Waste Product Value Chain Development Project:
PWANI UNIVERSITY

Biogas International

P1: Biogas production from Cashew waste and cattle manure: influence of biomass composition on methane yield

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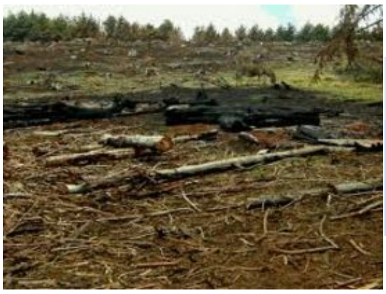
Abstract

Waste management strategies in Kenya are not yet optimal resulting in the formation of massive landfills of waste by most municipal councils. The increase in cashew nut waste is expected with the revitalization of the cashew industry and would require strategies of management, for instance, utilization in the production of green energy. Little has been done to explore the potential of agricultural waste as alternative source of biomass for biogas production in Kenya. This study focuses on options for sustainable management of cashew nut waste through alternative use, specifically, cashew nut waste as biomass for biogas production. This project will therefore contribute to the body of knowledge on utilization of cashew trees byproducts with potential positive impacts on the environment. The overall goal of this project is to optimize the production of methane from cashew nut waste and cattle manure within Kilifi County. A broad-based survey using semi-structured questionnaires will be conducted in priority areas to quantify level of cashew nut waste. Biogas plants utilizing the cashew nut waste with cattle manure as a base will be set up to investigate the retention time. Retention time is defined as the period a substrate takes to fully decompose under anaerobic conditions giving methane gas as a byproduct. The proportion of methane gas produced from the biogas plants will also be analysed using sampling gas bags and potassium hydroxide. Five biogas plants will be studied with incremental levels of cashew nut waste from 0% to 100%. A completely randomized design will be used in a 5 x 3 replicated experimental design to test the null hypothesis with respect to the recorded retention time, the collected daily mean biogas yield data and the methane concentration and will be subjected to an analysis of variance (ANOVA). Orthogonal contrasts from the Statistical Analysis Software (SAS, 2004), will be used to check for the significance of differences in the means. A Methane Energy Value Model will be designed and developed using algebraic combinations of relevant equations depicting the relationship of inputs in- and outputs from- the biogas plants. It is expected that at the end of the project, there will be a resultant establishment of a small scale biogas plant at Pwani University as a model with potential out-scaling to small-holder farmers. The project also aims to contribute to clean energy production and mitigation of global warming through the degradation of methane for use as energy. Methane is a potent green house gas 21 times more dangerous than CO_2. This is in line with one of the millennium development goals aimed at environmental sustainability. Utilizing the waste for biogas energy will promote a new value chain for this product with potential benefits towards the livelihoods of farmers and also enhance waste management in cashew growing areas.

Key Words: Cashew nut, biogas, methane energy value model

At a Glance

"Charcoal is the cancer of poverty" a comment from ***Biogas International Limited*** ***(http://www.biogas.co.ke/)*** captures the spirit in the vision of this Project. The high dependency on coal and fire wood is a great burden to ecosystems and its diversity globally. The use of firewood and open fires for cooking also present is considered also as a health risk. Notably, with diminishing sources of forest wood and charcoal due to deforestation and strict regulation of cutting trees, there is a dire need to establish affordable, renewable, green sources of energy.



Left Photo: Depleted forest for firewood and charcoal

Right Photo: A typical Flexi-Biogas System (Pwani University Flexi Biogas Unit)

The Pwani University Flexi-Biogas Project was envisioned as an adaptation model to package Biogas Technology for small-holder resource poor farmers while testing alternative substrates for methane gas production. The Project aims to test various alternative substrates generated from both plant and animal waste products.

