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Feasibility study Of Biogas Production From Cow Dung In Cow Market In Wukari, Nigeria

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***Abstract*—Our life is completely dependent on a reliable and adequate supply of energy, in other to reduce dependence on fossil fuel, the use of various waste in producing a renewable alternative source of energy has been proved using waste. This work aimed at finding out the possibility of producing biogas, which is a mixture of different gases composed mostly of methane produced by anaerobic digestion could be generated from dung in Wukari cow market. From the study, the amount of biogas produced is 150m from 300 cows yielding 0.9m^3 of biogas per day and this biogas can generate 1.12kw of electricity per day. Also, biogas when produced, is use for direct combustion in gas stoves for cooking, gas lambs for lighting and also converted from it chemical to mechanical and finally to electrical energy for the generation of electricity. Therefore, it is recommended that since enough quantity of biogas could be produced from dung that could generate 1.12kw of electricity, the project is worth undertaken as this will serve as another means of electricity generation.**

Index Terms- **Anaerobic, Biogas, cow dung, Fermentation, Renewable Energy**

I. Introduction

Energy is an integral component of any socio-economic development and a central factor for eliminating poverty in any society (Aderemi etal, 2009). In Nigeria located on the west coast of Africa, lack of access to wide range of modern energy services has remained a major barrier to improving key indicators of human development (Onafeso, 2006). Presently over 60% of the country population depends almost entirely on fire wood for cooking, heating and agro processing activities. Petroleum products such as gasoline and kerosene are marked by acute shortages and mounting price, with the product sold over 300% above the official pump price (Anonymous, 2012). Additionally, electricity which is the foundation of modern economies is non-available and if available is of poor quality or better still unreliable as less than 4,000 MW of the 7,876 MW installed electricity capacity is been generated (Sambo etal, 2010).

The introduction of mechanization and automation of food processing operations to drive conveyors, pumps, compressors and equipment like steam boilers, dryers, refrigeration equipment, ventilation and ovens has made the use of electricity critical in food industries. The non-availability of electricity supply or poor quality and unreliable nature of electricity supply by power company in Nigeria has resulted in the increasing use of stand-by generators of various shapes and sizes (Adegoke and Akintude, 2000), which depends entirely on petroleum products as fuel. In spite of the obvious advantage offered by these stand-by generators as a dependable solution to erratic power supply; the re-current perennial petroleum products scarcity and it rising cost contribute to high cost of production and loss of competitive advantage of processed foods when placed side-by-side with the imported ones (Aderemi etal, 2009). Additionally, petroleum products are finite in nature and their combustion bye products are major contributors to environmental degradation, climate change and global warming (Das etal, 2000). Awareness on the limitations of the convectional fuel has enhanced the growing interest in the search for alternative, cleaner and sustainable source of energy (Goodger, 1980). Biogas which has a relatively significant comparative advantage due to the country huge biomass potential estimated to be about 8 x 102 MJ offers a promising sustainable solution (Nwoke and Okonkwo, 2006), however the wastes are usually dumped indiscriminately in landfills and unauthorized areas contributing further to environmental degradation and global warming (Adeola,1996; Igbinomwanhia and Olanikpekun, 2009). In-order to reduce the current over dependence on fossil fuel, enhance energy availability and safeguard the natural eco-system in the face of Nigeria huge biomass potential (Garba and Sambo,1992), biogas technology represents a viable alternative due to its simple technology and rural possible adaptability, (Diaho etal,2005). Biogas is a fuel gas consisting of a mixture of methane (CH4), carbon dioxide (CO2) and traces of other gases, produced through microbial processes under anaerobic conditions from bio-degradable materials (Dennis and Burke,2001). Although biogas technology is yet to be adequately exploited in Nigeria and other Africa countries, the technology is a common place in countries like India, China, Pakistan, U.S.A and most European nations (Nwoke and Okonkwo, 2006). Utilization of biogas as fuel in internal combustion engines have witnessed a substantial breakthrough and improvement over the years (Mitzlaff and Mkumbwa, 1980; Mitzlaft, 1988; Huang and Crokes, 1998; Midkif etal, 2001; Eshan and Naznin, 2005). Although biogas engines are presently not available in Nigeria markets; the crippling fuel prices and high cost of food processing coupled with the growing problem of food wastes management has remain an intractable national problem. One of the main important of

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biogas production is the ability to transform waste materials into a valuable resource, by using its substrate. Modifying these existing engines via rural adaptable technology to use biogas produced from these food wastes and animal dung is an essential springboard for a shift to an eco-system friendly technology and sustainable rural development. The scope of this paper is to under study the feasibility of biogas production from cow dungs in Wukari cow market in Nigeria.

