DESIGN AND FABRICATION OF LOW COST BIOGAS DIGESTER USING POULTRY WASTE AND PIG MANURE

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Abstract – *The huge waste loads generated by the animals in farms have made animal waste treatment a critical issue. Proper treatment is required to avert the adverse effects of these wastes on water quality, public health, and air quality. This project assessed the feasibility of anaerobic co-digestion of the smell nuisance producing, poultry waste and pig manure and evaluated the optimum biogas production by comparing these two substrates in different mixing ratios at different atmospheric temperatures in three mini biogas plants for 26 days. Based on the optimum biogas production, a low cost biogas digester of 1 m^3 size is designed and fabricated which will help the pig farmers especially who lease the land for pig farming who have to move from one place to another after their prescribed period of leasing and the biogas production performance from this is analyzed for 30 days.*

Key Words: Biogas Production, Biogas Digester, Poultry waste, pig manure.

1. INTRODUCTION

To prevent damaging the earth's ecosystems and maintain a high quality of life for the planet's inhabitants, humans must manage their waste efficiently and safely. Agricultural wastes from animals such as poultry droppings, cow dung, and pig dung usually produce obnoxious odour and environmental problems for the people living around the areas where such wastes are dumped. These animal wastes have been found to consist of exploitable gas and energy which can be obtained by a process called Anaerobic Digestion and the gas produced can be used as a source of energy. Biological process of treating solid and liquid organic residues that leads to formation of digestrate and biogas production is called Bio-methanisation or Anaerobic digestion. Biogas can be produced from almost all organic materials that could be decomposed or processed by anaerobic digestion. These include animal dung, sewage, landfills and industrial wastes. Animal wastes are available close to the point-of-use of the feedstock and economical for biogas production. It is inevitable that with large volume and high density poultry and pig productions, there will be large quantities of poultry wastes and pig wastes, which are rich in methane content, can be used to produce biogas through the process of anaerobic digestion. Improvement can be done in the efficiency of the biogas production by utilizing the poultry waste along with pig manure by co-digesting them. Also most of the pig farmers in kerala are poor, who used to lease the land for pig farming. So a cost effective pig manure management is necessary that will not affect when they move from one place to other after the prescribed period of leasing and which will help them to meet their cooking fuel demand. The main objectives of the project are to evaluate the optimum biogas production by utilizing the poultry waste along with pig manure, in different mixing ratios, to design a low cost biogas digester based on the optimum production, to fabricate the digester with the designed specifications

2. METHODS AND PROCEDURE

2.1 Collection of the substrate

Fresh samples of poultry waste and pig manure used for the study were obtained in a large clean plastic container, in which Poultry waste (manure) is obtained from Regional Poultry Farm, Malalampuzha, palakkad and Yakkara Poultry Farm and Pig manure is obtained from the pig farm IRTC, Mundur, Palakkad.

2.2 Physio Chemical Analysis of the Input Substrate

Inorder to check the suitability of the substrates for anaerobic digestion, certain parameters are tested. The different parameters include pH, total solids, volatile solids, carbon to nitrogen ratio etc. The values of these parameters in poultry waste alone, pig manure alone, are tested and these values when poultry waste, pig manure and water mixed in different ratios also calculated. The different mixing ratios of poultry waste, pig manure and water respectively are 3:1:6, 1:1:3, 1:3:6.

2.3 Experimental Procedure

In order to find the optimal biogas production, a small scale testing of the sample in which poultry waste and pig manure at different mixing ratios is to be tested.

Three identical biogas digesters of capacity 25 litres are made and used for the study. 25 litres capacity PVC-barrel will act as the digester unit. PVC pipes are used for feeding the substrate waste (inlet), outlet for the slurry, tire tube connected will act as gas storage. Barrels are painted in black in order to prevent the entry of light thus preventing the algae growth. Since algae produces oxygen, microbes inside the digester will respire aerobically, thus the production of biogas stops. Also black colour will maintain the temperature needed for the gas production. The experimental study was conducted in 3 digesters at different mixing ratios of poultry waste and pig manure. The substrate and water should be mixed in the ratio 1:1.5. Performance was analyzed for 26 days.

