RENEWABLE ENERGY FOR COOKING: THE ROLE OF LOW-COST PLASTIC-TUBE BIODIGESTERS

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ABSTRACT

The plastic (polyethylene) tube biodigesters on small farms can make a good impact because of the low costs, the simplicity of construction and operation, high rate of benefit, positive effects on the environment and improvement of women's lives in rural areas. The biodigesters have become an important component of integrated farming systems in rural areas in some countries: Colombia, Ethiopia, Tanzania, Vietnam, Cambodia and Bangladesh. This can also be done in Nigeria. This paper highlights the importance of polyethylene tube biodigester constructed and exposed to sunlight in Bauchi (latitude N 10^0 16' 45.68", longitude $E009^0$ 47' 47.38" and altitude of 605.2m). The average sunshine duration for this location was found to be 9hrs in the month of March and April with an average solar radiation of $5kWh/m^2$. Methane gas was produced after seven days for the experimental set-up as against fourteen recorded for the control digester in the shed. The gas was stored in a polyethylene tube and used on the specially constructed stove for cooking. A flame temperature of 283^0C was recorded. 0.42kilogrammes of rice was cooked in just thirty minutes!

KEY WORDS: *biodigesters, farming systems, integration, solar energy, biogas-stove*

INTRODUCTION

Developing countries are facing a low living standard and dangers to the environment because of increasing population, exploitation of natural resources and growth of industries, and at the same time increasing demand for food and fuel. These problems have led to scientific and social initiatives focused on sustainable development including the use of renewable energy sources. In ASEAN member countries, energy from biomass such as wood and agricultural residues represents about 40% of the total energy consumption, equivalent to some 2.5 million Tetra-joules per year. The bulk is from wood, with an estimated value of US$ 7 billions per year (Biomass energy in ASEAN member countries 1997). The world presently derives some 60% of its energy from fossil fuels. The supplies of these are limited and at projected future rates of consumption are likely to be depleted well before the end of this century (ASPO 2002).

There is therefore an urgent need to develop alternative energy sources. For rural areas, the use of local resources in integrated farming systems is projected to bring most benefit to small scale farmers and the environment (Leng and Preston 2005). The recycling of livestock wastes through biodigesters to produce biogas for cooking and nutrient-rich effluent as fertilizer is one of the ways to reduce dependence on fossil fuel-derived inputs in an environmentally friendly way that benefits small scale farmers (Preston 2000).

Recent research has shown that the effluent from biodigesters is a better fertilizer than the original manure when applied to crops such as cassava and duckweed (Le Ha Chau 1998a,b) or when used in fish ponds (Pich Sophin and Preston, 2001).

The insufficient energy situation in our country Nigeria has continued to get worse despite promises of improvement by succeeding governments. This has had a ripple effect on the economy since there is no facet of human activity that does not depend on one form of energy or the other. Consequently, the lack of consistent availability of energy has aggravated the poverty status of Nigerians.

A large population of Nigerians lives in the rural areas, where the only form of available energy is firewood. The present government's posture is about making Nigeria one of the 20 largest economies in the world by 2020. This means that the time is ripe to pursue an energy policy that is effective and sustainable. Biogas if properly harnessed can play a significant role in expanding and enriching the energy mix in the country in the years ahead.

For example the renewable energy projection in Nigeria as at the year 2002 can be seen in Table 1. However, Nigeria's livestock manure aggregated production was put at 285.1 million tonnes and is potentially able to produce over 3billion cubic meters of gas yearly (NREMP, 2005). This is more than 1.25million tones of fuel oil per annum.

The effort of the Energy Commission of Nigeria towards the National Energy Master Plan and particularly the National Renewable Energy Master Plan should be pursued with vigor and not abandoned like many reports before it. It has a clear pathway that the government can adopt in order to realize the 2020 dream.

Table 1: Renewable Energy Resource Endowments in Nigeria (Umar, 2002)

TYPE	Estimated Reserve
Large Scale Hydropower	100,000 MW
Small Scale Hydropower	734MW
Solar Radiation	3.5 – 7.0 kWh/m^2 day
Wind	2 – 4 ms^{-1}
Fuel wood	43.3 x 10^6 tonnes/year
Animal Waste	61 x10^6 tonnes/year
Crop Residue	83 x 10^6 tonnes/year

BIOGAS

Biogas is a form of energy that can be generated naturally. Nature has endowed us with a wide range of raw materials from which biogas can be generated: human and animal excreta, leaves, twigs, grasses stalks from crops, garbage and some agricultural and industrial wastes whose organic content is greater than 2% (An Bui Xuan, et al., 1994, 1996). Biogas which is flammable is produced when organic materials are fermented in a certain range of temperatures, moisture content and acidities under air – tight conditions.

