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Production of Biogas at Mesophilic and Thermophilic Temperatures

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Experiments were accomplished for the production of biogas using a slurry comprising 50% fresh buffalo dung and 50% water at ambient and elevated temperatures. After 2 weeks, observations for the release of biogas were noted. It was observed that with the increase of temperature, the rate of generation of gas was enhanced. A slurry containing 200 g fresh buffalo dung and 200 g water produced 121.5 ml gas / day at an average ambient temperature of 35°C, whereas at 45°C, 50°C, 55°C and 60°C, the average rates of gas generation were noted as 152.0, 221.5,292.0 and 354.0 ml / day. The volume of 232.5 ml of biogas in excess was produced with the temperature difference of 25°C (60°C - 35°C). The input of 42000 joules of energy for heating 400 ml of slurry produced gas of 5196.375 joules. It shows that there is a loss of 36803.625 joules of heat which makes the process, thermally, not viable. Hence, ambient temperature is recommended for the production of biogas for domestic plants.

Keywords: Buyffalo dung, Fermentaion, Biogas, Thermophilic temperatures.

Introduction

Biogas generation is one of the techniques for the utilization of animal, agricultural and industrial wastes, combating deforestation and better environment by disposing of wastes beneficially. A voluminous work has been done on biogas generation to improve the technology and to make it economical (Christopher *et al* 1973; Govinda 1983; Narasimhamurty and Purush 1986; Ismat Ali 1987a; 1993b; and 1994c; Kishore 1989; Kasali 1989; Liachena 1989; Qureshi 1989). Biogas, generated from digestion of animal excreta, is composed of methane (60 - 65%) and carbon dioxide (35 - 40%) and traces of hydrogen sulphide (H_2S) of heating value 22.35 MJ / m^3. Usually, it is being produced at ambient temperature when the slurry containing cow / buffalo dung is kept in sealed vessel at ambient temperature. The biogas produced is an ideal domestic fuel for cooking and lighting. The gas is smokeless, inexpensive and environment friendly as the raw material (animal refuse) is abundantly, available in the villages of developing/underdeveloped countries either free or at very reasonable cost. On comparison, the cost of biogas with other domestic fuels, it is found lowest / cheapest. The cost of biogas is approximately Rs.100/- per Giga joule, whereas, the cost of Liquefied Petroleum Gases (LPG), kerosene, charcoal, wood are Rs.750/=, 400/=, 250/=, 180/=, for one Giga joule, respectively. The cost of these fuels is constantly increasing day by day. The only drawback of this technology is the low rate biogas generation. It is 0.25 unit per unit of slurry per day (Ismat Ali 1993). Attempts have been made to produce biogas at elevated temperature to examine the enhancement in the rate of biogas generation.

Since, the technology of biogas generation is simple and straight forward, it does not need any technical skill to operate and maintain biogas plants. Hence, this technology is recommended for such areas (particularly villages) where natural gas is not available to meet domestic fuel requirements. This paper describes the methods of biogas generation at ambient and elevated temperatures (45°C, 50°C, 55°C, 60°C) with a view to examine its economic feasibility.

Experimental

Material. Buffalo dung and water.

Procedure. In laboratory, 400 g slurry (buffalo dung + water in equal proportion) was confined in one litter amber colored reagent bottle stoppered and connected them with polythene tubes to 10 litter aspirators as shown in Fig 1 (a & b). The main aim of connecting the aspirators was to collect the gas by displacing water and the displaced water was collected in graduated cylinder. The amount of water collected in the cylinder was assumed equal to the amount of the gas produced per day. Five such sets of experiements were designed to examine the rate of gas generation. One of the set of experiments was kept at ambient temperature, whereas, other four sets of experiments were controlled at 45°C, 50°C, 55°C, 60°C (Fig 1 a & b).

Analysis of animal excreta. Normally, animal excreta (buffalo dung) contains 80% moisture when fresh. It is in emul-

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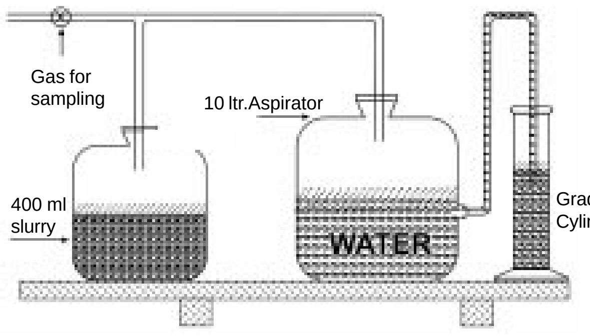

Fig 1(a). Experimental setup for biogas generation at ambient temperatures

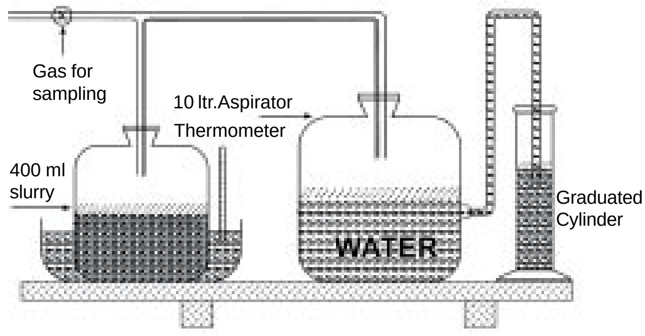

Fig 1(b). Experimental setup for biogas generation at elevated teperatures

Table 1
Proximate analysis of buffalo dung (Aerial and oven dried)

