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# Determination of biogas yield from co-digestion of cow and goat dung

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**ABSTRACT**

*This study was carried out to assess and determine the biogas yield from cow and goat dung. Biogas yield assessment was carried out at room temperatures (26.0– 30.0 °C) for a period of 20 days from a solid dung mixture of 1000 g in each sample (fermentation slurry) left to ferment over 35 days. The objectives were to determine cow and goat dung ratio that give optimal output and to model the relationship between cow:goat dung ratio and the output which can be used to predict gas yield at various ratios. Three samples composed of a ratio of cow to goat dung were prepared to make sample D1 (100:0), D2 (75:25) and D3 (50:50). Fermentation occurred in a water dispenser container of 20 litre capacity used as the improvised digester and the temperature of the digesting chamber noted over the fermentation period of 20 days. A constructed metallic prototype digester was used for the collection of biogas produced. Preliminary studies showed that biogas release started to decline at the tenth day of the fermentation period for almost all samples. Sample D2 (75 % by weight cow dung and 25 % by weight goat dung) showed the highest biogas production (361.00 ml) at the end of fermentation. A portion of sample D2 was transferred into the constructed prototype digester and the gas produced was collected into the gas cylinder for determination of volume collected. A mathematical model derived using regression analysis on MATLAB software indicates that biogas production can be predicted based on a dung concentrate.*

**Keywords:** Biogas, Dung, Anaerobic, Cow, Goat and Methanogens.

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## INTRODUCTION

Energy sources are broadly classifies into two main groups: Renewable and Non-renewable.

Renewable energy is energy, which is generated from natural sources that is sun, wind, rain, tides and can be generated repeatedly as and when required. They are available in plenty and by far the cleanest sources of energy available on this planet. Energy that we receive from the sun can be used to generate electricity and similarly, energy from wind, geothermal, biomass from plants and tides can be used this form of energy to another form.

Non-Renewable energy is energy, which is taken from the sources that are available on the earth in limited quantity and will vanish with time. Non-renewable sources are not environmental friendly and can have serious effect on our health. They are called non-renewable because they cannot be re-generated within a short span of time. Non-renewable sources exist in the form of fossil fuels, natural gas, oil and coal [14].

About one third of the world's population still uses biomass products for their cooking and heating. In developing countries, the need for biomass energy is not because biomass-based technologies can entirely resolve their nation's difficulties with escalating petroleum prices, but because of the urgency of their energy need. For the rural and urban poor areas, properly designed biomass conversion technologies could reduce the economic and environmental cost for cooking and heating and in some cases provide opportunities for economic growth and employment [9].

Biogas is a by-product of the breakdown process from biodegradable waste such as waste food, cow dung, cassava peels, pigs and poultry waste, a renewable energy source [1]. This research project intends to address the issue of the production of biogas from cow and goat dung, which can produce biogas through the process called 'anaerobic digestion'. Recently, developed countries have been making increasing use of biogas treatment systems for municipal waste. The project has as its main thrusts to; design a process of converting cow and goat dung into biogas; study the process of converting cow and goat dung to biogas using water displacement method; and determine if methane could be produced/constituent of gas produced under retention period of 20 days.

The digestion process produces the principal acids, which were processed by methanogenicy bacteria to produce methane. Conditions necessary for the optimum production of biogas are: pH value and temperature as well as a continuous feed digester. The biogas production plant comprises of- the digester, the scrubber, the gasholder; the gas mains. Biogas containing methane could be efficiently produced from food waste and cow dung slurry in a continuous feeding process digester [1].

Biogas as an alternative source of energy is renewable. But petroleum is non renewable and it has been confirmed that non renewable source of energy could only last for over a given period of time. [6]. This uncertainty has created a lot of anxiety for industrialized and developing nations and they are now looking back to the past methods of using biomass as one of the most viable remedy with purpose of improving it and eventually making it an alternative to the current methods.

In the production of biogas, the biomass (cow and goat dung) are allowed to decompose anaerobically at room temperature, producing a gaseous product which contains methane, carbon dioxide and hydrogen sulphide. This biogas, which comprises mainly of methane, has to be refined of $CO_2$ and $H_2S$ in other to improve its efficiency and thermal content, which can be used for cooking and generating power. At present, countries like India, United States, Pakistan and China have actualized this idea and are still thriving well. The merit of turning to this alternative source of energy especially for those countries listed above are labour intensive, low cost and its decentralized source for supplying energy in rural households or communities. It is easily controlled and reduces emission of gases into environment since there is no smoking or ash from the stock. Agricultural and other organic wastes are mostly the raw materials for biogas generation.

