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Biogas production from cow dung and food waste

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The present study was based on a pilot biogas plant of 6 m^3 installed at College of Agriculture and Rural Transformation campus in University of Gondar. The ideal feed size for food waste was 2.5 cm. The co-digestion of food waste with fresh cow dung as a starter gave significantly better results. The process was successfully demonstrated by using temperature controlled system to maintain thermophilic conditions. The process resulted in the production of nutrient rich slurry with high NPK content and high C/N ratio. This slurry can be used as a natural fertilizer. Thus the food waste proved to be a valuable alternate source of energy. The setup confirmed to be cost effective as it was not only a cheap source of energy but also a source of nutrient rich organic fertilizer. In the long run it will help in minimization of solid waste disposal and ultimately the reduction in greenhouse gas emissions from the waste. Therefore, the application of biogas technology has economic, environmental, health and social benefits. It ultimately contributes towards sustainable development.

Key words: Alternative energy source, biogas, food waste, Methane, slurry.

INTRODUCTION

The Agricultural potential and natural resource bases of Ethiopia have been continuously exploited for a long period of time without appropriate conservation practices. This inappropriate use has led to environmental degradation and cyclic drought (FAO, 1988).

One of the reasons for the decline of land productivity in many areas is the removal of forest and vegetation cover due to increased human population pressure (Beets, 1989). According to the environmental protection authority of Ethiopia some two million hectares of land in the country has now become irreversibly barren as a result of the extensive deforestation (WIC, 2002).

The prevailing deforestation has also resulted in serious ecological degradation and loss of socio-economic welfare (Hurni, 1998). More than 85% of the population of Ethiopia lives in rural areas, and more than 90% of the energy requirement of the country comes from fuel wood (EGAP, 1994).

The problems arising from non-sustainable use of fossil fuels and traditional biomass fuels have led to increased awareness and widespread research on the accessibility of new and renewable energy resources, such as biogas. The development of renewable energy technologies and in particular biogas technology can help reduce the dependence on non-renewable resources and minimize the social impacts and environmental degradation problems associated with fossil fuel.

Renewable energy could provide the much desired sustainable rural revitalization in most developing countries. It is an ideal alternative because it could be a less expensive option for low income communities. An ideal renewable energy source is one which is locally available, affordable and can be easily used and managed by local communities. Biogas is one of a number of technologies that offers the technical possibility of decentralized approaches to the provision of modern energy services using resources such as; cow dung, human waste and agricultural residues to produce energy. It can be used for heat and electricity production and the digester residue can be recycled to agriculture as a secondary fertilizer. Biogas plant is relatively simple, economical, and can operate from small to large scales in urban and rural locations. In this regard, many African governments have realized that renewable energies could play a very important role in supplementing other existing energy sources.

Biogas is a clean-burning, "green" fuel used for heating and cooking, transport and power generation. Biogas usually contains about 55-65% methane, 30-35% carbon dioxide, and traces of hydrogen, nitrogen and other impurities. Biogas typically refers to a gas produced by the biological breakdown of organic matter such as dead plant, animal material, human faeces, and kitchen waste in the absence of oxygen. Biogas can be used as a fuel in any country for any heating purpose, such as cooking, electricity and when compressed like natural gas can be used as vehicle fuel to power motor vehicles (Biogas & Engines, 2011). Biogas is a renewable fuel, so it qualifies for sustainable energy subsidies in some parts of the world. Biogas can also be cleaned and upgraded to natural gas standards when it becomes bio methane.

According to Schnepf (2007), food waste produces two clean energy gases-hydrogen and methane (other waste materials just produces methane gas), which can be burned to produce electricity and heat, or to propel vehicles. Even though these seem to be more productive, much work has not been done in the evaluation of biogas production from food waste.

This research was carried out to evaluate biogas production from some common food wastes and to determine the food waste component that produces the highest biogas quantity. These food wastes were then co-digested to evaluate the biogas production. The following food wastes were used: fish parts, orange rind, yam peels and plantain peels. The digestion was carried out in batch type anaerobic digesters. The experiment is completed within ten weeks i.e. seventy days retention period.

Statement of the Problems

Energy has become an important prerequisite for the economic development of a country. Ethiopia is currently facing a serious energy crisis, which is costly and multi-dimensional. This extreme shortage of energy resources in the country has lead to increase in fossil fuel prices. Therefore, research for developing alternative biomass for bio-energy has become increasingly important. Food waste and cow dung are a very good source of biomass to be used in biogas plants for generating energy. Ethiopia has great potential for the production of biogas. This technology will not only produce energy but will achieve waste minimization as well. Minimization of waste has always been a serious problem.

