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# Efficacy of Organic Nutritive Additives on the Quantity and Fuel Value of Biogas from Donkey Dung as Alternative Source of Gaseous Fuel

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**Abstract**
Five (5) different slurries of donkey dung were prepared by dissolving 20.00g of ground donkey dung in 125.00cm$^3$ distilled water. Each of the slurries was placed in a 500cm$^3$ Buchner flask (as a reactor).The reactors were made in triplicate and, labeled A, B, C, D and control. A quantity of 0.15g each of blood meal (as source of proteins), ethanoic acid, ground nut oil and sugar was added to A, B, C and D, respectively while the control reactor was kept unaided (without additive). The slurries were subjected to anaerobic microbial decomposition at 33$^o$C for 30 consecutive days. The biogas (gaseous product) generated in each reactor was collected over brine (28% NaCl) and, the average daily and total volumes of biogas for each reactor was purified by absorption process using appropriate absorbents and subsequently dried by passing over activated silica gel. The work showed that the mean total volumes of the gaseous product collected from A, B, C, D and control reactor were 49.52dm$^3$, 49.66dm$^3$, 49.88dm$^3$, 52.44dm$^3$ and 48.52dm$^3$, respectively; the percentages of the fuel contents of the mean total columes of biogas collected (based on the respective $CH_4$ contents of the gaseous products) from A, B, C, D and control wee 60.78%, 60.62%, 60.42%, 64.75% and 60.39%, respectively; the increase in the volumes of the gaseous product in A, B, C and D were 1.00dm$^3$, 1.14dm$^3$, 1.36dm$^3$, and 3.02dm$^3$, respectively and; the percentages of the increase in the fuel value in A, B, C and D were 0.39%, 0.23%, 0.03%, and 4.36%, respectively.
**Keywords:** Donkey dung; organic nutritive additives; biogas; gaseous fuel; fuel value.

## 1. Introduction

The cost and scarcity of improved petroleum products used for agricultural, industrial and domestic fuels are drastically increasing everyday. This makes it very difficult for most people to rise beyond subsistence level especially in developing countries (Nigeria inclusive). There is also the problem of environmental pollution due to the release of by products such as $SO_2$, $CO_2$ and PbO in the atmosphere when petroleum products (petrol, and diesel) are combusted in internal combustion engines (Yaro, 2011). The use of firewood as fuel for domestic energy supply also causes environmental pollution, as well, as desertification and erosion and reduced biodiversity due to the frequent felling of trees (Yerima and Abubakar, 2005). In addition, there is the problem of tremendous amount of biodegradable wastes produced everyday due to increase in population, which constitutes nuisance to the environment and reduces the aesthetic (beautiful) value of the environment (Yerima and Abubakar, 2005).

On the other hand, there is the need for large amount of energy for industrialization, this led the world to search for alternative sources of energy for domestic and industrial fuels so as to become less dependent on improved petroleum products. Developed countries are now concentrating on nuclear and electrical sources of energy, which are cost prohibitive and in accessible by rural populace in most of the developing countries of West Africa. This necessitated most developing countries to search for cheaper alternative sources of fuels, which are environmentally-friendly (Ekwenchi and Yaro, 2010). Development of biogas technology in which clean and cheaper fuel is produced is one of the routes through which alternative fuels can be generated (Ariane, 1985).