However, biogas production involves three basic steps; hydrolysis, acid formation and methane formation. Depending on the type of raw material, biogas contains an average of 50.0-70.0 % methane, 30.0-40.0 % carbon dioxide, 1.0-2.0 % nitrogen, 5.0-10.0 % hydrogen, and trace amount of hydrogen sulphide and water vapour [8].

## MATERIALS AND METHODS

### Design Method

The flow chart below describes the experimental designed for the work.

The study was carried out by varying the proportion of biomass while the amount of total solid and detention time were constant. Also, the ratio of amount of total solid to water in each of the fermentation digester was the same.

### Sample Collection

Cow and goat dung were obtained from the farm of the Department of Agricultural Technology, Federal Polytechnic Mubi, Adamawa State, Nigeria. Approximately 10 kg of cow dung was collected for the purpose of this research. The cow and goat dung were collected was sun dried and has been crushed manually to ensure homogeneity before mixing with water to produce biogas by anaerobic decomposition. The most prominent breeds of cows and goats in the livestock farm of Federal Polytechnic Mubi are Cow (90 % white Fulani and 10 % sokoto gudali) and Goats (94 % west African duaf  and 6 % red sokoto).

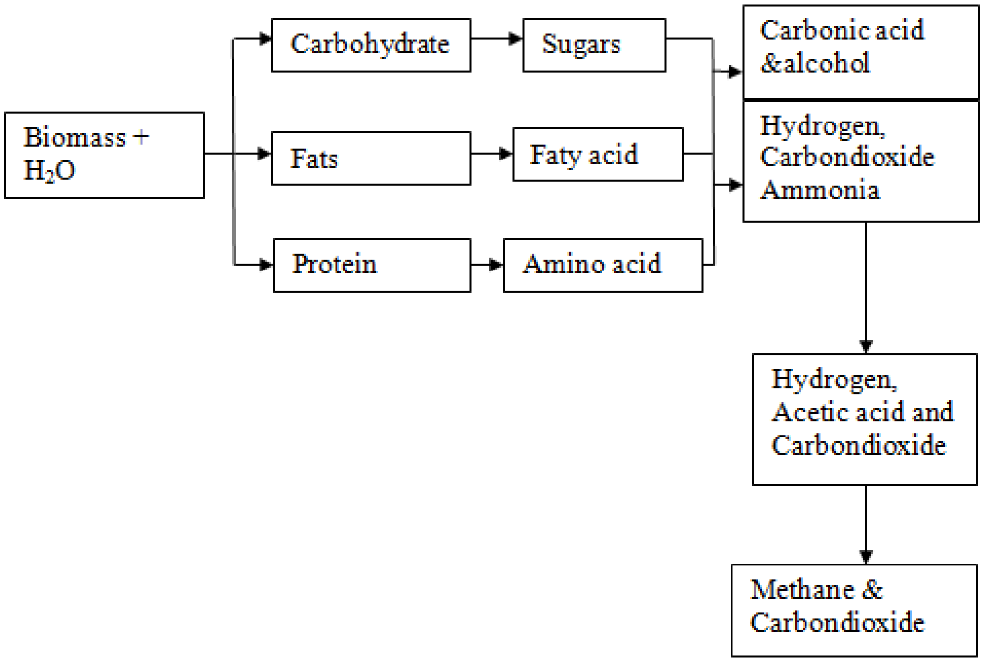


**Fig: 1. The key process of anaerobic digestion**

**Experimental Method and Procedures**
The set up for the experiment is shown below

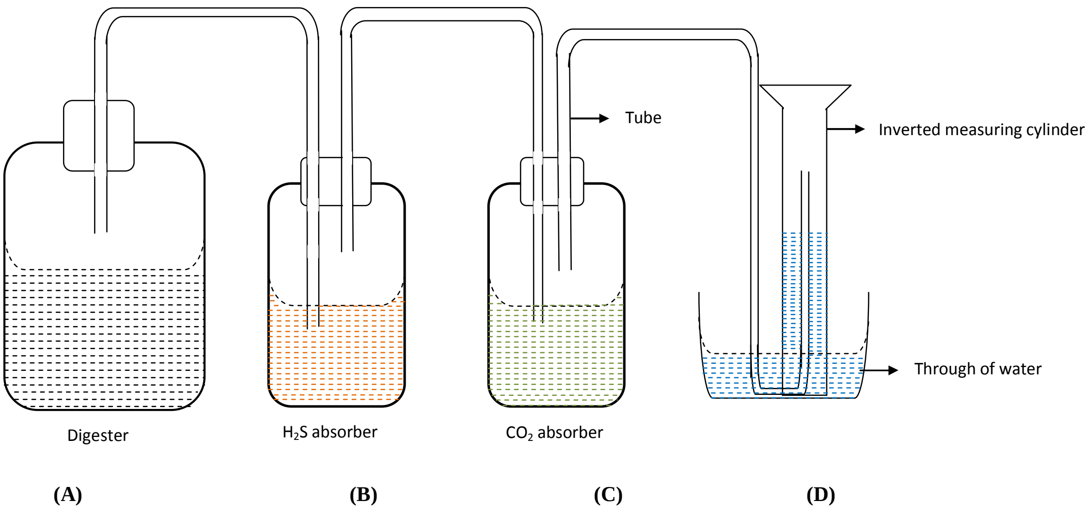


**Fig. 2: Experimental Model Setup**

Production commenced in the fermentation chamber, it was delivered to the second chamber which contained lead acetate solution and then passed unto the third chamber containing potassium hydroxide solution which was then measured at the last chamber by inverting a measuring cylinder over a through of water. Since the biogas is insoluble in water, a pressure build-up provided the driving force for displacement of the water in the measuring cylinder. The displaced water was measured to represent the amount of biogas produced [5].

For the set up, a hole was bored on top of the container (A) which was used as the digester and the PVC tube was inserted into the hole and glued. The output of the tube from (A) was channel into (B) and glued on top. The outlet from (B) was also channeled into (C) and glued as shown in fig.2 above. The last end of PVC from (C) was channeled into an inverted cylinder over a trough of water.