Food waste is mainly organic matter, which can be converted to useful energy by biochemical process (Angelidaki *et al.,* 2003). It results in two by-products: biogas and digested organic slurry (Hessami *et al.,* 1996). Biogas is a mixture of gases produced naturally from the decay of organic wastes (Igoni *et al.,* 2008). A variety of factors affect the rate of digestion and biogas production including temperature, pH, water/solids ratio, carbon/nitrogen ratio, mixing of the digesting material, the particle size of the material being digested, and retention time (Vindis *et al.,* 2009). The significance of biogas all over the world shows that it can be easily implemented the technology in Ethiopia. Therefore, a research study was conducted on the biogas plant installed at college of Agriculture and Rural Transformation campus in University of Gondar, Ethiopia, for converting the organic waste into a renewable source of energy.

Objective of the Study

General objective: To promote sustainable bio-energy and bio-fertilizer production using local available wastes such as cow dung and food waste for environmental and economic benefit.

Specific Objectives

- ✓ To improve the overall sanitation and hygiene conditions and reduces energy dependence on the biomass
- ✓ To increase the access of bio-energy and bio-fertilizer
- ✓ To create awareness about the technology to local farmers by giving training
- ✓ To up-scaling the technology to the poor rural households

MATERIALS AND METHODS

The study was carried out in College of Agriculture and Rural Transformation campus in University of Gondar, Ethiopia. A specially designed fixed dome biogas plant of 6 m^3 was installed. The plant was built with bricks in such a way to keep the temperature of waste inside at a suitable temperature, which is necessary for its decomposition. The main part of biogas plant was the digester, its food inlet for the waste and an outlet for the slurry. The digester had a waste and an effluent tank to collect the effluent slurry.

During the start-up period, the biogas plant was inoculated with 3750 kg of cow dung mixed with water. Thereafter, the plant was left without further feeding until the gas produces. After the gas produces, the cafeteria used it and then the biogas plant was fed with 2 kg/day food waste. The feeding rate of 2 kg per day was chosen because on one hand it represents a realistic quantity of food waste produced from students' cafeteria (Mbuligwe & Kassenga, 2004) and on the other hand it conforms to the reactor specifications.

All waste materials were chopped and mixed with water before they were fed to the digester. All the prepared food waste and cow dung was added in the digester in one day. Mixing was achieved by putting the daily waste amount into a bucket and adding water in equal proportion. To minimize the risk of blocking the inlet pipe, the feedstock was first stirred to to best homogenize the slurry. Then digester effluent (20-30 Litters taken from the overflow) was recirculated and poured into the inlet two to three times. Main objective was to flush the inlet pipe and at the same time ensure good mixing of bacteria available in the effluent with the new feedstock.

The gas composition was measured on a daily basis in the afternoon (before feeding) when the gas was released. To measure the gas production, scaling of the gasholder was done. Initially, the biogas produced was allowed to accumulate in the closed gasholder until the drum was lifted to the maximum height. Some amount of gas was released to filter out from the water. The tap was then closed and a white line drawn on the gasholder just above the surface of the digester liquid, using a permanent marker pen. This procedure was repeated until all the biogas was released.

The scaling was related to production rate of biogas by simple calculations. To get further information on how the installed biogas systems are performing, interviews with users of existing biogas plants were conducted. This household survey aimed to compare the results from the research plant run under controlled conditions with the performance of plants operating under real conditions in private households.

The headspace to be left for biogas collection in the digester should be 5 to 10% of the total volume of digester. As the volume of digester is 6 m3, so its capacity for digestate is about 5.25 m^3. The remaining space should be left for biogas to be collected in the dome.

Sampling

A representative sample of the feed material was taken from the raw waste, as received from the generation source. The digestate samples were taken in 100 milliliter plastic bottles, by opening the cap of the outlet channel of the plant. In order to take a representative sample, the inner material was thoroughly mixed manually by using a metal rod before taking the sample. A gas collection fixture was installed on the opening on the dome of digester for taking samples of biogas in football bladders. The slurry samples were taken in plastic bottles from the slurry collected in the effluent tank.

Analytical Procedure

All the parameters tested during the study for the performance evaluation of biogas plant were analyzed using standard methods.

Analysis of Feed Material

The proximate analysis was done to analyze the potential of food waste to produce biogas. The initial analysis of feed material includes the analysis of feed size by using a measuring scale. According to EPA report by Hedman (2009), the appropriate feed size for a biogas plant is between 0.6 to 5 cm. To measure the moisture content the sample was dried in the oven Model WTC Blender for about 24 hours at 103°C till a constant weight was obtained. The sample was placed in muffle furnace Model NEY M 525 Series-III at 550°C for 5 hours, to measure the ash content (APHA, 2005).