II. THEORY

Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic condition. It is composed majorly of CH_4 (methane 50-70%) and CO_2 (30-40%).

Additionally, it consists of traces of H_2S, N, CO, O etc. The content of CH4 and CO_2 is a function of the natter digested and the process conditions like pH, temperature, ionic strength or salinity, nutrients and inhibitory substrates. Biogas burns with an almost odorless blue flame with heat of combustion equivalent of 21.5MJ/M3.Relative density of biogas compared to air of about 0.8.Auto-ignition temperature in the range of 6500-750 compared to petrol 5000-600 and 800-8500.Huge volumes of agricultural wastes in the form of livestock manure, corn cobs, cassava peelings rice husk, ground nut shells, sawdust, bagasse, human excreta and the resultant gas (BIOGAS) can be converted into potential sources of energy for food processing activities.

This is achievable with the use of bio-digester. This is sustainable in Nigeria as about 70% of the population are involved in agricultural activities and producing diverse varieties of plant and animal products. Presently biogas is not widely used in Nigeria's rural economy due to poor knowledge of its energy potential as well as limited resource to purchase the required equipment for its conversion. Furthermore, even if the gas is produced, it may not be in a form that can be easily transported or converted into electricity, which is necessary to power food processing equipment.

A. Design and Operation of Laboratory-Seale Anaerobic Fermentors

Pathe etal, (1977) used a 10-litre anaerobic digester and measured the biogas produced by the downward displacement of brine solution. Hawkes and Young (1980) stated that small-scale anaerobic digesters may provide more stable rates of gas production than large-scale plant, since fluctuations in the feed waste is minimized. A readily assembled 5-litre digester with gas collecting systems was used for the production of methane.

B. Effect of Temperature on Anaerobic Fermentation

Stanier etal, (1963) stated that microorganisms exhibited prolific growth over a relatively narrow range of temperatures. Three temperature ranges were grouped as thermophilic (45^0C or more), mesophilic (20° to 45°C) and psychrophilic (less than 20^0 C). Malina (1964) reported that the biogas production was maximum at 40*0, decreased to minimum at 30° C and rose again as the temperature was increased. Kirsch and Sykes (1971) stated that anaerobic digesters operating at 350-60 were superior to those operating at 30 in relation to percentage of degradation of volatile matter and volume of biogas. Pfeffer (1973) showed that there was a maximum biogas production at the mesophilic range of 40 and at the thermophilic range of 60^0 C. Van den Berg etal (1976) stated that maximum biogas production occurred at temperatures of 40^0C-45^0C. Zeikus and Winfrey (1976) reported that Methanosarcina and Methanobacterium required optimum temperature above 30^0C in pure culture conditions. Pathe etal, (1977) stated that the optimum temperature for maximum biogas production ranged between 28^0C and 70^0C. Ward (1978) reported that natural thermophilic methane producing bacteria occur over a temperature range of 30^0C – 68^0C with optimum methanogenesis at 45°C. Hashimoto etal, (1979) reported that specific growth of microbes was maximum, when fermentors were operated at optimum temperature of 42°C for mesophilic and 62°C for themophilic forms. Van Velsen etal, (1979) stated that at the temperature of 13℃ no methane was produced, while in mesophiTlc range(20^0-40^0C) methane production increased with temperature and under thermophilic condition (55°C), it decreased by 250^0C. Pfeffer (1980) classified two optimum temperature levels for the production of biogas. The mesophilic level of temperature ranged from 35°C to 40 and for thermophilic level it ranged from 55^0C to 60^0C. Ranade etal,(1980) reported that Methanobacterium ruminatum, M. formicicum and Methanobacterium sp. were predominant in the anaerobic digester at an optimum temperature of 37^0C. Lo etal,(1985) stated that the optimum temperature for thermophilic bacteria was 55^0C and for mesophilic it was 35^0C. Nipaney and Panholzer(1987) reported that at 37.5 temperature, the biogas output was maximum.