<u>Experiment 1</u>

- 25 litres mini plant is filled with 20 litres of substrate (poultry waste, pig manure and water) in the ratio 3:1:6.
- 6 kg of Poultry waste, 2 kg of pig manure and 12 litres of water are used.

<u>Experiment 2</u>

- 25 litres mini plant is filled with 10 litres of substrate (poultry waste, pig manure, water) in the ratio 1:1:3.
- 4 kg of poultry waste, 4 kg of pig manure and 12 litres of water are used.

<u>Experiment 3</u>

- 25 litres mini plant is filled with 20 litres of substrate (poultry waste, pig manure, water) in the ratio 1:3:6.
- 2 kg of poultry waste, 6 kg of pig manure and 12 litres of water are used.

Daily measurement of biogas production, methane percentage and temperature were calculated for each experiment. The optimum biogas production was taken for the large scale experimental design. The complete burn off time of the maximum production among the three is used for calculation.

3. DESIGN AND FABRICATION

Location of the site is selected which has large exposure of sunlight, nearer to the kitchen and place is away from the animal attacks. When considering the cost of installation, features of the material and the fact that farmers move one place to another after 3 or 4 years, the suitable type biogas digester is Flexible Biogas Digester or Inflated digester.

3.1 Dimensions of the Biogas Digester

The size of the system depends on the desired volume of daily gas production. The volume the gas holder should equal one day's gas production.

For the ratio 1:3:6,

Maximum biogas production =7890 ml / day =7.89 L/ day.

Maximum time taken for 7.89L biogas to burn off in the burner = 2 minutes 4 seconds.

Biogas needed for 1 minute burn off time =7.89/2.4 =3.2875L.

Expected cooking time/day from biogas =2 hrs =120minute.

Biogas needed to have a burn off time of 2 hrs = 3.2875×120=394.5L ≈ 400L.

Capacity of plant to produce 7.89 L biogas from the result = 25 L.

Capacity of plant to produce 400L biogas ≈ 1000 L=1 cubic meters.

Therefore, the Capacity of the Biogas Digester on the whole = 1m^3.

<u>Digester Body</u>

Digester body Volume = 0.6m^3 (600 litres), since the gas holder volume is 400 L= 0.4 m^3.

Shape of the Digester body = Rectangle.

Volume of the Digester body = Length of the digester body (L) × Breadth of the digester body (B) × Height of the digester body (H) = 0.6m^3.

Let us choose the length of the digester body (L) = 2m.

Let us choose the breadth of the digester body (B) = 1m.

The height of the digester body (H) = Volume of the digester body ÷ (L×B) = 0.6 / (2 × 1) = 0.3 m.

<u>Gas Holder</u>

The volume of the gas holder should equal one day's gas production which is 400 L = 0.4m^3.

Gas Holder Volume = 0.4 m^3.

Shape of the Gas Holder = Rectangle.

Volume of the Gas Holder = Length of the gas holder (l) × breadth of the gas holder (b) × height of the gas holder (h) = 0.4 m^3.

Since the length and breadth of the digester and gas holder are same, Length of the gas holder (l) = 2 m.

Breadth of the gas holder = 1 m.

Height of the gas holder (h) = Volume of the gas holder ÷ (l× b) = 0.4 / (2 × 1) = 0.2 m.