Constituents	%	% on dry basis
Water	74.4	
Moisture (corrected on Mac - 400)	5.4	
Total water	79.6	
Volatile matter 650˚C	15.6	76.47
Ash (Residue)	4.8	23.53

Table 2
Ultimate (elemental) analysis buffalo dung on CHN-600, LECQ, USA (dry ash free basis)

Elemental	Percent
C	37.5
H	6.8
N	1.4
O	54.3
Total	100.0

sion form and is problematic to remove its great amount by heating as there was loss of gases too. In the present study, 100 g of dung was first aerial dried in a partially covered petri dish for two days noting down weight loss for every four hours in the day time. The results of water content of dung were further cross checked by Dean and Stark method. It was noted that moisture content of dung varies with the passage of time due to atmospheric evaporation of water. The proximate analysis of dried dung was carried out on Mac - 400 LECO. USA and Ultimate (elemental) analysis was carried out on CHN - 600, LECO, USA. Results are presented in Table 1 & 2. Carbon and nitrogen ratio is one of the most important parameters which palys an important role in the degradation of cellulosic material (Almassi and Dunn 1974).

Table 3
Gas production from 400 ml slurry (buffalo dung + water) at ambient and elevated temperatures (45˚C, 50˚C, 55˚C, 60˚C)

Days	Ambient temperature (ml)	45˚C (ml)	50˚C (ml)	55˚C (ml)	60˚C (ml)
01	124	150	226	290	350
02	120	154	220	294	256
03	122	152	220	290	354
04	122	150	220	296	360
05	124	154	224	290	354
06	120	150	220	300	352
07	120	150	220	290	350
08	124	150	220	290	360
09	124	158	230	296	354
10	120	150	220	286	352
11	122	150	220	286	350
12	124	152	222	296	350
13	120	154	220	290	360
14	120	152	220	292	354
15	120	152	220	292	352
Mean	121.5	152	221.5	292	354

Results and Discussion

Table 1 and 2 describe proximate and ultimate (elemental) analysis of buffalo dung, respectively. Data on production of biogas from 400 ml slurry (buffalo dung + water) at ambient temperature and 45˚C, 50˚C, 55˚C, 60˚C are summarized in Table 3 and 4.

The only drawback of biogas generation from fermentation of dung is its slow rate of degradation of carbohydrates / cellulosic material to methane (CH_4) and carbon dioxide (CO_2) (Barker 1956). Incubation period varies from 2 - 6 weeks depending upon the nature of dung (fresh or otherwise). The release of biogas, in the present studies, is observed 0.3 unit per unit of slurry at ambient conditions. The ideal conditions

Table 4

Cumulative gas production from 400 ml slurry (buffalo dung + water) at ambient and elevated temperatures (45˚C, 50˚C, 55˚C, 60˚C)

Days	Ambient temperature (ml)	45˚C (ml)	50˚C (ml)	55˚C (ml)	60˚C (ml)
1	122	150	226	290	350
2	244	304	446	584	706
3	366	456	666	874	1060
4	488	606	886	1170	1420
5	612	760	1110	1460	1774
6	732	910	1330	1760	2126
7	852	1060	1550	2050	2476
8	976	1210	1770	2346	2836
9	1000	1368	2000	2632	3196
10	1220	1518	2220	2918	3542
11	1342	1668	2440	3214	3892
12	1466	1820	2662	3504	4244
13	1586	1974	2882	3796	4604
14	1606	2126	3102	4088	4958
15	1826	2278	3322	4380	5310

for the degradation of organic waste /cellulosic material for the production of biogas are total solid content (7 - 9%) total volatile of the total solid (70 - 80%), pH (6.8 - 7.4), carbon / nitrogen ratio (25 - 30), temperature range (27 - 71˚C) (Amassi and Dunn 1974). The entire biochemistry of conversion of cellulosic wastes to combustible gas is not completely understood. However, it is assumed that the following reactions take place during the anaerobic digestion of cellulosic material.

Cellulosic material $\longrightarrow$ Carbohydrate $\longrightarrow$ $nCH_4 + nCO_2$

Above mentioned reaction, following two routes are suggested:

$C_6H_{12}O_6 \longrightarrow 3CH_3COOH$ (Carbohydrate from organic wastes)

The route of the above mentioned reactions is likely to be:

$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ (Carbohydrate from digestion of organic waste)

$2C_2H_5OH + 2CO_2 \longrightarrow 3CH_3COOH$

$3CH_3COOH \longrightarrow 3CH_4 + 3CO_2$

For the preparation of biogas in the laboratory, the proximate and ultimate analyses of buffalo dung were accomplished. The results are shown in Table 1and 2. The proximate analyses of buffalo dung based upon aerial and oven dried conditions show moisture as 79.6%, whereas volatile matter at 650˚C and ash (residue) are 15.6% and 4.8% respectively.

