

STUDY ON THE IMPROVE UTILIZATION OF BIOGAS AND BY-PRODUCT OF DIFFERENT RAW MATERIALS

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ABSTRACT

Land, marine, agricultural residues and animal waste were subjected to a bioassay for an ultimate methane yield. Methane yields from woody plants were lower in general than from other plant resource groups. High methane yields were obtained from several aquatic plants, some crop residues and some root and tuber plants and animal waste. Methane yield varies among different groups, various species within each group and different parts of the same plants species. Water hyacinth (*Eichornia crassipes* (Mart.) Solms.) and some animals waste are investigated in lab scale and GGC 2047 model Biogas Plant at F.R.I, Yezin. Chemical analysis of produced gas and by-product were tested and discussed.

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1. INTRODUCTION

About 75% of the total population of more than 50 million people in Myanmar live in rural areas where biomass fuel is the main source of energy. In the case of Myanmar, 84% of the total amount of energy consumed is biomass based, including fuelwood, charcoal and agricultural wastes. The remaining 16% consists of commercial sources of energy like oil, gas and electricity. Due to the population pressure and heavy reliance on biofuel, the forest cover of the country has been greatly affected and become decrease.

Nowadays, the use of firewood substituted fuel is an essential requirement for our country. Biological conversion of biomass into methane gas has received increasing attention in recent years. Biogas, methane is produced when organic matter is decomposed by bacteria in an anaerobic environment. The basic objective of biogas technology has been to produce energy and fertilizer on a decentralized basis for small farms.

The sample household solid-fuel stoves commonly used in developing country, do not obtain high combustion efficiency. They emit a substantial amount of fuel carbon as products of incomplete combustion (PIC) such as carbon monoxide (CO), Methane (CH₄) and total non-methane organic compounds (TNMOC) as well as carbon dioxide (CO₂). Some of the PICs are hazardous to health when breathed in the concentrations commonly found in the homes using unvented biomass or coal stoves, while some are direct or indirect greenhouse gases (GHG). This implies that reducing their emission will benefit health and mitigate GHG at the same time. The stove are small through numerous and thus have the potential to contribute significantly to national inventories of GHG. This applies particularly to many developing countries where household use is a significant part of total fuel use. It is estimated that, overall, biomass combustion contributes as much as 20-50 percent of global GHG emissions of which perhaps one-third may come from household.

In China and India, all the biomass stoves tested, as well as most coal stoves, had substantially greater PIC and CO₂ emissions per unit delivered energy than liquid and gaseous fuels. In general, the ranking follows what has been called the “energy ladder” from lower to higher quality fuels, i.e, emissions decrease and efficiencies increase in the following order: crop residue> brush wood> fuel wood> kerosene> gas. The ranking for coal was largely dependent on the specific coal types and stove designs. If the GWCS (Global Warming Commitment) from only CO₂, CH₄, and N₂O are considered a few of the crop residues and dung stove are comparable to kerosene. When renewable, about half the biomass fuel-stove combinations produce less GWC than kerosene. Interestingly, confirming the result from China, biogas is by for the best of all, with only about 10% of the GWC of LPG and more than a factor 100 less than the most GWC intensive solid biomass fuel-stove combinations. (K.R. Smith, Fuel Emission, Health and Global Warming)

Biogas has multiple benefits: Saving of energy in the form of fuelwood or kerosene or other fuels, reduction in greenhouse gas emission, improved sanitation, health, reduction in work-load for women, improvements in soil fertility and at the same time it can provide rural employment (construction and maintenance of bio-gas systems). (J.de Castro, A.J mathias and H.Why Kong 1999)

In this paper, investigated the biogas and organic fertilizer produce from water hyacinth, cow, pig and chicken dung.

2. LITERATURE REVIEW

Methane gas can be used for the generation of mechanical, electrical and heat energy, and is now extensively used as a fuel source for domestic and industrial purposes.

The microbiology of methane production is complex, involving mixture of anaerobic microorganism. In principal, anaerobic fermentation of complex organic mixture is believed to proceed through three main bio-chemical phase, each of which requires specific microbiological parameters. The initial stage requires the solubilisation of complex molecules such as cellulose, fats and protein, which make up most raw organic matter. The resultant soluble, low molecular weight products of this stage are then converted to organic acid; in the final phase of microbial activity, these acids (primarily acetic) are specifically decomposed by the methanogenic bacteria to methane and carbon dioxide.