3.2 Dimensional View of the Biogas Digester

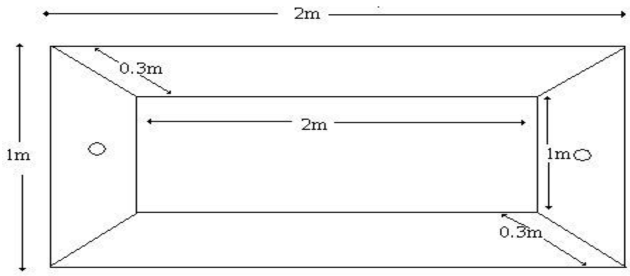

Fig-1: Top View of the Digester Body

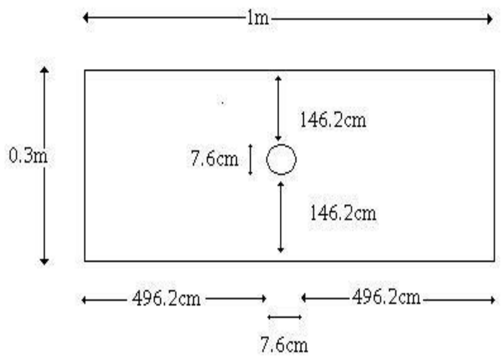

Fig-2: Side view of the Digester Body

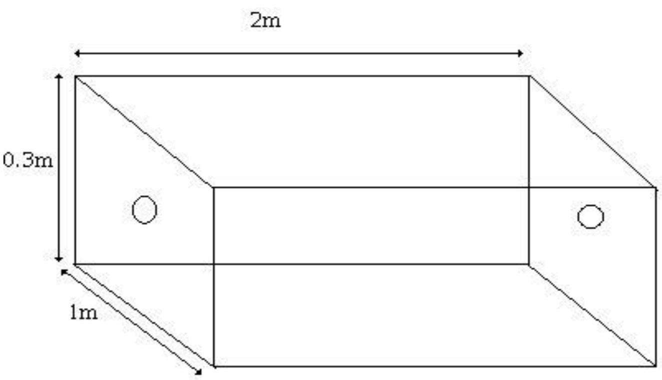

Fig-3: Three Dimensional View of Digester Body

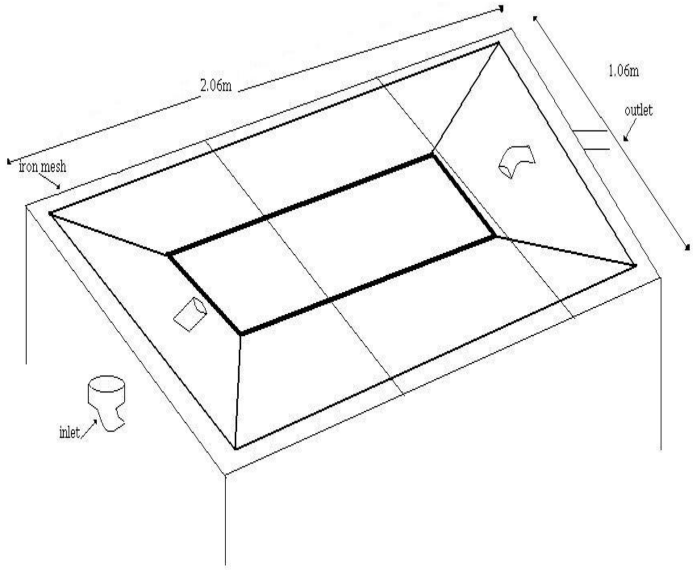

Fig-4: Top View of Digester Body with Iron Mesh

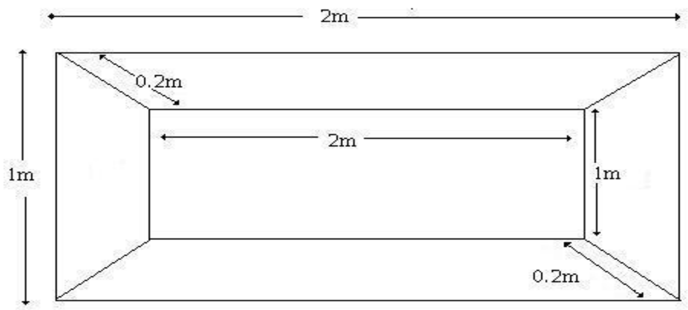

Fig-5: Top View of Gas Holder

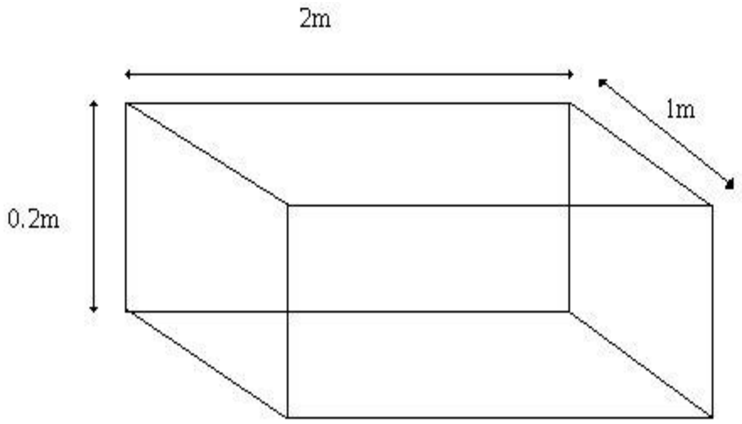

Fig-6: Three Dimensional View of Gas Holder

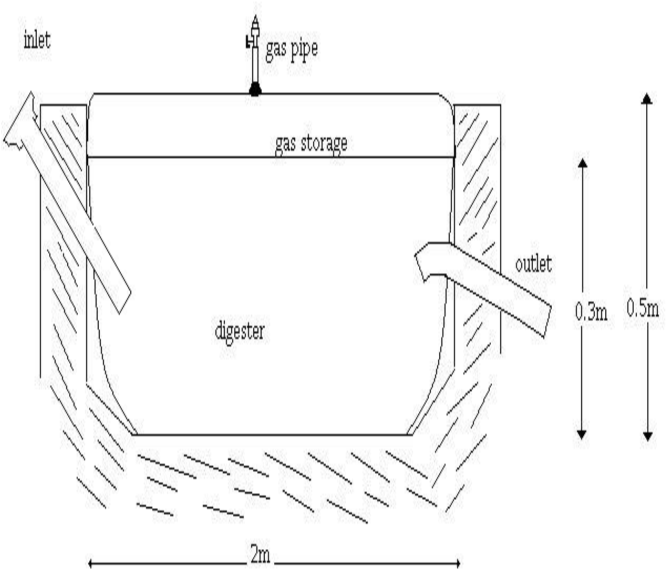

Fig-7: Section of the Whole Biogas Digester

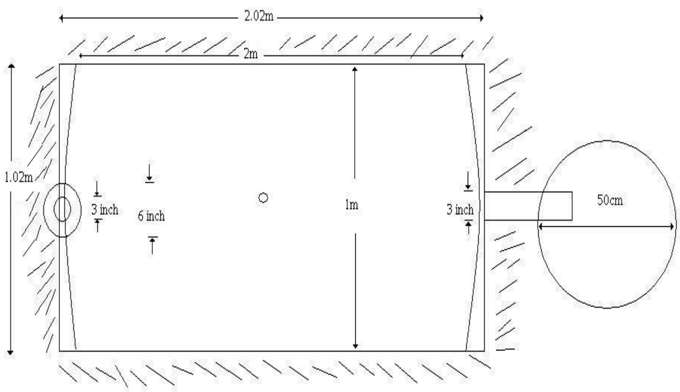

Fig-8: Top View of the Whole Biogas Digester

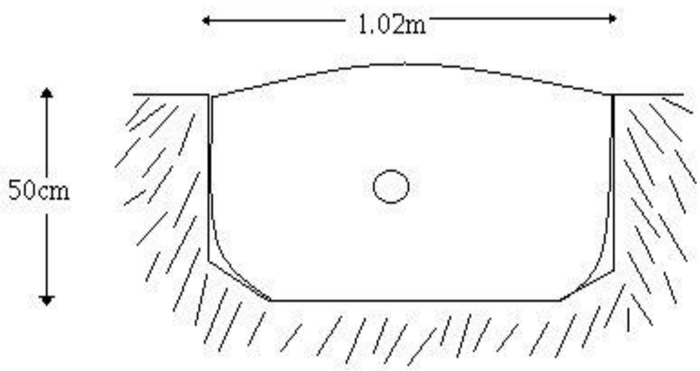

Fig-9: Side View of the Whole Biogas Digester

3.3 Components

Inlet: It is a 3 inch diameter PVC pipe having half meter in length, which is fixed at an angle that allows the feedstock to move into the digester. A pipe reducer having an inner diameter of 8cm and outer diameter of 6 inch is used as funnel.

Outlet: Through which the slurry after the digestion is moved out. It is made by a 3 inch diameter PVC pipe. It is placed at an angle that allows the slurry come out from the digester and reach in the outlet chamber.

Digester Body: This is the place where the anaerobic digestion takes place. The feedstock is mixed well and fed through the inlet will reach the digester body and after the digestion process slurry goes outside through the outlet or effluent chamber. Here the digester body is of capacity 600 litres or 0.6 m^3 which is made of a flexible material, Silpaulin. Silpaulin is widely known for its waterproof and fire-proof characteristics.