Analysis of Digestate

The analysis of digestate was carried out to check the trend of reduction in the organic content of food waste. Electrometric method was used to measure the pH of the digestate samples. A glass electrode pH meter Model Cyberscan 500pH was used to measure sample pH daily. The temperature of digester and ambient temperature were recorded three times a day, by using the electronic temperature sensor. Gravimetric method was used to determine TS and VS of the sample on daily basis. For TS an accurately measured volume of sample in the evaporation dish was placed in the oven at 105°C and allowed it to dry. Total Solids is the material residue left in the vessel. VS are solids that were removed by igniting a sample in a 550°C muffle furnace for one hour. The weight lost on ignition is the volatile solids. The closed reflux titrimetric method was used to determine COD of the samples daily. The samples were analyzed in duplicate and their average value was taken (APHA, 2005). The percentage removal of organic matter is expressed as COD removal, TS removal and VS removal, which gives the strength of effluent slurry (Qureshi, 2005).

Analysis of Biogas

The volume of gas was measured three times a day by installing a liquid displacement setup. Following Itodo *et al.* (2007) a manometer was made to measure the pressure of biogas three times a day. The difference in the liquid column gave the reading of pressure in cm, which was converted into pascal (SI Unit). The gas pipe was connected to a bunsen burner. The gas was ignited to observe the flame of biogas. If combustion is perfect, the flame is dark blue and almost invisible in daylight. Ghani and Idris (2009) used gas chromatography; therefore, the composition of biogas samples was analyzed in triplicate by gas chromatography.

Materials

The waste materials used for the study were: food waste and cow dung from Veterinary Medicine faculty and students' cafeteria in University of Gondar.

The following equipment was used in the study.
i. **Weighing balance:** to determine the weight of food waste samples.
ii. **PH meter:** to measure the pH of the digested materials.
iii. **Measuring Cylinder:** to measure the volume of water displaced by the biogas generated.
iv. **Mixing Tank:** a big plastic container for mixing the food waste.

Experimental Procedure

Each of the food waste was measured and poured into the mixing tank which contained cow dung (about 60% of the digester volume) and then stirred to ensure homogeneity. The homogenous mixture of food waste and dung slurry was then introduced into the digesters and hermetically sealed. Manual agitation was performed on the digester on a daily basis in order to ensure intimate contact between the microorganisms and the substrate for effective biogas production. The gas produced by the substrates inside the anaerobic digester was passed to the cooking house through pipe. The weight of gas produced was equivalent to the amount of water displaced in the water chamber (Archimedes' principle of floatation). The pH was measured weekly using a digital pH meter. The sample analyzed was collected in a dry bottle from the digester and then analyzed. The probe of the pH meter was immersed into the sample to be analyzed and the meter was allowed to stabilize before the reading was taken.

RESULTS AND DISCUSSION

General Technical Aspects

A positive aspect regarding the dome shape biogas plant is that all the materials necessary for the installation are locally available. The whole installation including the inoculation of the research plant at University of Gondar was completed within fifteen days. Blocking of the inlet pipe seems to occur frequently as a result of the rather small diameter of the inlet pipe or the insufficient chopping or dilution of the feedstock. In addition, it was observed that the moistness of the system attracts African Giant Land Snails (*Achatina fulica*), which can also lead to clogging of the inlet pipe. Therefore, the inlet pipe should permanently be covered to avoid entering of such snails.

Survey of Biogas Systems

The household survey conducted in regions of Southern Nations Nationalities and Peoples of Ethiopia and Amhara regions revealed that most of the installed dome biogas plants are functional in the former regions where as it was poorly operated and maintained in Amhara region. For example from the survey result, out of 10 biogas plants only three were in operation, whereas seven were not in use due to various reasons, which include: (1) Poor maintenance by the operators, which has resulted into inappropriate operation, poor performance and damage and (2) poor monitoring system which has largely been responsible for failures of the plant.

The major causes for the breakdown of the seven biogas plants systems include breakage and blockage of inlet pipe, overfeeding, and damage of gas tap. In some cases, the digester was not in use for several months and the real cause of the failure could not be determined. In general, the operators of the plant did not seem to be well informed in terms of potential feedstock, quantity of water required for dilution of feedstock, recirculation of effluent, correction of defects, etc. Considering the fact that even minor problems can lead to a complete failure of the system (e.g. blockage of the gas pipe due to condensation of water in the pipe), proper training and effective follow-up services are inevitable for the sustainability of the plants.

