generation is shown in Figure 4.4. As seen from the diagram, the pH varies from 6.4 to 7.2. In the initial period of fermentation, a drop in pH was noted which is due to formation of large amount of organic acids produced by acid forming bacteria.
This inhibits the fermentation process due to the fact that methogenic bacteria are very sensitive to pH and do not thrive below 6.5. This is reflected in the corresponding reduction in the gas generation. Later as the digestion process proceeds, concentration of NH$_4$ increases due to the digestion of N$_2$, which results in increased pH value. After the stabilization of gas generation, the pH value increased and remained above 7.

### 4.3.3 COD variation

Figure 4.5 shows the variation of COD during the gas generation period along with the cumulative gas generation. As seen from the diagram, during the initial stage of fermentation, an increase in COD was noted till the 6$^{th}$ day and then it started decreasing till the end. The initial increase is due to the fact that some of the particulate organic matters were hydrolyzed and solubilized. This initial increase in COD resulted in the corresponding reduction in the gas generation during the same period.
After this, a gradual reduction in COD was noted till the end of gas generation. Nearly 86% of the COD reduction has been achieved during the bio-digestion process.

4.3.4 BOD variation

The variation of BOD during the gas generation period along with the cumulative gas generation is shown in Figure 4.6. The variation characteristic of BOD during the period of gas generation is very similar to that of COD. The value of BOD increased in the initial stage of fermentation and then started decreasing till the end of the acclimation period. The BOD reduction is due to substantial biomass production with low biogas generation in the later stage of fermentation.
4.3.5 Ammonia Nitrogen variation

The variation of ammonia nitrogen during the gas generation period along with the cumulative gas generation is shown in Figure 4.7. Accumulation of nitrogen in the sludge of the biodigestion process is an additional advantage of getting improved manure value and hence the variation of nitrogen was observed during the biodigestion process. The ammonia nitrogen at the beginning and end was less than the toxic limits for the anaerobic digestion process. During the period of gas generation, the ammonia nitrogen started increasing till the 12\textsuperscript{th} day (peak gas generation period) and there after started reducing and reached a final value higher than the initial value recorded for the cake. The initial rise in the value could be due to the hydrolysis of protein during the digestion process with the consequent liberation of ammonia.
Figure 4.7 Variation of ammonia nitrogen during gas generation period

4.3.6 Total nitrogen variation

The variation of total nitrogen during the gas generation period along with the cumulative gas generation is shown in Figure 4.8. The total nitrogen includes organic nitrogen, ammonia nitrogen, nitrates and nitrides. The pattern of variation for the total nitrogen is very similar to that of ammonia nitrogen.
Figure 4.8 Variation of total nitrogen during gas generation period

4.3.7 Manure value

The sludge coming out of the digester after the biodigestion process contains improved N, P, K values and hence it has better manure value than the raw oil cake. Biogas manure (BgM) is promising and capable of supplying essential nutrients, enhanced water holding capacity and soil erosion, accelerated root growth and inhibited weed seed germination. Thus the biodigestion process apart from producing a clean source of energy produces better manure for agriculture.