Preliminary Laboratory Experiments on Production of Biogas from Different Biomass

The biogas production from Gobar has been used extensively. It is imperative that other available biomass like plants should also be utilised for biogas production. Gobar is an ideal biomass rich in C-content (about 9-9.5 of the total mass) and is present as adequately homogenised mass which can be converted into slurry with simple addition of water. Other dung samples and human excreta can be similarly treated.

Huge quantity of biomass coming from the terrestrial ecosystems, animal excretion and residues in agricultural remains from crops after harvest can be recycled for the conservation of energy and minimization of pollution. The economics of the biogas plants utilizing the organic substrates like raw jute sticks, banana stem, water hyacinth, municipal wastes etc. should be assessed taking proper consideration regarding the mode of collection, transportation, processing and utilization of wastes in harnessing them either by way of production of a) compost or b) biogas.

Raw jute sticks, banana stem, municipal wastes, market wastes, water hyacinth, sewage etc. are some easily available biomass which can be recycled for energy purposes. These can be utilized singly or collectively (as mixed biomass) for economic generation of fuel. The criteria for selection of the biomass are:

1) fairly rich in carbon content,
2) ready availability in large quantities at moderate cost,
3) transportation and charging of biomasses easy and economical,
4) Consumption of end products i.e. biogas and digested slurry (to the agricultural field) is easy and economic.

The screening of the biomass should, therefore, be made to assess their viability as an economic source of wastes for biogas production.

Raw jute sticks are available only seasonally. There were about 2480 tonnes of jute sticks in 1981-82 (in India) and the production appears to be more or less stagnant. They are to be crushed and pretreated before they can be subjected to biomethanation. The cost of the jute sticks are relatively high and they are usually utilised for the production of paper pulp, newsprint, box board, smokeless charcoal etc.

The banana stem is available in plenty in India. West Bengal also shares production of banana in the districts Hooghly, Burdwan Midnapore etc which are fairly away from our place. The collection and transportation of the banana stem proved costly and trouble-some. Production of methane from the biogasification of banana pealing (BP) and Ipomoea fistulasa leaves (IF L) and their 75 : 25 mixture had been reported to be good (Sharma et al. 1988).

Municipal waste is another unending source of biomass. However, wastes contain garbage (or food organic wastes) along with rubbish or roughage content paper, rage, wood, polymers (usually not biodegradable), glass, wood, grass etc., ash and soils. Roughage contents in the municipal wastes are usually 50-60% of the total. The separation of these wastes proved to be costly. Unless
proper care is taken to isolate organic wastes from other wastes, biogas production cannot be suitable choice. However, it is well known that rags, papers, metal scraps, plastic and glass materials etc. if collected properly can be used for various purposes making resource generation.

Efforts had been made to utilise water hyacinth, perthenium, market wastes, sewage and other available weeds as biomass as such and as mixed biomass. Water hyacinth, an aquatic plant is available in plenty in rural Bengal. Moreover, its growth is extremely rapid and the production cost is negligible. (Water hyacinth notoriously known as 'Bengal tiger' grows in ponds and scavenges heavy metals, nitrogen, phosphorus and other toxic substances from water). Therefore, steady availability of water hyacinth can be assumed.

Perthenium, another weed, causing concern for its pollution characteristics, have been found to be fairly available (particularly during the rainy season and after). It can be suitably utilised.

Market wastes, mainly vegetable wastes, can be utilised for anaerobic digestions.

It is known that market waste contains a numerous biodegradable substrates, rotten vegetables, fruit skin, potatoes etc. having high potentiality for biogas production. These were subjected to biomethanation in a 25 l capacity laboratory scale digester for 75 days. The production of biogas was reported to be 35 l kg$^{-1}$ at 20 days of hydraulic retention time.

But the economics of production and other details are lacking (Ranade et al. 1987).
Sewage containing industrial and domestic effluents is another unending source of biomass.

The aquatic plant hydrilla when available during the rainy season was also utilized.

For the continuous and economic running of a digester of moderate capacity, the biomass requirement is quite large. Therefore, search for other weeds and plants, fairly available throughout the year was made to assess their suitability as biomass. The water, carbon and nitrogen contents of different plant biomass were estimated using standard laboratory procedure.