Although the research plant at College of Agriculture and Rural Transformation did not experience noticeable problems and was regarded as simple to operate, the inspection tours clearly proved that a proper follow-up service is not optional but absolutely essential.

Safety Issues

Although a theoretical risk of explosion with biogas exists, such catastrophe is not likely to occur. Danger arises mainly in closed chambers, where a mixture of air and biogas (6-12%) exists. However, no explosion related to biogas utilization has been reported in Ethiopia (Schmitz, 2007), probably because digesters and burners are normally located in open and well ventilated areas.

Quality of Feed Material

Moisture Content

The results of the proximate analysis of feed material showed that the moisture content of food waste was 88.4%. This result is comparable with the study done by (Zhang *et al.,* 2007) who carried out the study on food waste and found that the optimum moisture content was 74 to 90%.

Ash Content

The ash content of the waste in this study was found to be 17.6%. According to Khan (2010), the ash content of waste was 15%. Therefore, the result is more likely similar to this researcher.

Quality of Digestate

The analysis of digestate showed that it was thick slurry, blackish in color. It was very smelly in the start, but the smell reduced with the passage of time as the degradation proceeded.

PH

The trend of variation in pH during the process showed that the pH of digestate increases as the process proceeds. The value of pH ranged from 6.1 to 8.1. The optimum pH on which biogas production was observed was ranging from 6.6 to 7.6. The biogas production started when pH of the digestate was 6.6 and the maximum production was seen at 7.0. Ayu and Aryati (2010) conducted a study on biogas production from cassava starch effluent in which the pH was maintained between 6.8 to 7.2 to get maximum yield.

Biogas Production

Initially 3750 kg of cow dung was added in the biodigester. The production of biogas started after five days. The maximum production of biogas was observed at a temperature of 58.5 ^{o}C in the biodigester. The biogas production increased for three consecutive days. After that, it reached at its peak point. The amount of methane gas produced was indicated by pressure gauge. It tells how much methane gas was produced from the biodigester within the indicated time. The average digester temperature was 56.3 ^{o}C, whereas the average ambient temperature was 30.2 ^{o}C. The cumulative biogas production was 0.035 m^3/kg of food waste. This was the most effective as it showed maximum percentage removal of organic matter due to efficient working of the digester. The maximum production was also due to relatively small feed size of 2.5 cm of food waste, addition of cow dung and manual mixing of digestate reduced the risk of the formation of scum. All these factors lead to maximum production of biogas. Islam *et al.* (2009) carried out a study on vegetable waste along with cow dung and results showed maximum gas production of 1200 ml/kg of total waste.

Biogas Flame

No flame was obtained initially due to low pressure of biogas. According to Mandal *et al.* (1999), the burning of flame depends on the change in the methane content of biogas. The experiment showed that this process of biogas production from food waste and cow dung was successful and the biogas can be used for heating and cooking purpose.

Biogas Composition

The resulting biogas was composed up of 66.8% of CH_4, 27.2% of CO_2, 1.5% of O_2 and 4.5% of N_2. Thus the methane content was high. According to Voegeli *et al.* (2009) the methane in biogas produced from food waste was 56.8%.

Effluent Slurry Production

The average slurry produced during the process was analyzed to be 2.5 litres per day. The total slurry produced from the plant was estimated to be 25 litres in a week. The slurry can be used as organic fertilizer.

C/N Ratio of Effluent Slurry

Total carbon content in effluent slurry was 2123.5 mg/l. The result of C/N ratio was 25:1, which was relatively high due to addition of cow dung in the food waste. The C/N ratio of cow dung was calculated to be 30:1, which was productive for the slurry. According to Verma (2002) the optimum C/N ratio in anaerobic digestion is between 20 to 30.

CONCLUSION

In the present study, 6 m3 of fixed dome biogas plant at College of Agriculture and Rural Transformation Campus demonstrated was an efficient setup. The results of the study have revealed that there is a great potential for anaerobic digestion of the organic fraction of food waste in low income societies. The system has proved to be effective in terms of the reduction of waste volume and organic load. Although the performance of the system regarding gas production is good, the design of digester needs especial attention. The unnecessarily large gap between the digester and gasholder leads to a loss of gas. Minimizing the space between these system components would considerably reduce atmospheric loss of biogas. Although there is some room for improvement, the biogas system has proven to be technically and environmentally viable.