Achieved outputs

A working Flexi-biogas system with a user portal which has totally replaced the use of electricity and charcoal for cooking has been established at Pwani University Farm. The Flexi-biogas Demo Unit is now one of the PU-FARM highlight sites for educational trips for Colleges and Schools. The site is also a fixed asset available for other biogas Projects. A new phase has been envisaged towards constructing a slurry pathways and pit for harvesting the bio-slurry useful as very potent organic manure. Other substrates in the pipeline for testing include the kitchen waste, and waste from poultry, rabbits, small ruminants and donkeys and Jatropha pruning waste.

Some Key information on Biogas Production

Hydrolysis

In general, hydrolysis is a chemical reaction in which the breakdown of water occurs to form H^+ cations and OH^- anions. Hydrolysis is often used to break down larger polymers, often in the presence of an acidic catalyst. In anaerobic digestion, hydrolysis is the essential first step, as Biomass is normally comprised of very large organic polymers, which are otherwise unusable.

Through hydrolysis, these large polymers, namely proteins, fats and carbohydrates, are broken down into smaller molecules such as amino acids, fatty acids, and simple sugars. While some of the products of hydrolysis, including hydrogen and acetate, may be used by methanogenesis later in the anaerobic digestion process, the majority of the molecules, which are still relatively large, must be further broken down in the process of acidogenesis so that they may be used to create methane.

Acidogenesis

Acidogenesis is the next step of anaerobic digestion in which acidogenic microorganisms further break down the Biomass products after hydrolysis. These fermentative bacteria produce an acidic environment in the digestive tank while creating ammonia, H_2, CO_2, H_2S, shorter volatile fatty acids, carbonic acids, alcohols, as well as trace amounts of other byproducts. While acidogenic bacteria further breaks down the organic matter, it is still too large and unusable for the ultimate goal of methane production, so the biomass must next undergo the process of acetogenesis.

Acetogenesis

In general, acetogenesis is the creation of acetate, a derivative of acetic acid, from carbon and energy sources by acetogens. These microorganisms catabolize many of the products created in acidogenesis into acetic acid, CO_2 and H_2. Acetogens break down the Biomass to a point to which Methanogens can utilize much of the remaining material to create Methane as a Biofuel.

Methanogenesis

Methanogenesis constitutes the final stage of anaerobic digestion in which methanogens create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis. There are two general pathways involving the use of acetic acid and carbon dioxide, the two main products of the first three steps of anaerobic digestion, to create methane in methanogenesis:

$$CO_2 + 4\ H_2 \rightarrow CH_4 + 2H_2O$$

$$CH_3COOH \rightarrow CH_4 + CO_2$$

While CO_2 can be converted into methane and water through the reaction, the main mechanism to create methane in methanogenesis is the path involving acetic acid. This path creates methane and CO_2, the two main products of anaerobic digestion.

Temperature Measurement

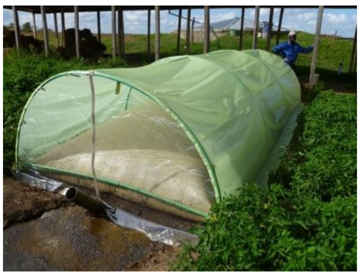
Temperature is a key component to the efficiency of anaerobic digesters. As in other chemical and biological processes, the more energy that is put into a reaction, the faster the reaction runs, until a point of degradation occurs. Being that organisms are responsible for the digestion process, it is vital to ensure that the entire process is kept within a certain temperature range to maximize reaction speed and organism livelihood. That being said, the range depends on the species of organism used. The two most widely used types of microorganisms are mesophiles, which undergo mesophilic digestion, and thermophiles, which undergo thermophilic digestion. Mesophiles are most efficient at moderate temperature ranges between 25-40°C while thermophiles run most efficiently at higher ranges between 45-80°C. The words mesophile and thermophile are simply terms used to classify broad groups of organisms and just describe the temperature of their livable environment. Ideally, one should know the exact microorganism used and know the range that is most suitable for that specific species. As in other chemical processes, if the temperature is monitored during the digestion process and kept in the upper portion of the specific range given, the rate of reaction will be at its highest value producing more gas in the same amount of time. While higher temperatures produce higher gas yields, they are also more difficult and expensive to maintain making temperature a vital aspect to measure throughout the digestion process.