C. Effect of PH on Methanogenic Process

Methanogenic bacteria are extremely sensitive to pH. The optimum pH range for methane production was between 7.0 and 7.2, although biogas production was satisfactory between 6.6 and 7.6, pH below 6.2 was found to be toxic to methanogenic bacteria. The optimum pH ranges according to Smith and Hungate (1958) was between 6.5 and 7.7 for hydrogen utilizing methanogenic bacteria. Hamer and Borchardt (1969) found the optimum pH for methane production was 7.05 to 7.20. According to Zeikus and Wolfe (1971), the maximum growth of methanogenic bacteria ranged from pH 7.2 to 7.6, Sathianathan (1975) indicated the optimum pH for most of the bacteria involved in biogas production was between 6.5 and 8.0. According to Pathe etal, (1977), the optimum pH for biogas production ranged from 6.8 to 7.0. Ranade etal, (1980) reported that optimum pH for c Methanobactenum mobilis, M. ruimnatum, M. formicium, Methanospirilium hungati, Methanobacterium sp. was 7.1, 7.5, 7.1., 7.,1 and 7.5, respectively. Schwartz etal, (1981) stated that optimum pH of an anaerobic digester for biogas production was between 7.3 and 7.6.

D. Optimum C: N Ratio for Biogas Production

Singh (1974) reported that the biogas production v/as influenced by optimum C: N ratio of 30:1 for an anaerobic digester if other conditions were favorable. The bacteria-use carbon 30 times more than nitrogen. Takatani etal, (1975) stated that optimum C: N ratio for anaerobic digestion was

20:1.C: N ratio close to 30:1 was the best to achieve an optimum rate of digestion. Barnett etal, (1978) suggested that the optimum C: N ratio for anaerobic digester was 30:1. Hawkes (1979) stated that an optimum ratio of C: N is between 20:1 and 30:1. Hills (1979) reported that the greatest methane production per unit, occurred when the C: N ratio of the digester was 25:1.

E. Role of Volatile Fatty Acids and Volatile Solids in Methane Formation

Sathianathan (1975) stated that during anaerobic digestion, bacteria release cellular enzymes into the medium to hydrolyze large molecules into smaller molecules, especially volatile fatty acid (VFA), namely, acetic acid. Optimum amount of VFA influences high methane formation. Van Velsen and Lettinga (1980) stated that VFA is an intermediate product of anaerobic digestion with adverse effect if the concentration is high. Higher concentration of VFA can bring about a drop in the pH level below 5.8, which is toxic to methanogenic bacteria. Aller (1979) studied at 55-60"C the anaerobic digestion of organic matter of urban solid waste. Methane production increased with increasing retention time and pH. Methane production enhanced with increasing concentrations of volatile acids. Ghose etal, (1997) stated that when plant waste was added to cow-dung and subjected to anaerobic digestion, the methane content in the biogas was more due to the presence of volatile solids. Rorick et al. (1980) stated that methane production was high in thermophilic reactors, with substrata adjusted to 4.1 per cent volatile solids. Singh etal, (1984) used daily fed digesters at volatile solids concentrations ranging from 2,25 to 18.0 percent. Digestion was more efficient at 13.5 per cent total volatile solids with a retention time of 30 days.

F. Electricity Generation

Generating electricity is a much more efficient use of biogas than using it for gas light. From energy utilization point of view, it is more economical to use biogas to generate electricity for lighting, in this process, the gas consumption is about 0.75 m3 per kW hour with which 25 to 40-watt lamps can be lighted for one hour, whereas the same volume of biogas can serve only seven lamps for one hour (Karki etal 2005). Small internal combustion engines with generator can be used to produce electricity in the rural areas with clustered dwellings. Bio digesters can be used to treat municipal waste and generate electricity (Karki etal, 2005). One of the options to utilize biogas is to produce electricity using a gas engine or gas turbine.