The weighing balance was used to determine the mass of cow dung and goat dung that made up the total solid for particular fermentation slurry. The digester was operated at ambient temperatures. A thermometer was used to determine the daily temperature and the average temperature was calculated and assumed to be the operating temperature. A digital pH meter was used to determine the pH of the fermentation slurry (sample) on the first day of the experiment.

**Data Collection**

The method of data collection that was used is that described by [4], after absorption of $H_2S$ and $CO_2$ the remaining gas is methane which was recorded by downward displacement of water in the measuring cylinder.

**Data Analysis**

This was carried out using a special computer program (MATLAB and EXCEL). Regression analysis was used to determine the fitting coefficient and also to determine the yield versus dung ratio based on the following regression equation,

$$G_y = k_1t^{a1}+k_2t^{a2}+k_3t^{a3}+k_4t^{a4}+\ldots\ldots \qquad (1)$$

Where:

$G_y$ = Gas yield (ml)

t = Time (days)

$k_1$, $k_2$, $k_3$, a1, a2, a3, a4 = Constant

The regression constants were determined leading to an empirical equation relating the yield and the dung ratio.

**Total Solid Content**

For the purpose of this research, there were three x: y proportions aimed at investigating the efficiency of mixing cow and goat dung in biogas production (Table 3).The amount of dung combined for the volume of slurry in each digester is as follows.

D1 – 1000g of cow dung, no goat dung
D2 – 750g of cow dung and 250g of goat dung
D3 – 500g of cow dung and 500g of goat dung
Preparation of slurry using the variation of ratio (cow and goat dung) described by [13].

**Table: 3. The variation of the ratio of Cow to Goat dung is shown below**

| Digester | Ratio of cow to goat dung(x:y) |
|---|---|
| D1 | 100:0 |
| D2 | 75:25 |
| D3 | 50:50 |

**Procedure for the collection of Biogas**

The general fermentation formula is
$(C_6 H_{10} O_5)n + H_2O$ ---------> $3nCH_4 + 3nCO_2$ [11].

The method of gas collection that was used is that described by [4], in their kinetic study of methane and biogas. The unattached end of the PVC tube from the digester was channeled through the container of 30 % acetate solution to absorb hydrogen sulphide. Below is the equation of the absorption of hydrogen sulphide.

$$(CH_3COO)_2 Pb_{(aq)} + H_2S_{(g)} \longrightarrow 2CH_3COOH_{(aq)} + PbS$$

The outlet of the container containing lead acetate acid was attached to another container of 10% potassium hydroxide solution to absorb $CO_2$ according to the equation.

$2KOH_{(aq)} + CO_{2(g)} \longrightarrow K_2CO_3 + H_2O$

The remaining gas after absorption of $H_2S$ and $CO_2$ is methane which was recorded by downward displacement of water in the measuring cylinder.