The C, N, water and ash contents of the dung samples were also estimated given in Table 1. The water and ash content of dung samples are also recorded in Table 2.

However, the carbon content of plant materials are usually low (3-7% of the total mass). The use of plant materials requires cutting the roots and chopping or crushing them into appropriate sizes. Nearly homogenised slurry increases biogas production. Pretreatment of properly sized plant biomass is usually helpful for increased production.

Experimental:

1. Determination of water content: (Humphries, 1956)

The sample was placed in a weighed porcelain boat and weighed. It was placed in an electric oven at 105°C for several until constant weight was attained. The percentage of moisture was thus calculated.

2. Estimation of organic matter: (Humphris, 1956)
The sample after elimination of moisture content was ignited in an electric furnace to about 650 - 700°C for more than 30 minutes. The sample was then covered with a mica sheet and ignition was continued for an hour. The usual method of cooling and weighing till a constancy between two consecutive weights agree were followed. The percentage of the organic matter was calculated from the loss in weight.


Accurate estimate of organic matter involves the oxidation of the sample by N K₂Cr₂O₇ solution in presence of concentrated H₂SO₄ acid. However, for a rough estimate the total organic matter was divided by 1.724 on the assumption that the plant organic matter contains roughly 58% carbon.

4. Determination of ash content: (Humphries, 1956)

The dried sample was heated in a porcelain boat in the muffle furnace at 800°C for 6 hours.

The remains formed ash content of the sample.

5. Estimation of Nitrogen (N): (Humphries, 1956)

Reagents (1) 50% H₂SO₄ solution (2) 20% CuSO₄ solution (3) 30% NaOH (cooled) solution + 5% Na₂S₂O₃ mixture (4) N/50 HCl, N/50 NaOH and N/50 oxalic acid solutions were prepared and estimated standard procedures. (5) Weslow's indicator containing equal volume of solutions (A) and (B).

Solution A - Methyl red (125 mg dissolved in rectified spirit)

Solution B - Methylene Blue (83 mg dissolved in rectified spirit).
Procedure:

Digestion: 20 mg of dried sample was digested for 6-8 hours in a microkjeldahl flask adding 3 ml of 50% H₂SO₄, 1 ml of 20% CuSO₄ solution and a few crystals of K₂SO₄ till a clear solution was obtained. N was converted to (NH₄)₂SO₄·7.

Steam distillation: Markham-Smith's apparatus was profusely steamed and washed thoroughly for 30 minutes. When a steady state was reached, 20 ml of 30% NaOH + 5% Na₂S₂O₃ was poured into the distilling chamber through the funnel and the tip of the condenser was dipped in 20 ml of standard N/20 HCl with a drop of Weslow's indicator (colour in acid solution - pink) in a receiving flask. The digested material prepared previously was poured in the contents totally and carefully into the distilling chamber through the funnel. Care was taken to ensure the complete transfer of the digested material into the distilling chamber. The distillation was allowed to continue for about 30 minutes for the completion of the reaction as indicated by the chocolate brown colour of the contents in the distillation chamber.

The excess HCl in the receiving flask was titrated against N/50 NaOH and nitrogen content of the material was estimated.

Calculation

1 (N) of HCl ≡ 1 (N) NH₃

1 ml of N/50 HCl = 0.28 mg of N.

It is to be noted that the plants materials could not be
thoroughly homogenised resulting in considerable error in the estimated values.

The results are presented in Table 1.

It is to be noted though we have enough of different biodegradable biomass but the real difficulty lies in their proper utilization. This requires the conditions for maximum economic methane generation though laboratory scale experiments had been made, but the economic viability for the commercial production of methane from these biomass is yet to be ascertained properly.

Production of biogas using aspirator bottles:

The green water hyacinth (or hydrilla) were chopped, pulverised (after eliminating the roots) and made into slurry with sufficient amount of water containing calcium carbonate to make the solution alkaline (pH 7.5 - 8.0). Different concentrations (approximately 3, 8, 10, 12 and 20 wt. % estimated by drying the slurry and then heating to 120°C for an hour) of biomass were taken. They were subjected to biomethanation in closed aspirator bottles and conical flasks using added inoculum (like Gobar, Goat dung etc.) or without added inoculum in presence of sunlight and in absence of sunlight. The aspirator bottles (or conical flasks) were made airtight with rubber corks, properly sealed having outlet and inlet tubes for gas collection and passing inert gas like N₂ (Fig. 1).