Biogas, or methane, is produced when organic is decomposed by bacteria in an anaerobic environment. The bacteria survive and multiply only in an air-free condition. In a biogas plant, complex molecules are broken down step by step into methane and carbon dioxide through the simultaneous action of different kind of bacteria. The decomposition process can be divided in 2 broad categories: acid formation and methane formation. During the acid formation stage, short chain fatty acid such as acetic acid and formic acid are generated. In the second stage these acid are converted into methane and carbon dioxide.

When the methane is produced by the fermentation of animal dung the gaseous products are usually referred to as biogas and the installations called biogas plant or bioreactors. Biogas is a flammable mixture of 50-80% methane, 15-45% carbon dioxide, 5% water and some trace gases. Biogas is produced via biomethanation and is in fact a self-regulating symbiotic microbial process operation under anaerobic conditions, and function best at temperatures around 30°C. In such systems the animal dung is mixed with water and allowed to ferment in near anaerobic conditions. Production of biogas by such methods goes back into antiquity and is of particular importance in India, China and Pakistan.

The bacterial process in the reactor are mainly influenced by the P^H and temperature. A temperature around 35 degree Celsius is the optimum. The temperature plays an important role in biogas yield. The bacteria, like other living

organisms are active when conditions are favorable. If the temperature is below 25°C or tends to fluctuate, gas production drops abruptly and below 15°C gas production stops. Thus biogas plants have limited value in mountainous areas with cold winter. In warm tropical zone there is no problem in maintaining the required temperature. The fermentation period depends greatly on the temperature. The higher the temperature, the shorter the time to start gas production. A smaller digester with less mass heats up faster. Other factors which influence methane production are carbon to nitrogen (C/N) ratio, retention time, loading rate, total solids concentration, and mixing.

The carbon/nitrogen ratio (C/N) is one of the important factors in gas production and a ratio of 30 is optimum. The microbes utilize nitrogen to produce protein. If there is not enough nitrogen, the microbes are not able to use as all the carbon dioxide required to produce energy. Too high a C/N will decrease the rate of reaction and too low will produce excess ammonia compound which is toxic to the microbe.

Under ideal condition, 10kg of dry organic matter can produce 3m³ of biogas, which will provide 3h of cooking, 3h of lighting or 24h of refrigeration with suitable equipment. Biogas, does, in fact, furnish a considerable part of the world's energy source; China is the largest user with over 7 million biogas units providing the equivalent energy of 22 million tones of coal and, with current subsidies, a biogas plant in China is cheaper than a bicycle.

Methane generated from organic material by anaerobic fermentation offers a valuable source of energy that could be put directly to many uses. Furthermore, the associated by-product may be useful forms fertilizers for agriculture. Yet, before the full realization of these systems can be achieved, very considerable biotechnological studies must be undertaken. (John E. Smith, Biotechnology, 1996)

The following are some advantage of biogas.

1. It is an economical and easily accessible fuel;
2. It is smokeless, reducing eye and lung ailments significantly;
3. It meets more than 75 percent of the cooking energy needs, resulting a saving of about 100kg of firewood annually;
4. It saves cooking time.

At the other extreme there is the example of very young residues with a relatively high nitrogen content. Here the nitrogen supply will be in excess of microbial needs and the excess, broken down ultimately to nitrate, will be liable to loss drainage if not absorbed by a growing crop. In brief then, material of high carbon/nitrogen ratio are nitrogen taken and as spoken of as having a positive nitrogen factor; materials of low carbon/nitrogen ratio are nitrogen givers and have a negative nitrogen factor. It is a simple matter chemically to distinguish between

organic, i.e. protein nitrogen, and the simpler mineral forms (Which by common convention comprise ammonia and nitrate)

Nitrogenous fertilizer fall into the classes, (1) the relatively simple chemical compounds which are either mined as such, or are the product of chemical industry, and (2) the residues from processing of animals and vegetable products. The latter have their nitrogen in a more complicated form (protein) and may contain appreciable quantities of potash and phosphate. The emphasis laid on the arguments in favor of the “organic” fertilizer has varied from time to time. It is known that plants cannot make use of the nitrogen in these products till it has been broken down into simpler forms. Manure release their nitrogen gradually and cater for the needs of the plant at a rate appropriate to its powers of absorption. The strength of this contention is weakened by the fact that the carbon/nitrogen ratio of these manure is low.