Gas Holder: The biogas formed after the anaerobic digestion is collected on the top of the plant, called gas holder. As the gas formation starts the gas holder will expand or inflate and if pressure reduces the gas holder deflate, since the digester is a flexible biogas digester. Here the gas holder is having a capacity of 400 litres or 0.4m^3. It is also made of silpaulin.

5.3.5 Gas Outlet

The biogas which is present in the gas holder is taken using the gas outlet, which is a gas valve connected with a reducer. The gas valve is opened when it is to be used. Here a gas valve is made of brass.

4. RESULTS AND DISCUSSIONS

As per the work plan, a mini biogas experiment and based on which a large scale experiment was conducted. The results of the Physiochemical analysis of the input substrate, Gas volume measurement, Methane and CO_2 measurement and Output slurry analysis are discussed here.

4.1 Results of Physiochemical Analysis of Input Substrate

pH, Total Solids, Volatile solids, Carbon to Nitrogen ratio etc. of the input substrates which are Poultry waste alone, Pig manure alone and different mixing ratios of these substrates (Poultry waste, Pig manure and water in the ratio 3:1:6, Poultry waste, pig manure and water in the ratio 1:1:3, and Poultry waste, pig manure and water in the ratio 1:3:6) were determined in the laboratory.

Substrate 1- Poultry waste alone

Substrate2- Pig manure alone

Substrate3- Poultry waste, Pig manure and water in the ratio 3:1:6

Substrate4- Poultry waste, pig manure and water in the ratio 1:1:3