According to Igboro (2011), other benefits of biogas include

1. Improvement of hygienic conditions through reduction of pathogens worms' eggs and flies,
2. Reduction of workload, mainly for women in firewood collection and cooking.
3. Environmental advantages through protection of soil water, air and woody vegetation.
4. Micro-economic benefits through energy and fertilizer substitution, additional income sources and increasing yields of animal husbandry and agriculture;
5. Macro-economic benefits through decentralized energy generation and import substitution.

Thus, biogas technology can substantially contribute to conservation and development, if the concrete conditions are favorable (Igboro,2011).

III. MATERIALS AND METHODS

A. Materials

This study is accessing the feasibility of producing biogas from cow dungs in Wukari cow market. The materials for feasibility study of biogas from cow dung include; hand gloves, shovel, shovel nose respirator, 30cm distilled water, fresh cow dung, clean container with cover, four sets of 250ml conical flask and glass rod.

Fig.3.1, The section of Wukari cow ranch.

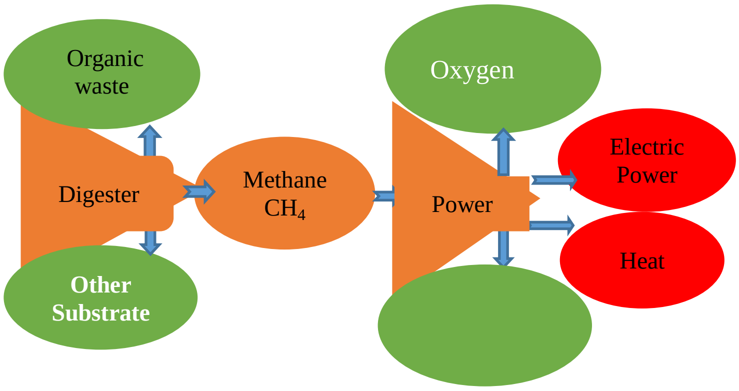

Fig.3.1 Main components and general process flow of biogas production

B. Methods

The amount of biogas generated each day G, is calculated on the basis of specific gas yield Gy of the substrate and the volatile solid content of daily substrate Vs.

Biogas production is calculated using the equation below;

$$G = V_S * G_Y \quad (1)$$

Where;

V_S = weight of feedstock available per day in kilograms

G_y = specific gas yield in cubic meters

G = daily biogas production in cubic meters.

Then the specific gas production or gas production rate is calculated using equation (2) below.

$$G_P = G \div V_d \quad (2)$$

Where;

G_P = Gas production rate in cubic meters per day

G = Daily biogas production in cubic meters

V_d = Container volume in cubic meters.

C. Gas Holder System Design:

i. Gas holder volume (Vg):

According to Kossmann etal (2001) and Ahmadu 2009, the size of the gas holder, ie the gas holder volume (Vg), depends on the relative rates of gas generation and gas consumption

The gas holder should be designed to:

Cover the peak consumption rate(gc_{max}) for the period of maximum consumption

(tc_{max}), $V_g = V_{g1}$ (3)

Hold the gas produced during the longest Zero consumption period

(tz), $V_g = V_{g2}$(4)

From equation (3)

$V_{gl} = gc_{max} x tc_{max}$ (5)

From equation (4)

$V_{g2} = Gh * tz_{max}$ (6)

Where,

Gc_{max} = maximum hourly gas consumption(m^3hr.)

Tc_{max} = time of maximum consumption (hr.)

G=daily gas production(m^3/day)

G_h= hourly gas production (m^3/hr.) = G/24 hrs./day

T_z=maximum zero consumption time(hrs.)

The larger value, (V_{gl} or V_{gs}) determines the size of the holder. A safety margin of 10-20% is then added (Ahmadu,2009).

i. Gas holder dimensions:

Having determined the volume of the gas holder, a desired ratio for the dimensions can be adopted,depending on the geometric shape of the design.For a cylindrical gas holder,

$V_g = \pi r^2 ghg$(7)

Where,

V_g=volume of gas holder`

r_g=radius of gas holder

h_g=height of gas holder

ii. Force on Gas Holder(F_g):

The force on the gas holder is given as:

$F_g = P_g * A_g$ (8)

P_g=Pressure in gas holder

A_g = Cross-section area of gas holder (Ahmadu, 2009)

Size of Ranch	Size of Land (in Acres)	No of Cows
Small	500 - 2000	300 cows
Medium	2000 – 20,000	2000 cows
Large	20,000 – 100,000	6000 cows

Table.3.1 Acres of Ranch

1 cow for 6-17 acres.