The openings were properly closed with pinch cocks.

The biogas production started and was fairly appreciable from 3 to 6 days depending on the pulverisation of biomass.
The collection of gas was made over water in closed eudiometer tube during the day time. Occasional filling of the gas in balloons were also made for the analysis of methane content. Biogas production became quite appreciable even during night and the pressure created were sufficient to remove the rubber corks after seven to ten days. Therefore, the analysis was rather qualitative.

The biogas production was appreciable even upto 25 days after which gas production decreased.

The percentage of methane was 45-57% approximately from 7 to 10 days upto 20 to 24 days. The study was discontinued after 30 days. The other substrates (biomass) were similarly treated and anaerobic digestions were carried out. The results were more or less similar but the yield of % CH\textsubscript{4} was different for different cases. Some of the generalizations from our study are given below:

(a) pH of the digester slurry decreased considerably (below pH 6.5) after 17 to 20 days depending on experimental conditions and biomass selected and the production of biogas also decreased.

(b) A solid biomass concentration of 6-8% N at best 10% usually gave good result. Higher biomass concentration was not suitable for anaerobic digestion. The digested sludge became sticky with increase in the concentration of solid biomass and the gas production dropped.

(c) Biogas production increased as the particle size decreased. The greater the pulverization, the greater was the yield, the gas generation was very high even after 24 days.
(d) As expected, biogas production increased if water hyacinth or perthenium was mixed with Gobar or dung samples. But no appreciable increase was observed with mixed plant biomass.

(e) Anaerobic digestion of biomass first digested with acid (dil H₂SO₄) for an hour and subsequently digested with alkali (pH 8-9) increased the yield. However, fresh inoculum like Gobar, Goat dung etc. is to be added before anaerobic digestion.

(f) Sunlight usually increased biogas production.

(g) The optimum temperature of 35-40°C appeared to be suitable for gas production. At higher temperature, methane production decreased considerably.

(h) The biomass containing mucilagenous substance gave low yield of gas.

(i) As expected, sterilized biomass required considerable amount of added inoculum.

(j) The solid content of waterhyacinth (~ 7%) or hydrilla and other plant biomass are usually low compared to dung samples. The biogas production required considerable amount of water. So the biogas plants were usually of large volume. Thus a low cost technology should be favoured for biogas generation to make it economically viable.

(k) Excess of water should be avoided. If definitely lowered gas production as the concentration of biomass per unit volume of slurry will decrease and it will be harmful for fermentation. But
water content must be sufficiently high 85-90%.

The observations may be helpful for biogas production in the commercial or semicommercial scale though the results derived microscopically differ widely from the results derived from commercial biogas plants.

Biogasification of market wastes at low biomass concentration (upto 10% solid):

Laboratory experiments showed that methane production is usually good with market wastes (55-60% of CH\textsubscript{4} as observed from CH\textsubscript{4} production using Netal Gas Chromatograph, Model Omega QC, India). However mucilegenous substances, if present in the market wastes, abnormally reduces the CH\textsubscript{4}-production. Biogas formation was vigorous if the wastes are pulverized. Appreciable gas production occured even within 24-48 hours. The biogas formation became maximum usually within 9 to 12 days depending on the condition of the experiment. The pHs of the media were usually 8-8.5 initially which dropped gradually and became 6.4-6.8 within 15 to 18 days. Naturally, CH\textsubscript{4} production also decreased. The change in C-content was only 5-6% after 10 days but increased with the degree of pulverization. Once charged, the gas formation continued for a longtime.

Solid Gasification of concentrated market wastes:

The different ways of gasification of solid wastes are given below (schematically):
Pyrolysis, Steam refining and partial oxidation was beyond the scope of the investigation. The experimental set up was also not congenial for undertaking those processes. Only laboratory scale digestion of solid biomass was studied. The sundried market wastes were pulverised and mixed thoroughly with inoculum and subjected to biomethanation anaerobically in aspirator bottles. The solid biomass content was roughly in the order of 15%, and 20% by weight. The systems were made anoxygenic by passing N$_2$ gas. The brisk biogas production was observed within 24-48 hours. The gas production was only 4-5% in terms of total carbon content of the biomass in 15 days and methane content of the biogas ranged from 45-60%.