Substrate5- Poultry waste, pig manure and water in the ratio 1:3:6

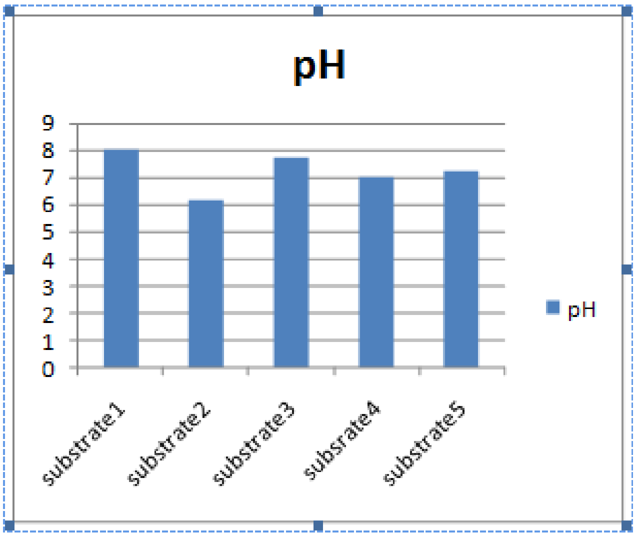

Chart -1: Ph of Different Input Substrates

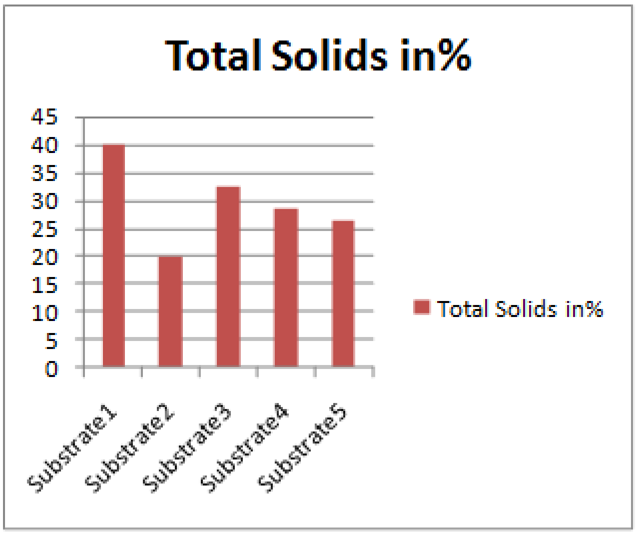

Chart -2: Total Solids for Different Input Substrate

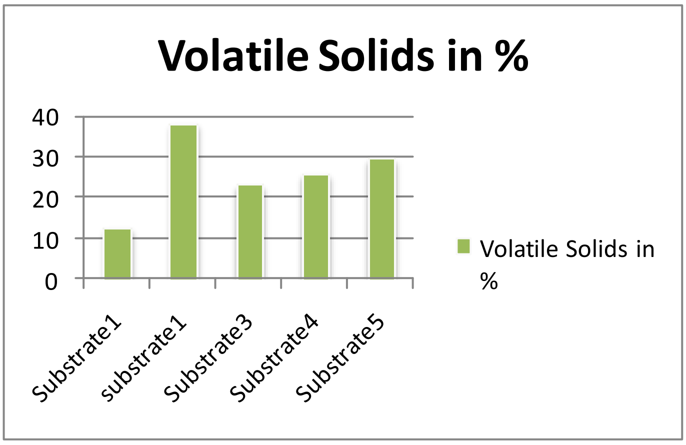

Chart -3: Volatile Solids for Different Input Substrate

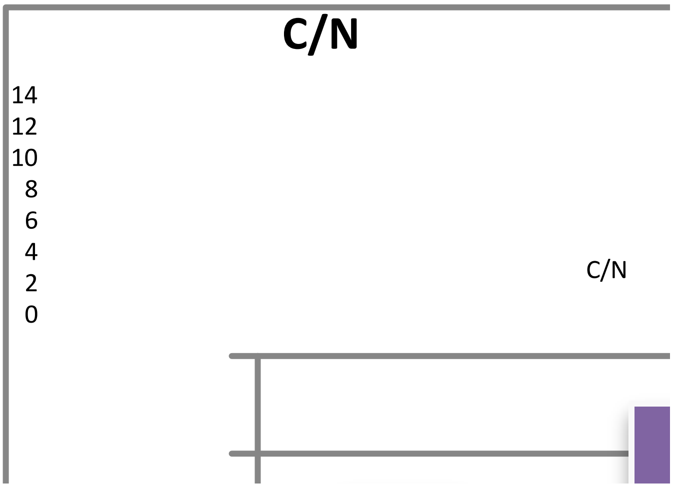

Chart -4: Carbon to Nitrogen Ratio of Different Input Substrate

4.2 Results of Small Scale Experiments

Among the 3 mini biogas digester experiments, 3rd ratio started its gas production from the 5th day onwards, the other two started on the 6th day. Maximum gas production obtained was for experiment 3 with total biogas production 7890 ml. The average biogas productions for the 3 experiments were 1757.38 ml/day, 1666.7 ml/day, and 2864.61 ml/day respectively. The yield of biogas was determined using the expression stated below:

Biogas Yield (%) = Average volume of gas collected in ml/mass of input waste in L × 100

- Biogas Yield for digester 1 = 1757.38 / 20 L × 100 = 8.78%
- Biogas Yield for digester 2 = 1666.7 / 20 L × 100 = 8.33%
- Biogas Yield for digester 3 = 2864.61/ 20 L × 100 = 14.32%

The best ratio of Poultry waste, Pig manure and Water among the 3 experiments is 1:3:6. The suitable pH range for this substrate was 7.2. And suitable temperature range for higher production of biogas was between of 31^{0}C to 35^{0}C.

Maximum time taken for 7890 ml (Maximum production in a day) biogas to burn off in a burner = 2 minutes 4 seconds.