**Procedure for determining the Biogas yield of the sample dung**

The setup was maintained at a retention time of 20 days for the assessment and 35 days for the collection. The biogas generated was measured and recorded on daily basis. And also the ambient temperature was also observed.

## RESULTS AND DISCUSSION

The results of this study are discussed using the variation of ratio of cow and goat dung.

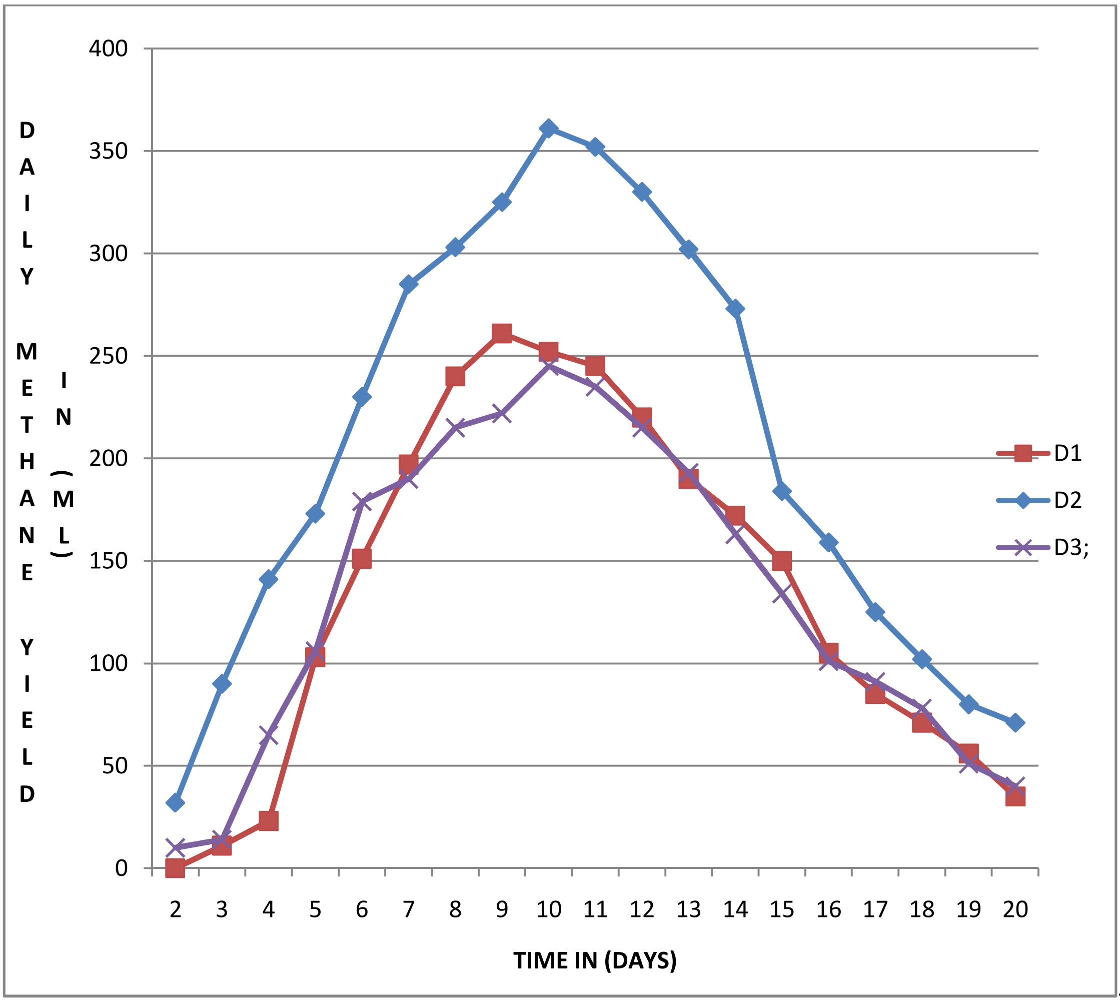


**Fig. 3: Combined graph of the general variation of cow to goat dung**

According to the graph, the ratio of 75:25 (D2) gave the optimal yield compared with the other ratios; this implies that the concept of animal (cow and goat) waste combination for the ratio of 75:25 (D2) for this particular specie is the viable alternative source of energy. According to the graph, there was no production within the first day of the experiment, because the methanogenic bacteria which act upon the organic material were inactive within this period due to the formation of organic acid which decreases the pH value to below 5.