The degradation of organic matter to produce methane depends on the complex interaction of several different groups of bacteria. Stable digester operation requires that these bacteria groups be in dynamic and harmonious equilibrium. Any changes in the environmental conditions can alter this equilibrium and result in the buildup of intermediate which may inhibit the overall process.

The effect of environmental factor on anaerobic digestion

Environmental factors which influence biological reactions are pH values, Temperature, Nutrients and inhibitors concentrations. Of these factors, temperature is of importance from this paper's point of view while keeping other factors constant.

Temperature in the digester

The metabolic and growth rate of chemical and biochemical reactions tend to increase with temperature and within the temperature tolerances of the microorganisms. Too high a temperature however, will upset the metabolic rate due to degradation of enzymes which are critical to the life of the cell. Microorganisms exhibit optimal growth and metabolic rate within a well defined range of temperature, which is specific to each specie, particularly at the upper limit which is defined by the ability of the protein molecules synthesized by each particular type of organism.

Methanogenic bacteria are more sensitive to temperature change than other organisms (such as acetogenic bacteria) present in digesters. This is due to the faster growth rate of the other groups such as the acetogens which can achieve substantial catabolism even at low temperatures (Schmid and Lipper, 1969).

All bacterial populations in digesters are fairly resistant to short-term temperature upsets, up to about two hours and return rapidly to normal gas production rates when the temperature is restored. However, numerous or prolonged temperature drops can result in unbalanced populations and lead to the low pH problems. Temperature variations can have adverse effects on mesophilic (35^{O}C) digestion, or thermophilic (55^{O}C) digestion. The temperature effect also depends significantly on the solids concentration of the fermentation. When high concentrations of organic loadings are used (over 10%), the tolerance for changes of 5-10% is much higher and bacterial activities return quickly when the temperature is raised again (Marchiaim, 1990). Two distinct temperature regions for digestion have been noted above. Optimal digestion occurs at 35^{O}C in mesophilic range and 55^{O}C in the thermophilic range, with decreased activities at around 45^{O}C. This response to temperature may be due to effects on methanogenic bacteria, since this appears to exhibit similar optimal regions.

An advantage of thermophilic reaction is that the rate of methane production is approximately twice that of mesophilic digestion and thermophilic digesters could accept higher organic loads than mesophilic systems at the same hydraulic retention time (HRT). This advantage becomes more pronounced as the retention time decreased (San Thy et al. 2003)

Biogas in improving rural development, environment and ecology

Biogas technology is an effective way to solve the problems of environmental sanitation both in cities and rural areas. Anaerobic fermentation process is an important way of making use of biomass resources to achieve a number of benefits through biogas technology in the production of energy which is an important measure to curtail the problems of fuel shortage in rural areas. It is also meant for the protection of the environment and the improvement of the ecology by reducing dependence on natural resources like forests. The process improves the sanitation and hygienic condition of the local areas. It reduces or eliminate bad odour coming from disposed wastes.

The effluent is used as farm manure which improve soil conditions and enrich it with higher quantities of plant nutrients like nitrogen, phosphorus and potash. There are no pathogens existing in the effluent (slurry) since they will all die in the absence of oxygen. This can boost agricultural production, conserve soil and erosion losses, reduce cost of purchasing chemical fertilizers and lead to a sustainable farming system.

Biogas equivalent and uses

The gas generated can be used as a substitute to other source of non-renewable energy as shown below: one cubic metre of biogas is equivalent to: 3.47 kg of wood, 0.62 litres of kerosene oil, 0.61 litres of diesel oil, 1.5 kg of coal, 0.45 kg of LPG and 0.5 kg of butane (Adisa, 2006). 1m^3 can keep one biogas lamp of luminosity equivalent to 60watt electric bulb burning for 6 – 7 hrs, cook 3 meals for a family of 6, drive a 3tonne lorry for 2.8km and run a one horsepower (0.746kW) generator for 2hrs.