3. Materials and Methods

3.1. Materials

The following materials were selected for intensive study.

1. water hyacinth (*Eichornia crassipes* (Mart.) Solms)
2. Cow dung
3. Pig dung
4. Chicken dung

All of its were obtained from F.R.I compound.

3.2. Methods

The Biogas Plant Construction

The success or failure of any biogas plant mainly depends upon the quality of construction works. To come to a successfully constructed biogas plant the mason should not only respect the dimensions as indicated on the drawing but also follow the correct construction method. Thus the performance of the fixed-dome plants 4m³ size was constructed in a step by step fashion, the right construction method of the 2047 design GGC model biogas plant (See Appendix II) beside the Wood Chemistry Section, Forest Research Institute, Yezin.

Construction Site Selection

The following points were kept in mind when deciding on a site for biogas plant construction.

1. For proper functioning of the plant, the right temperature has to be maintained in the digester. Therefore, a sunny site has to be selected.
2. To make plant operation easy and to avoid wastage of raw material specially animal dung, the plant must be as close as possible to the stable (animal shed) and water source. If the nearest water source is at a distance of more than 20 minutes walk, the burden of fetching water becomes too much and no plant should be installed in such places.
3. If longer gas pipe is used the cost will be increased as the pipe is expensive. Furthermore, longer pipe increases the risk of gas leakage due to more joints in it. The main valve has to be opened and closed before and after used. Therefore, the plant should be as close as possible to the point of use so that the above problems are eliminated.

Sample Preparation

For water hyacinth

The water hyacinth are chopped by knife into small pieces less than one inch in size.

For animals dung

Each of these are first put into the inlet pit and mixed with water 1:3 ratio in weight and stirred well.

Gas production

First the digester was checked for water leaks and air leaks.

Each of the samples, the chopped water hyacinth, cow dung, pig dung and chick dung 1½ tones were mixed with the water by 1:3 in inlet pit and then put it into the digester.

Recorded the Data

After 4 to 5 days gas production started and recorded the gas yield every day.

Daily rainfall, the highest and lowest temperatures and the relative humidity were also recorded.

After 4 to 5 days gas production started but at first it did not burn readily due to the carbon dioxide and other gases, mixed with the methane. When the gas were found to burn, the biogas plant was ready for consumption.

1 liter (1000 cc) of water boiled daily, the time require to boil the water were recorded for every raw materials.

Chemical analysis

First the flesh water hyacinth, cow dung, pig dung and chicken dung were tested for the following chemical analysis

1. Moisture content
2. Total nitrogen
3. Total phosphorous
4. Available potassium
5. Solid content
6. Carbon
7. Carbon-nitrogen ratio
8. pH

After gas production, the byproducts, the fertilizers were also tested for the above chemical analysis.

4. RESULTS AND DISCUSSIONS

The chemical composition of selected raw materials and the carbon / nitrogen ratio (C/N) of selected organic raw material are given in Table I.

Table I showed that Water hyacinth is too high C/N ratio in 40.745. The lowest C/N ratio is Pig dung in 17.202.

The carbon/nitrogen ratio (C/N) is one of the important factors in gas production and a ratio of 30 is optimum. The microbes utilize nitrogen to produce protein. If there is not enough nitrogen, the microbes are not able to use up all the carbon dioxide required to produce energy. Too high a C/N ratio will decrease the rate of reaction and too low will produce excess ammonia compound which is toxic to the microbes.

Table (1) Chemical Composition of Selected Raw Materials

Sr. No.	Material	moisture content	organic carbon %	solid content	Total nitrogen % (by wt.)	Total Phosphorous % (by wt.)	Total Potassium % (by wt.)	C / N ratio
1.	Water hyacinth	5.50	24.325	82.1	0.579	0.017	4.2344	40.745
2.	Cattle dung	4.49	32.163	76.5	1.547	0.027	0.3906	20.791
3.	Pig dung	3.63	36.900	80.7	2.145	0.034	0.2656	17.202
4.	Chicken dung	1.32	45.775	51.7	2.470	0.029	0.4063	18.532

The monthly average gas outturn for different raw materials water hyacinth, cow dung, pig dung and chicken dung are given in Table II. The monthly rain fall, daily average temperature and relative humidity % (RH) are included.