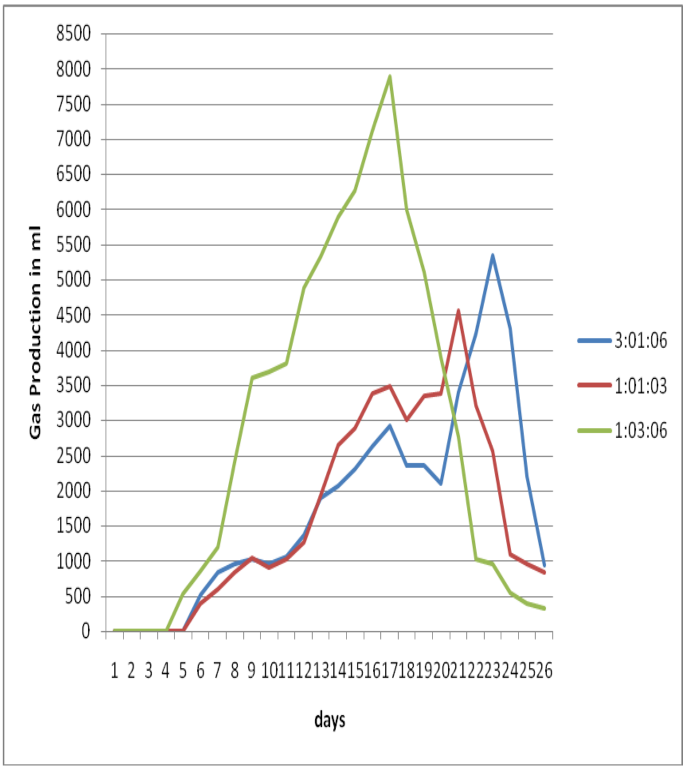

Chart -5: Comparison of Gas Productions in 3 Mini Biogas Digesters

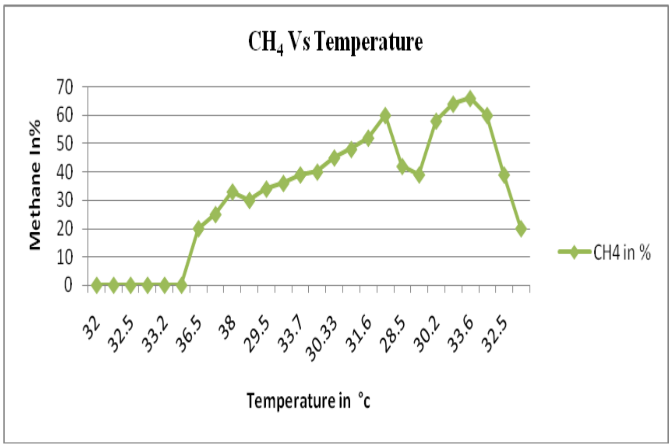

Chart -6: Methane Formation Vs Different Temperature for Experiment 1

Methane formation was not found on the day of gas production, but it was obtained on 7th day. As the temperature increased methane production has good yield. Low temperature resulted in a small increment in CH_4. Maximum methane formation was on 23rd day at 33.6^{0}C which was 66% and 34% was Carbon Dioxide.

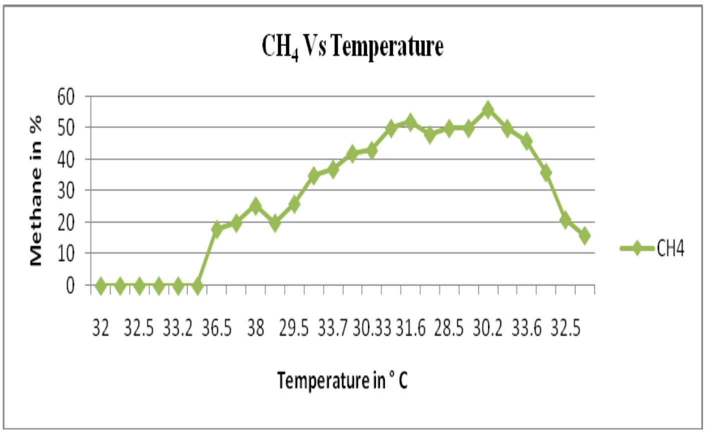

Chart -7: Methane Formation Vs Different Temperature for Experiment 2

Methane formation was obtained on 7th day. As the temperature increased methane production has good yield. Low temperature resulted in a small increment in CH_4. Maximum methane formation was on 21 day at 30.2^{0}C which was 56% and 44% was Carbon Dioxide.