However, reliable operation and maintenance services are needed to ensure long-term and sustainable use of the system. The co- digestion of food waste and fresh cow dung proved to be suitable with feed size of 2.5 cm. The process was successfully demonstrated by using temperature controlled system to maintain thermophilic conditions in batch mode. The resulting successful production of biogas was used for heating purpose such as cooking. The nutrient content of the effluent slurry indicated its potential use as a fertilizer in the botanical garden of campus. This would certainly contribute to waste minimization and a truly Green Campus and a Zero Waste College.

REFERENCES

Angelidaki I, Ellegaard L, Ahring BK (2003). Applications of the anaerobic digestion process. Adv Biochem Eng Biotechnol. **82**:1-33.

APHA (2005). Standard Methods for the Examination of Water and waste water. 21st Edition, American Public Health Association, Washington, DC, USA.

Ayu A, Aryati VD (2010). Biogas production using anaerobic biodigester from cassava starch effluent with ruminant bacteria as biocatalyst. Thesis Dissertation, Chemical Engineering Department Technical Faculty Diponegoro University, Semarang.

Beets WC (1989). The potential role of agro-forestry in ACP countries. Technical center for Agricultural and Rural co-operation (CTA): the Netherlands. 68pp.

Biogas & Engines (2011). “Biogas and engines”. Retrieved from http://www.clarke-energy.com, July, 2012.

EGAP (1994). Ethiopian Forestry Action Program. EFAP, Addis Ababa.

FAO. 1988. Report of the mission to the Ethiopia on tropical forestry action plan. Rome. FAO.

Ghani WAWAK, Idris A (2009). Preliminary study on biogas production of biogas from municipal solid waste (MSW) leachate. Journal of Engineering Science and Technology, **4(4):** 374 – 380.

Hedman B (2009). Biomass CHP, an overview. Report by EPA Combined Heat and Power Partnership Webinar, ICF International.

Hessami MA, Christensen S, Gani R (1996). Anaerobic digestion of household organic waste to produce biogas. Renewable Energy, **9(1-4):** 954-957.

Hurni H (1988). Degradation and conservation of the resources in the Ethiopian highlands. Mountain Research and Development, **8 (2/3)**: 123-130.

Igoni AH, Abowei MFN, Ayotamuno MJ, Eze CL (2008). Effect of Total Solids Concentration of Municipal Solid Waste on the Biogas produced in an Anaerobic Continuous Digester. Agricultural Engineering International: the CIGR Ejournal, X: 7-10.

Islam M., Salam B., Mohajan A. (2009). Generation of biogas system from anaerobic digestion of vegetable waste. Proceedings of the International Conference on Mechanical Engineering 26-28 December 2009, Dhaka, Bangladesh.

Itodo IN, Agyo GE, Yusuf P (2007). Performance evaluation of a biogas stove for cooking in Nigeria. Journal of Energy in Southern Africa, 18(3).

Mandal T, Kiran BA, Mandal NK (1999). Determination of the quality of biogas by flame temperature measurement. Energy, Conversion & Management, 40: 1225-1228.

Mbuligwe SE, Kassenga G (2004). Feasibility and strategies for anaerobic digestion of solid Published by GTZ, Eschborn.

Qureshi IA (2005). Characterization and treatment of waste water using grass plots (Nala Lai case). MS Thesis dissertation, Institute of Environmental Sciences And Engineering, National University of Sciences and Technology, Islamabad, Pakistan. Recycling **42**:183-203.

Schmitz TD (2007). Feasibility study for a national domestic biogas programme in Tanzania.

Schnepf K (2007). ‘Project converts biomass and food processing waste into useable energy’. Retrieved from http://www.plantservices.com/articles/2007/003.html, September 2012. waste for energy production in Dar es Salaam city, Tanzania; Resources, Conservation.

Verma S (2002). Anaerobic digestion of biodegradable organics in municipal solid wastes. Thesis dissertation, Department of Earth & Environmental Engineering (Henry Krumb School of Mines) Fu Foundation School of Engineering & Applied Science Columbia University.

Vindis P, Mursec B, Janzekovic M, Cus F (2009). The impact of mesophilic and thermophilic anaerobic digestion on biogas production. Journal of Achievements in Materials and Manufacturing Engineering, 36(2).

Voegeli Y, Lohri C, Kassenga G, Baier U, Zurbrugg C (2009). Technical and biological performance of the Arti compact biogas plant for kitchen waste- case study from Tanzania. Proceedings Sardinia 2009, Twelveth International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy; 5 - 9 October 2009.

WIC (2002). Deforestation leaves two million hectars of land barren in the country: EPA http://www.geocities.com/akababi/news1/nwjanl402.htlm January, 12, 2002. Accessed on 20.08.02.