Further, the ultimate analyses of the dung indicate C = 37.5%, H = 6.8%, N = 1.4%. These estimations show that buffalo dung may be used for the production of biogas, the heating values of different fuels were also taken into consideration. The heating value of different fuels comparing with the heating value of the biogas. Coke oven gas and retort coal gas

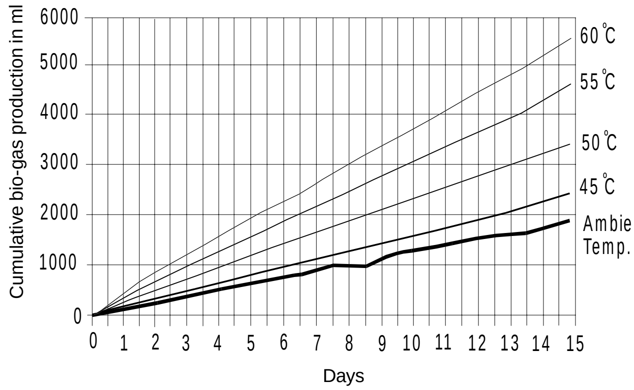

Fig 2. Cumulative gas production from 400 ml slurry (buffalo dung + water) at ambient and elevated temperature (45˚C, 50˚C, 55˚C and 60˚C)

show heating values as 21.90 and 21.42 MJ /m^3 respectively, whereas, the heating values of carbureted water gas is 19.67 MJ/m^3. Blue water gas and water gas have similar heating values 12.1 and 11.47 MJ /m^3. Among these fuels, biogas is the only one which shows maximum heating value as 22.35 MJ /m^3.

Tables 3 - 4 describe the data obtained for the gas production from 400 ml slurry (buffalo dung + water) at ambient and elevated temperatures (45˚C, 50˚C, 55˚C, 60˚C). These results show that the release of biogas increased with increase in temperature. At ambient temperature of 35˚C, the average rate of gas generation was 121.5 ml / day, whereas, at temperatures 45˚C, 50˚C, 55˚C, and 60˚C the average rate of gas generation was 152, 221.5, 292 and 354 ml / day, respectively from the same composition of slurry, 232.5 ml of gas in excess was produced with the temperature difference of 25˚C (60 - 35˚C). The graph shown in Fig 2 shows that the rate of release of biogas is enhanced with the rise in temperature.

It is very important to examine the energy balance due to change in temperature. Assuming that there is no loss of heat and entire energy from the water bath was absorbed by 400 ml (m = 400 ml = 0.4 kg) slurry and specific heat of slurry is c = 4200 J / kg ˚C (as slurry contains 90% water). The energy input due to change in temperature (Δt = 25˚C) is calculated as:

$\Delta E = mc\, \Delta\tau$

[m = mass of slurry, c is the specific heat of slurry and $\Delta\tau$ denotes temperature difference]

$\Delta E_{input} = (0.4) \times 4200 \times 25 = 42000$ joules.

The heat potential of excess gas produced 232.5 ml / day (232.5 x 10^{-6} m^3 / d) due to change in temperature from 35˚C to 60˚C can be calculated from the heating value of biogas i.e. 22.35 mega joules /m (22.35 x 10^{+6} J /m^3)

Heat potential of 232.5 x 10^{-6} m^3 biogas = Heat Output = 22.35 x 10^{+6} x 232.5 x 10^{-6} = 5196.375 J (1 m^3 biogas has heat potential = 22.35 x 10^{+6} J).

Heat input = 42000 J.

Heat output = 5196.375 J.

Loss = 36803.625 J.

Now, we see that the input of 42000 joules of heat for heating 400 ml of slurry produces heat potential as 5196.375 joules. It shows that there is a loss of 36803.625 (42000 - 5196.375) joules of heat. It is therefore, obvious from above calculations that the production of the biogas at elevated temperature is thermally not favorable.

As far as the use of dung cake as such for cooking purposes is concerned, there will be a loss of manure potential. The heat potential of the dried dung is 16 MJ/kg of total solid. The maximum conversion efficiency is reported as high as 90% (John Twidell and Tony 1980).

In brief, warming of slurry from external source of energy (heat) for the production of biogas is thermally not favorable i.e. at elevated temperature as energy input is more than the energy output. It is, therefore, on large scale production of biogas, the ambient temperature is the only suitable temperature. It will be very simple and economical and there will be no problem of maintaining temperature. Furthermore, conversion of biomass into combustible gas through anaerobic fermentation increases the potential of nitrogen rich fertilizer available/applicable to nearby farms (Mahajan 1987).

It is also concluded that biogas technology, still, needs more research and development work for the increase of energy output from the biomass and to enhance rate of gas generation by the addition of chemicals / inoculum so as the cost of the plant is reduced to a level that a common man can afford to install biogas plant for meeting his energy requirements.

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