A fuel can simply be described as any substance which on burning or decomposing provides heat (Robinson, 1973). A part from atomic energy, all common fuels are carbon containing compounds, which can be solid, liquid or gas (Robinson, 1973). Solid fuels include wood, lignite, peat, anthracite, coke, etc; liquid fuels include petrol, kerosene, diesel, etc and; gaseous fuels include natural gas, town gas, coal gas, producer gas, water gas, biogas (the $CH_4$ content), e.t.c (Ekewunchi and Yaro, 2010). It should be noted that the fuel value of a biogas depends on its $CH_4$ content. A biogas containing 65% $CH_4$ and 35% $CO_2$ has a fuel value of 24MJ/m$^3$ while pure $CH_4$ has a fuel value of 37MJ/m$^3$, which is half the heat value per volume of $C_2H_6$, a third of $C_3H_8$ and 50% more than coal gas and; 1m$^3$ of biogas is equivalent to 20kg of firewood, 0.6dm$^3$ of kerosene, 0.5dm$^3$ of petrol and 0.4dm$^3$ of diesel (Dangoggo, 1984). Biogas is also a very efficient fuel for cooking, lighting and other energy demanding processes. For instance, 1m$^3$ of biogas can: cook 3 meals for a family of 3-6; keep biogas lamp of a luminosity equivalent to 60W of electricity light burning for 6-7 hours; keep 1hp internal combustion engine working for 2hours, roughly equivalent to 0.6-0.7kg of petrol; drive a 3 tone lorry for 2.8km and; generate 1.25 KWh of electricity (Ariane, 1985).

Based on the fact that energy is one of the basic requirments for industrial development of any nation in the world, it is necessary to think about the possible ways of generating fuels, which are cheap, clean, renewable in nature, environmentally- friendly and of good fuel value. In view of this, attention has seriously been focused all over the world towards generating fuels from wastes and other renewable sources, which are cheaper and relatively very available, such as solar, wind power, geothermal, and so on (Ekwenchi and Yaro,2010). This work reports the possibility of generating renewable energy resource (biogas) of good fuel value from donkey dung. The work also reports the effects of some organic nutritive additives (blood meal, ethanoic acid, ground nut oil and sugar) on the quantity and quality of the gaseous fuel ($CH_4$) generated from donkey dung.

## 2. Material and Methods

*2.1 Collection of the experimental Sample*

The sample (donkey dung) used for the research was collected from Dawakin Tofa town, Dawakin-Tofa L.G.A, Kano State – Nigeria. The sample was fresh at the time of collection. The sample was sun-dried for 5 days and subsequently dried in an oven at 105$^oC$ for 3 hours to eliminate moisture. The oven-dried sample was ground using wooden pestle and mortar and, sieved to a mesh size of less than 250 x $10^{-6}$m.

*2.2 Collection of Blood*

The blood used for the preparation of blood meal was collected from Jos main slaughter house.The blood was fresh at the time of collection.

*2.3 Preparation of Blood Meal*

The blood meal used as source of proteins was prepared by concentrating the blood at 110$^oC$ to a constant weight according to the concentration method described by Yaro (2011) with few adjustments in volume and temperature.

*2.4 Activation of Silica Gel*

The silica gel was activated by heating in an oven at 100$^oC$ for 24 hours according to the activation method described by Yaro (2011). The activated silica gel was used as drying agent, which eliminated water vapour ($H_2O_{(g)}$) from the biogas.

*2.5 Evaluation of the Weights of Ethanoic acid and Oil*

The weights of ethanoic acid and ground nut oil used as nutritive additives were evaluated using the following equation.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

For the evaluation of the weight of ethanoic acid, the density of ethanoic acid (1.22g/cm$^3$) and the required weight of ethanoic acid used (0.039) were used in the equation above, from which the volume of ethanoic acid, which corresponded to 0.03g was obtained and used.

The same procedure was followed for the evaluation of the weight of ground nut oil using its density (0.8g/cm$^3$) and the required weight of oil used (0.03g)

*2.6 Preparation of Slurries*

Five (5) different slurries of equal concentrations but different additives were prepared in triplicate and placed in Buchner filter flasks (as reactors). The reactsors were labeled as follows:

| | | | | | |
|---|---|---|---|---|---|
| A | = | 20.00g donkey dung | +25.00cm$^3$ $H_2O$ | + 0.15g | blood meal |
| B | = | " | " | " | ethanoic acid |
| C | = | " | " | " | ground nut oil |
| D | = | " | " | " | sugar |
| Control | = | " | " | " | without any additive |

*2.7 Production of Biogas From Donkey Dung at 33$^oC$*

Each of the prepared slurries was placed in a digester (reactor) and made air tight. The reactors were about ½ immersed in a waterbath, which was operated at 33$^oC$.The decomposition of the slurries was allowed to continue for thirty (30) consecutive days.The collection and analysis of the gaseous produces (biogas) were carried out according the methods adopted by Gumel and Yaro (2015) with few adjustments in the size of the gas holder and the volumes of the absorbents.