Table (2) The Monthly average gas outturn for different raw materials

Sr. No.	Month	Monthly rain fall	Average Temperature (°C)	Average Relative humidity (%)	Biogas yield (monthly total) (cu ft.)			
					Water hyacinth	Cow dung	Pig dung	Chicken dung
1.	Dec	-	26.93	53.28	2118.84	30723.18	33901.44	6356.2
2.	Jan	-	24.13	51.24	65684.04	104882.58	228834.72	59372.52
3.	Feb	-	29.01	53.64	6356.52	31782.6	354905.7	-
4.	March	-	30.31	53.56	31782.6	52971	583740.42	-
5.	April	-	36.31	62.63	63565.2	36020.28	275449.2	-
6.	May	6.70	33.02	57.77	-	4237.68	19069.56	-
7.	June	9.08	28.65	58.82	-	-	10594.2	-
	Total				169507.2	260617.32	1506495.1	65728.72

Observation showed that, the highest yield amount of gas produce from pig dung in March. The average temperature in March is 30.31°C. Temperature plays an important role in biogas yield. The bacteria, like other living organisms are active when condition are favorable. It is therefore important that temperature should be in the range of 25°C and 30°C. If the temperature is below 25°C or tends to fluctuate, gas production drops abruptly and below 15°C gas production stop. Thus biogas plants have limited value in mountainous areas with cold winters. In warm tropical zones there is no problem in maintaining the required temperature. The fermentation period depends greatly on the temperature. The higher the temperature, the shorter the time to start gas production. A smaller digester with less mass heats up faster.

After six months, gas produced negligible amount. The total gas outturn of all selected raw materials decrease in the rainy season. The total gas outturn was 163507 cu.ft in water hyacinth, 260617 cu.ft. in cow dung, 1506495cu.ft. in pig dung and 65728 cu.ft. in chicken dung.

The p^H value of different slurry are between (7.3-7.8). We should report the p^H or reaction value of water which is neutral as p^H 7 and of the highly acid as p^H 4. Alkaline would have values higher than p^H 7. The property of buffering is highly important because well buffered are less subject to fluctuation in reaction caused by climatic and environmental factors. A good fertile soil of suitable reaction, well buffered will not easily be changed for the worse. Conversely a very acid or alkaline infertile soil, also well-buffered, will need drastic treatment to bring it into good order.

The observation of p^H value for this organic fertilizer was round about 7 and it can say almost neutral (or) not very alkaline and it was well buffering for the soil to fertile.

The chemical composition of organic fertilizer (solid) for selected raw materials are indicated in table III. The chemical composition of organic fertilizer (liquid) for selected raw materials are indicated in table IV.

Table (3) Chemical Composition of Organic-fertilizer (Solid) for the Selected Raw Materials.

Sr. No.	Material	Nitrogen % (By wt.)	Phosphorous % (By wt.)	Potassium % (By wt.)	Total Carbon % (By wt.)	C/N Ratio
1.	Water hyacinth	0.908	0.012	0.3682	40.86	45
2.	Cattle dung	0.895	0.012	0.1875	32.02	35.78
3.	Pig dung	1.573	0.0275	0.5156	44.80	28
4.	Chicken dung	0.968	0.026	0.6016	26.82	27.71

Table (4) Chemical Composition of Organic-fertilizer (Liquid) for Selected Raw Materials

Sr. No.	Material	Nitrogen % (wt./v)	Phosphorous % (wt./v)	Potassium % (wt./v)
1.	Water hyacinth	0.002	0.0023	0.0711
2.	Cattle dung	0.014	0.001	0.0154
3.	Pig dung	0.045	0.0015	0.0525
4.	Chicken dung	0.182	0.001	0.669

The range of C/N ratio of organic fertilizer is between 27.7-45%. It is favorable for the growth of plants. The content of total nitrogen for different organic fertilizers varies from about 0.895 to 1.573 percent. The content of ammonium (NH₄) may reach 70 ppm (0.007%) in the humus layer of fertile soils (S.A.WILDS, 1958). Thus all organic fertilizers have sufficient amount of nitrogen for the plant growth.