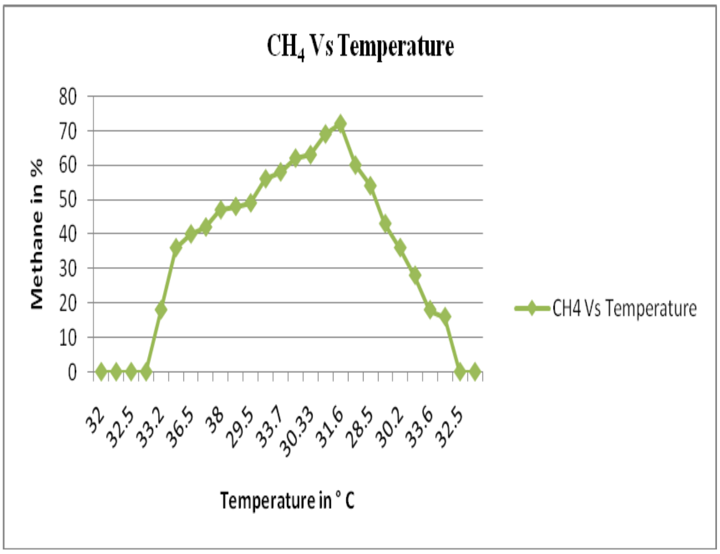

Chart -7: Methane Formation Vs Different Temperature for Experiment 3

Methane formation was seen on the day of biogas production (5th day). The slight decrease in the temperature didn't have an effect on methane production. Maximum methane formation was on 17th day at 31.6^{0}C which was 72% and 28% was Carbon Dioxide.

4.3 Results of Large Scale Experiment

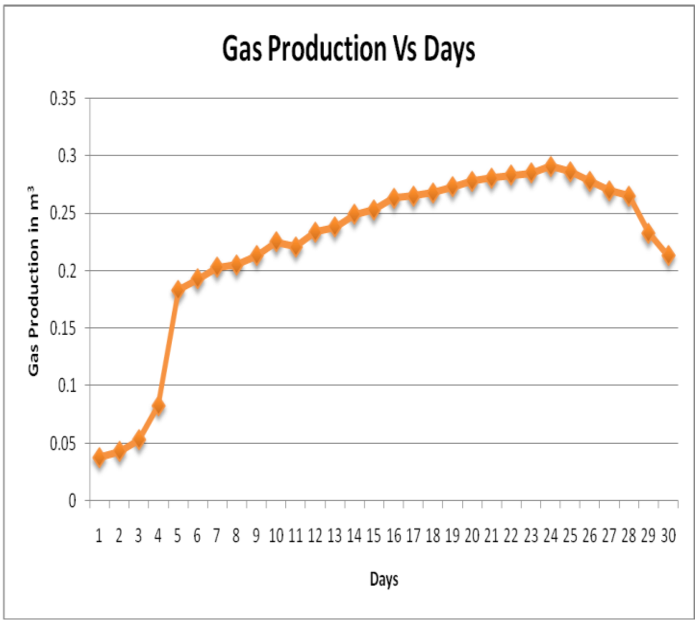

Chart -7: Gas Production Vs Days for 1m^3 Plant

Almost a linear gas production is obtained here. The maximum gas production was on 24th day, which is 0.291 m^3 (291 litres). The total biogas production for 30 days was 6.666 m^3 (6666 litres). Average biogas production was 2.222 m^3 (222 litres/day). The expected 0.4 m^3 biogas production was not obtained.

4.4 Analysis of Effluent Slurry

Table -1: Analysis of Effluent Slurry

pH	7.6
Nitrogen	0.5%
Phosphorous	1.98%
Potassium	1.32%

pH is not harmful and can be used as fertilizer. Nitrogen, phosphorous and potassium has lower yield in the slurry, but it can be used for plants.

4.3 Cost Analysis

For Flexible biogas digester,

Material Cost

- Silpaulin sheets = 1500 Rs
- Inlet pipe and outlet pipe = 55 Rs
- Female threaded adapter = 30 Rs
- Iron Mesh = 700 Rs
- Pipe reducer = 30 Rs
- Gas valve and reducer = 450 Rs
- Gas pipes = 60 Rs
- M seal, Flux gum and seal tape = 200 Rs

Labour cost = 500 Rs

Transportation charge = 0

Total = 3525 Rs

For 1m3 Floating dome plant,

Total digester cost = 14000 Rs

Labour Cost = 1500 Rs

Transportation cost = 450 Rs

Total = 15950 Rs

5. CONCLUSIONS

The results of evaluation of optimum biogas production showed that the best mixing ratio of poultry waste to pig manure to water is 1:3:6. Even though the solid content in the pig manure is low, while co-digesting with poultry waste showed very good biogas production. Elimination of smell nuisance of the pig manure and poultry waste was not present. The digester type of flexible biogas design is best suited for the poor lease land pig farmers; it is a beneficial model of waste management and energy production even though the production efficiency is low compared to the floating dome plant. The reason for low yield of biogas production may be due to low atmospheric temperature and lack of gas pressure regulation.

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