*2.8 Purification of Gaseous Fuel*

The gaseous fuel ($CH_4$) generated in each reactor was collected in pure and dry form by absorption using appropriate absorbents. The $CO_2$ and $H_2S$ contents of the gaseous product were removed by bubbling the gaseous product into 1M NaOH and 30% $(CH_3COO)_2Pb$ in 3M$CH_3COOH$ solutions, respectively, while the water content of the gaseous fuel was eliminated by passing the gaseous product over activated silica gel. The equations for the reactions of the absorption processes were as follows:

$CO_{2(g)} + NaOH_{(aq)} \rightarrow NaHCO_{3(aq)}$
$H_2S_{(g)} + (CH_3COO)_2Pb_{(aq)} \rightarrow PbS + 2CH_3COOH_{(aq)}$
$H_2O_{(g)} + SiO2_{(g)} \rightarrow H_2SiO_{3(aq)}$
The percentage of the gaseous fuel for each set was evaluated as follows:

$$\% \text{ gaseous fuel } (CH_4) = \frac{\text{volume of } CH_4 \text{ Collected}}{\text{volume of gaseous product}} \times 100$$

*2.9 Assessment of the Effect of Nutritive Additives on the Quantity and Fuel value of the Gaseous Fuel*
For the evaluation of the effects of nutritive additives on the volume of gaseous fuel collected from each set, the following relation was used:
Vinc = Vadd - Vcont
where Vinc = increase in the volume of gaseous fuel
Vadd = volume of gaseous fuel from a reactor with additive
Vcont = volume of gaseous fuel from control reactor.
The effects of the nutritive additives on the fuel value of the gaseous fuel for each set was evaluated as follows:-
% Vinc = % Vadd - % Vcont.
Where %Vinc = % increase in gaseous fuel

## 3. Results and Discussions

*3.1 Results*
The results of all the analysis carried out in this work are presented in Tables 1 and 2. Table 1 shows the mean biogas yields, as well, as the increase in the volumes of biogas under the influence of the nutritive additives used. Table 2 gives the fuel values of the gaseous fuel.

*3.2 Discussions*
The relative increase in biogas yield observed in “A” due to the addition of blood meal (as a source of proteins) when compared with the biogas yield in the control reactor as shown in Table 1 may be attributed to the amino group ($-NH_2$) of the proteins content of the blood meal, which serves as a source of nitrogen, which is needed for microbial growth and other anaerobic activities in the reactor during the decomposition of the slurry into biogas (Garba, 1998). The increase of biogas observed in ”A” could also be attributed to the alkyl, ketone and alkanoic groups of the proteins, which serve as sources of carbon that provides the fermentative microbes with the energy needed for the decomposition of the shrry into fermentative products (Obinwanne, 1999).

The high yield of biogas observed in “B” when compared with the biogas yield observed in the control reactor (Table 1) due to the addition of ethanoic acid may be associated with the decomposition of the ethanoic acid added into alkane ($CH_4$) and $CO_2$ by the action of methanogenic bacteria (Yaro, 2011).

From Table 1, it could be seen that addition of groundnut oil (reactor C) also enhanced biogas production when compared with the production of biogas noted in the control reactor. This may be connected to the chemical transformation of the fatty acid content of the oil into glycerol and alkanoic acids through hydrolysis, where the alkanoic acids formed decomposed into alkanes (usually $CH_4$) and $CO_2$ by the action of methanogenic bacteria (Yaro, 2011). The enhancing effect observed on biogas yield in “D” due to the addition of sugar as also shown in Table 1 can best be described based on the fact that polymeric materials (sugar inclusive) hydrolyse and yield monomeric substances, which transform into organic acids (usually ethanoic acid) and subsequently generate $CH_4$ and $CO_2$ ( Khanddwal and Mahdi ,1986).