Considering the use of small size ranch with 300cows.

D. The Expected Biogas Production Per Day

The daily amount of biogas produced can be determined when the daily amount of dung produced is known.

$$Amount\ of\ biogas\ per\ day\ (m^3) = \frac{no\ of\ cows * average\ amount\ of\ each\ cow}{amount\ of\ dung}\ (kg)$$

No of cow = 300, yielding per cow is 10kg on average, no of dungs = 20kg to generate 1m^3 of biogas.

Therefore, Amount of biogas produced = 300 x 10 = 150m^3

22 kg of cow dung will produce 1kg of purified biogas.

1kg of total solid will produce 0.2 m3 of biogas

1kg of dung contain about 20% TS

Now, 1kg of dung which contains 20% TS will produce, 0.2 * 0.2 = 0.04 m^3 of biogas.

1kg dung = 0.04 m^3 of biogas

Hence, 1/0.04 = 25kgs is required to produced 1m3 of biogas.

Density = mass/volume.

Density of biogas 1.15kg/m^3, mass (required here is 1kg)

Volume required to make 1kg biogas = mass (1kg) / density (1.15kg/m^3) = 0.86m^3.

Therefore, to produce 1kg of biogas we need 0.86 *25 = 21.7, approximately 22kg of dung.

E. Digester Dimension

There is an optimum relation between the diameter D, of the digester and the total volume V, as D = 1.3078V1/3, where f1/D =1/5, f2/D = 1/8 and H = D/2.5. This gives D = 0.49m, H = 0.19m, fl=0.1m and f2=0.06m.

IV. RESULTS AND DISCUSION

A. Results

The result shows that 22kg of dung will yield 1kg of purified biogas and 1kg of dung contain TS (total solid) which will have produced 0.2m of biogas. Therefore, to produce 1kg of biogas we need 22kgs of dungs.

Expected Amount of Biogas to be Produced Per Day

The daily amount of biogas produced can be determine when the daily amount of dung produced is known. Hence the daily amount of dung produced in the ranch is 22kg.1kg of cow dungs produce 0.04m3 of biogas.

From (1)

$G = V_S \times G_Y$

Where;

V_S = 22kg

G_y = 0.04m^3

G = 22 x 0.04 = 0.88m^3

Approximately, 0.9m^3

It means that 22kg of dung will yield 0.9m^3 of biogas per day, so in a mouth the ranch will yield 27m^3/mouth of biogas and 328.5m^3 of biogas.

1m^3 of biogas equivalent to 1.25kw of electricity (Alwis, 2001)

Electricity generation now will be 0.9x1.25=1.125kwiday

Taking a day to have 24hrs, electricity generation will be 1.125/24 = 0.047 kw/hr.

B. Discussion

Biogas composition and rate of it yield varies according to the input material or feedstock and retention time see figure above. The daily gas production from cow dung of 80 number of cows is 40m^3. While the gas yield from 22.5kg of dung is 0.9m3 of biogas. 1 kg of cow dung produce 0.04m3 of biogas. From the 21-30 day (time) the highest number of gases was produced see figure 4.2 above.

V. SUMMARY

A. Summary

The feasibility study of biogas production from cow dung from Wukari cow market has been carried out. The amount of dung produced per day was calculated to be 22kg and the expected amount of daily biogas produce per day was calculated to be $0.9m^3$ and the amount of electricity produced per hour was calculated to be 0.047kW/hour.

A. Recommendation

The technical problem of biogas production could be the initial involved in biogas digester construction and lack of trained operators, poor equipment design and failure to feed the digester regularly. It can therefore be recommended that;
i. Biogas being a fuel produced by a digester device fed by sewage running through the pipe isa very good gas as its will be used for many purposes such as lighting, cooking, etc.
There is need to sensitize people about the use of biogas as a cheap and reliable source of
energy.
ii. Government at various levels should come into the promotion of biogas through financing theconstruction of ranch to prevent conflict and waste of dung.

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