Types of biodigesters

There are three main types of biodigesters, they are:

a. Floating canopy or dome digesters
b. Fixed dome digester
c. Bag red mud or plastic red mud tubular plug flow model

PLASTIC BIODIGESTER

The high investment required to construct biodigesters of fixed structure proved to be a major constraint for low-income small farmers. This motivated engineers in the Province of Taiwan in the 1960s (FAO, 1992) to make biodigesters from cheaper flexible materials. Initially nylon and neoprene were used but they proved relatively costly. A major development in the 1970s was to combine PVC with the residue from aluminium refineries to produce the product named "red mud PVC". This was later replaced by less costly polyethylene which is now the most common material used. The plastic biodigester can be used as a cheap and reliable means of converting harmful biodegradable wastes to a useful source of energy (biogas) and fertilizer (slurry).

The plastic biodigester constructed (Fig.1) is a closed medium made of polyethylene material. Animal wastes (cow dung) were fermented anaerobically under the influence of solar energy (by mesophillic digestion) giving rise to a gas (biogas) and a residue (the effluent). To prevent the polyethylene from being degraded from the action of ultraviolet rays, another plastic material that shields the UV rays were used to give a green house effect. The temperature monitored in the system was in the range of 30^0C – 45^0C with a daily average of 38^0C throughout the retention time. Methane gas was produced after 7days instead of the normal fourteen recorded for the control digester in the shed whose temperature range was 20^0C – 28^0C with a daily average of 24^0C. The experiment took place in Bauchi metropolis (latitude N 10^0 16' 45.68", longitude E009^0 47' 47.38" and altitude of 605.2m). The retention time was 7 – 18days for the experimental setup and 14 – 24days for the control setup. The two digesters had capacity of 0.39m^3 and contained 50kg of cow dung and 150kg of water. Approximately 1.5m^3 of gas was collected over the retention time. The biogas produced was a mixture of methane (≈ 65-70%) and carbon dioxide and some impurities (traces of hydrogen sulfide and small fractions of nitrogen). If required, the impurities can be removed leaving pure methane. In complete combustion, a cubic metre of methane can attain a temperature of 1400^0C and release up to 5650kcal (23.67MJ) of energy. However, for this purpose, the gas was used directly without any purification. It burned with a blue flame at a temperature of 238^0C. Experimental tests showed that 0.42kg of rice was cooked in thirty minutes and a litre of water boiled in ten minutes. The effluent contained all the original mineral elements that give rise to needed plant growth. It can serve as an input to the fish farm and the gardens.

BIOGAS STOVE

The biogas so produced must be made useful. Unfortunately, methane gas cannot be compressed. The task became a challenge again to the engineer. A stove now exists to cater for the rural poor and those in the urban centres. Metallic and ceramic stoves have been designed and put to use with minimal costs. It consists of the burner, gas pipe with controlling valves burner shield and pot support (Fig.2). The storage problem posed by the incompressibility of the gas has been solved by using polythene (Fig.3) which can be easily transported or mounted and conveniently used in homes.

CONCLUSIONS

It has been proven that heat from the sun (solar energy) can raise the temperature of the biodigester and initiate gas production faster than the conventional process. HRT can be reduced by as much as 6days. The construction and effective utilization of low cost plastic biodigesters will boost the average standard of living of our people by solving the energy needs, conserving our forests reserves, stimulating agriculture and the same time maximizing the utilization of resources – switching from waste disposal to waste utilization. Low cost plastic biodigesters should therefore be encouraged.

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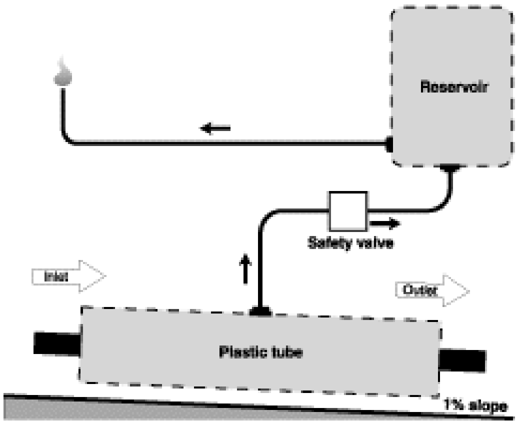

Fig. 1 Plastic biodigester

Fig. 3. A vertical biogas storage bag

Fig 2.Biogas stove

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