**For the ratio of 100:0**
Linear model polynomial 2:
$G_y = k_1t^2+k_2t+k_3$
Coefficients (with 95% confidence bounds)
$k_1$=-2.744 (-3.314, -2.174)
$k_2$=59.71 (47.38, 72.04)
$k_3$= -104.9 (-161.1, -48.67)
Goodness of fit:
SSE=2.18×10$^{004}$
$R^2$ = 0.861
Adjusted $R^2$ = 0.8447
RSME=35.81ml

The equation $G_y = -2.744t^2+59.71t-104.9$, can be used for the prediction of gas yield at various digestion time with 86.1% accuracy.

**For the ratio of 75:25**
Linear model polynomial 2:
$G_y = k_1t^2+k_2t+k_3$
Coefficients (with 95% confidence bounds)
$k_1$=-3.592 (-4.155, -3.029)
$k_2$ = 76.56 (64.39, 88.73)
$k_3$ =-92.43 (-147.9, -36.95)

Goodness of fit:
SSE=2.124×10$^{004}$
$R^2$ = 0.9146

The $R^2$ assumes that every independent variables in the model help to explain the variation in the deviation. So, its tells the percentage of explained variation as if all independent variables in the model affect the deviation (as if each independent variable passes the t-test).
Adjusted $R^2$ = 0.9045

While, the adj. $R^2$ tells the percentage of variation explained by only those independent variables that truly affect the deviation (only those independent variables that passes the t-test).

The value of the adj. $R^2$ will be ≤ value of $R^2$.
RMSE=35.35ml
$_y= -3.892t^2+76.56t-92.43$

This equation can be used for the prediction of gas yield at various digestion times with 91% accuracy.

**For the ratio of 50:50**
Linear model polynomial 3:
$G_y = k_1t^3+k_2t^2+k_3t+k_4$
Coefficients (with 95% confidence bounds)
$k_1$= 0.06429 (-0.02243, 0.151)
$k_2$= -4.549 (-7.316, -1.783)
$k_3$ = 71.92 (46.6, 97.24)
$k_4$= -116.8 (-179.7, -53.88)

Goodness of fit:
SSE= 1.182×10$^{004}$
$R^2$ = 0.9069
Adjusted $R^2$ = 0.8895
RMSE= 27.18ml

The equation $G_y = 0.06429t^3-4.549t^2+ 71.92t -116.8$, can be used for the prediction of gas yield for the ratio of 50:50 at various digestion times with 90.7% accuracy.

**Collection of biogas**

Since the ratio of 75:25 (D2) produces the highest yield compared with the other ratios in the assessment of the gas, then the same ratio was transferred into the constructed metal prototype digester of 25 litres capacity and the gas was compressed into the gas cylinder by the use of a compressor.

**Flammability Test**

After the gas has been collected into the gas cylinder, it was tested by using a gas burner to check its flammability and it has been confirmed that the gas was flammable.

## DISCUSSION

The experiment was conducted within the pH range for optimum methane production and there was little temperature variation throughout the experiment. Accordingly, there was a negligible temperature variation effect on biogas production. The results in (fig. 3) shows that, there was no methane production in the first day for the D2 and D3 ratios, this may be the methanogenic bacteria which act upon the organic material within the digester were inactive within this period due to the formation of organic acid which decreases the pH value below 5, [10].

On the other hand methane production started beyond second day for D1 ratio, this reaches its optimum at the $9^{th}$ day, because the carbon nitrogen (C/N) ratio is within the optimum value of 20-30.Methane production drops from the $10^{th}$ day gradually down to the $20^{th}$ day for D1 ratio and for the D2 and D3 ratios it started dropping from the $11^{th}$ day, this is because the C/N ratio being high due to consumption of nitrogen by the methanogenic bacteria.

Also the total methane yield for 1kg of cow dung from this research is found to be 2567ml.This value is high compared to the value obtained by [13], for same quantity of cow dung. This is possible due to the season at which the experiment was carried out and also depends on the type of breed that is being used. The experiment was carried out between January to May 2013, where the ambient temperature is between 24-29 $^{0}$C. This temperature range is low compared to the optimum temperature of 35 $^{0}$C at which the methanogenic bacteria are inactive. Hence the low temperatures adversely affect the methane yield. It is well known that the composition of biogas as well as biogas yields depend on the substrates owing to differences in material characterization in each feed material [2]; [3]; [7]; [15]; [12].

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