The content of available potash (K₂O) in forest soil commonly varies from 50 to 200 ppm. Most of trees are satisfied with small amounts of available potash, such as 30ppm(0.003%). Therefore the amount of potassium (0.0154 to 0.669%) of the organic fertilizers are also high level for the plant growth.

The content of available P₂O₅ of 50 ppm (0.005%) is sufficient for most forest trees. Phosphorus content of organic fertilizers varies about 0.01 to 0.03 percent and there have enough for the plant growth. But Grunes had reviewed and discussed research results on the biological and chemical effects of nitrogen on the availability of soil and fertilizer phosphorus to plants. This included that the nitrogen effect on increased uptake to phosphorus by plants by increasing root efficiency, root area and absorbing capacity, the effect on plant metabolism and root properties; the effects of nitrogen carries on P^H; and salt effects (Firman E. Bear.)

The experiment of boiling water (1000cc) consumed 1-2 cu ft of gas and took 10-15 min depending on the manometer pressure.

5. CONCLUSIONS

To reach a definitive conclusion with regard to fermentation ability of a particular raw materials, under the range of potential environments and growth stage are essential.

In selecting an energy raw materials, competition with the products for the use of land, economy, maintenance, harvesting, transportation to conversion side, etc. must be carefully evaluated. Excluding these factors the two most important factors to be considered are productivity and convertibility of the raw materials. High productivity and convertibility are highly desirable characteristics for an energy raw material. Material possessing low productivity and or low conductivity characteristics may be improved by using new biotechnology procedures.

Pig dung produced gas faster than others and produced more gas. In all selected materials the drier period encouraged more gas production than the wet season. Normally the gas production period in all selected raw materials was about six months.

The initial cost for the plant seemed high but it can be used long time only fill with suitable raw material. It can also be achieved so many advantages for the house wife, i.e, health, save cooking time and good for the environment. The by-product of organic fertilizer is also suitable condition for the plant growth.

Among the four raw materials studied, the author concluded that pig and cow dungs are more feasible for rural areas in availability and in gas outturn.

The byproducts, organic fertilizer have sufficient amount in nitrogen, potassium and phosphorus for the plant growth. Organic manure certainly stimulate micro-organic activity in the soil, does this more efficiently at less cost. This type of fertilizers can be used to good for the leaves, buds and root tips especially for the vegetables and annual crops.

Appendix I

The cost estimation for 4m³ size GGC 2047 Model Biogas Plant construction in November 2001.

1. Building Materials (bricks, sand, gravel, cement, 6mm rod, paint)	129300 kyats
2. Building Labour	59000 kyats
3. Pipe and Appliances (inlet pipe, dome gas pipe, GI pipe, socket, elbow, tee, union, nipple, main gas valve, water drain, rubber hose, teflon tape, gas stove, manometer)	56800 kyats
Total	<hr/> 245100 kyats

Appendix II

6. REFERENCES

- (1) Anon (1976); Biogas Production from Cattle dung. Agriculture Corporation Leaflet (in Myanmar)
- (2) Anon (1982); “Biogas Production and Utilization Course” Ywa Tha Gyi, Yangon. (Lecture note)
- (3) Anon (1984); “Test Results on Biogas Production from Cattle Dung” in Kayah State.
- (4) A Shiralipour et.al (1984); “Conversion of Biomass into Methane Gas”, University of Florida, USA.
- (5) Firman E. Bear (1967); “Chemistry of soil”. Second Edition, Reinhold Publishing Corporation, New York.
- (6) HD Kumer (2002); “Modern Concepts of Biotechnology”, Vikas Publishing House Pvt Ltd, New Delhi.
- (7) J.de Castro et.al (1999); “Construction and Maintenance of Bio-gas System”
- (8) John E. Simth (1996): “Biotechnology”, third edition (1996). Cambridge University.
- (9) K.R Smith: Fuel, Emission, Health and Global Warming
- (10) S.A Wild (1958); “Forest Soil” The Ronald Press Company, New York.
- (11) S.J. PIRT (1974); “Anaerobic microbial digestion as a route to methane and renewable carbon sources”, University of London, England.
- (12) Soe Tinth (1986): “Study on the Biogas Production of Bawzagaing and Thinbaw Kokko leaves”.
- (13) T.EDEN (1962); “Elements of Tropical Soil Science.” Macmillian, London.