Table 2 gives the percentages of the fuel content of the biogas generated under the influence of the organic nutritive additives used, as well as the fuel content of the biogas collected from the control reactor. The results (percentages of fuel contents) served as the index of fuel value for the biogas generated in each reactor. From the percentages of $CH_4$ contents of the gaseous degradation products (volumes of biogas obtained), it could be said the donkey dung is a suitable substrate for the generation of biogas of good fuel value because the percentages of $CH_4$ in all the reactors (A, B, C, D and Control) each was above 60% and for a biogas to be of good fuel value and high calorific value, its $CH_4$ content must not be less than 60% (Yaro, 2011). The results (Table 2) also showed that addition of blood meal, ethanoic acid, ground nut oil and sugar each enhanced not only the quantity of the biogas but also its quality as fuel (fuel value). This is based on the increase in the $CH_4$ contents of the biogas observed in A, B, C and D when each was compared with the $CH_4$ content of the biogas collected from the control reactor since the fuel value of biogas depends on its $CH_4$ content (Dangoggo, 1984).

## Conclusion

The production of gaseous fuel (biogas) of good fuel value through anaerobic decomposition of a waste (donkey dung) is established. Generally, the use of blood meal, ethanoic acid, ground nut oil and sugar (as nutritive additives) each enhanced not only the quantity of the biogas generated but also its (fuel value) and, of all the nutritive additives used, sugar was the most effective.

**Biographical Note of the Author**

Dr. M. N. Yaro was born at Dawakin-Tofa town, Dawakin-Tofa L.G.A., Kano State-Nigeria on the 26th December, 1971. He attended Central Primary School D/Tofa from 1976 – 1981; G.S.S. D/Tofa from 1981 to 1986; Advanced Teachers' College, Gumel, where he Obtained NCE (Chemistry / Physics) in 1989; Usmanu Danfodiyo University, Sokoto-Nigeria, where he obtained BSc. and MSc Degrees in Applied Chemistry in 1994 and 2004, respectively and; University of Jos-Nigeria from 2004 to 2010, where he obtained Ph.D in Applied Physical Chemistry in February, 2011. Dr. Yaro also attended a computer training course at Kano State College of Education from June 2004 – September 2004, where he obtained a Certificate in Computer Application and Data Processing. The area of research interest of Dr. Yaro is Renewable Energy and Environmental Chemistry. Dr. Yaro is a registered members of the:Institute of Chartered Chemistry of Nigeria (ICON), Chemical Society of Nigeria (CSN) and Teachers' Registration Council of Nigeria (TRCN). Dr. Yaro worked with Kano State Ministry of Education (As a teacher) from 1989 – 2001 and Federal College of Education (Technical), Bichi from 2002 – 2012 (as Chemistry Lecturer ). Dr. Yaro is Currently a senior lecturer in the Department of Chemistry of the Federal University, Dutse, Jigawa-Nigeria.

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**Table 1: Effects of Nutritive Additives on the Mean Total Biogas Yield After 30 Days.**

| Reactor | Additive used (0.15g) | Mean total Volume of Biogas ($dm^3$) | Increase in Volume ($dm^3$) |
|---|---|---|---|
| **A** | Meal | 49.52 | 1.00 |
| **B** | Ethanoic acid | 49.66 | 1.14 |
| **C** | Groundnut oil | 49.88 | 1.36 |
| **D** | Sugar | 52.44 | 3.92 |
| **Control** | No additive | 48.52 | - |

**Table 2: Effect of Nutritive Additives on the Fuel Value of the Gaseous Fuel**

| | **A** | **B** | **C** | **D** | **Control** |
|---|---|---|---|---|---|
| Fuel Value (% $CH_4$) | 60.78 | 60.62 | 60.42 | 64.75 | 60.39 |
| Increase in Fuel Value (%) | 0.39 | 0.23 | 0.03 | 4.36 | - |