It is apparent that conversion of waste was low. In general, biomethanation required a fairly large volume of water and a solid mass content of 8-10% is good for biogasification by anaerobic digestion process.
References:


Table 1 Physico-Chemical data of different plants on the basis of airdried sample (averages from five sets of measurements)

<table>
<thead>
<tr>
<th>Biological Name of the plants</th>
<th>% Moisture</th>
<th>% Organic content</th>
<th>% Carbon content</th>
<th>% N</th>
<th>% Water from fresh plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Eichhornia sp.</td>
<td>10.14</td>
<td>82.50</td>
<td>47.85</td>
<td>1.66</td>
<td>89.59</td>
</tr>
<tr>
<td>2. Parthenium hirsutum</td>
<td>14.47</td>
<td>83.25</td>
<td>48.29</td>
<td>5.39</td>
<td>82.84</td>
</tr>
<tr>
<td>3. Cassia sopheria</td>
<td>11.87</td>
<td>82.83</td>
<td>48.04</td>
<td>3.74</td>
<td>67.55</td>
</tr>
<tr>
<td>4. Cassia fristula</td>
<td>12.05</td>
<td>75.90</td>
<td>44.02</td>
<td>4.49</td>
<td>62.52</td>
</tr>
<tr>
<td>5. Solanum toryum</td>
<td>14.34</td>
<td>72.96</td>
<td>42.32</td>
<td>3.32</td>
<td>86.66</td>
</tr>
<tr>
<td>6. Croton bonplandianum</td>
<td>13.00</td>
<td>76.75</td>
<td>44.51</td>
<td>1.52</td>
<td>77.71</td>
</tr>
<tr>
<td>7. Jatropha gradiflora</td>
<td>18.55</td>
<td>67.38</td>
<td>39.08</td>
<td>4.15</td>
<td>87.51</td>
</tr>
<tr>
<td>8. Green coconut</td>
<td>18.16</td>
<td>79.57</td>
<td>46.16</td>
<td></td>
<td>60.45</td>
</tr>
<tr>
<td>9. Calotrope metel</td>
<td>8.34</td>
<td>85.41</td>
<td>48.91</td>
<td>3.45</td>
<td>82.60</td>
</tr>
<tr>
<td>10. Clerodendron viscosum</td>
<td>3.96</td>
<td>92.43</td>
<td>53.61</td>
<td>2.41</td>
<td>72.84</td>
</tr>
<tr>
<td>11. Cestrum diarnum</td>
<td>7.00</td>
<td>91.36</td>
<td>52.99</td>
<td>3.52</td>
<td>77.95</td>
</tr>
<tr>
<td>12. Lantana camara</td>
<td>5.00</td>
<td>89.56</td>
<td>51.95</td>
<td>1.47</td>
<td>63.37</td>
</tr>
<tr>
<td>13. Jatropha rotleri</td>
<td>6.30</td>
<td>87.43</td>
<td>50.71</td>
<td>1.66</td>
<td>77.17</td>
</tr>
<tr>
<td>14. Ipomea Impetance</td>
<td>4.80</td>
<td>85.94</td>
<td>49.85</td>
<td>1.93</td>
<td>69.46</td>
</tr>
</tbody>
</table>
Table 2 Water and ash content determination (averages from five sets of measurements)

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Water content (%)</th>
<th>Ash content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cow dung</td>
<td>82.0</td>
<td>4.8</td>
</tr>
<tr>
<td>2. Buffalo Dung</td>
<td>81.2</td>
<td>5.5</td>
</tr>
<tr>
<td>3. Goat dung</td>
<td>59.3</td>
<td>10.6</td>
</tr>
<tr>
<td>4. Piggery wastes</td>
<td>61.3</td>
<td>9.7</td>
</tr>
<tr>
<td>5. Poultry wastes</td>
<td>76.0</td>
<td>6.0</td>
</tr>
<tr>
<td>6. Water hyacinth</td>
<td>84.0</td>
<td>3.8</td>
</tr>
<tr>
<td>7. Parthenium sp.</td>
<td>49.0</td>
<td>18.8</td>
</tr>
</tbody>
</table>
FIG. 1 PRODUCTION OF BIOGAS USING ASPIRATOR BOTTLE