CO2 and Methane Measurement

Biogas production rate is also a key component to maximizing anaerobic digestion efficiency. It is vital to constantly measure Biogas emissions (methane, carbon dioxide, trace amounts of siloxanes, hydrogen sulfide, ammonia, hydrocarbons, and water) as the production levels are good indications of production abnormalities, Biomass quantities, and microorganism well being. Being that in anaerobic digestion, biogas is produced with a normal distribution; the

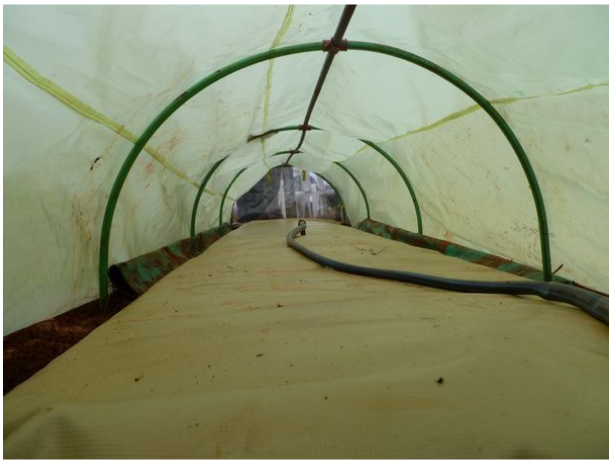
What then is Flexi-Biogas? *(a brief from BIL)*

This is a *Clean, Practical, Affordable, Sustainable* green energy technology with several advantages;



1. 100% of the Methane produced is capture in the Flexi biogas systems.
2. Harmless carbon dioxide and water are released when Methane-CH_4 is burned.
3. Fertilizer output is concentrated organic 100% composted and seedbed ready with no further processing or curing required.

Micro-Greenhouse Tunnel



Importance of The Tunnel

Temperature is a key catalyst to the production of biogas. Housed within a sealed tunnel, the system will quite easily achieve temperatures upwards 40C.

Heat Energy Capture

During the day, the tunnel captures solar radiation whereby increasing the temperature of the substrate within the digester. This also occurs on cloudy days but obviously to a lesser degree.

Heat Retention

Concealing the digester envelope, during the evenings the tunnel becomes an insulated jacket preventing heat losses and therefore continued high rate of fermentation and gas production.

UV filter

Also, the greenhouse fabric is a UV filer and so further extends the life expectancy of the digester fabric.

Flexi Biogas Systems, a Total Energy Solution

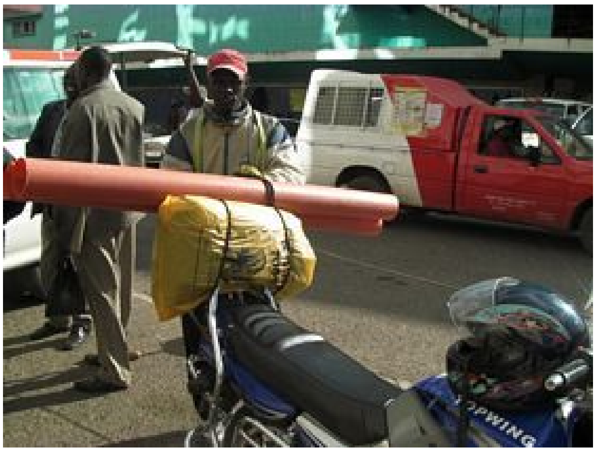
With this increased efficiency and large gas production capacity, one is now able to run generators and conventional agri-tool such as chaff cutters, water pumps, milking machines, etc from a single BG6 Flexi-Biogas system.

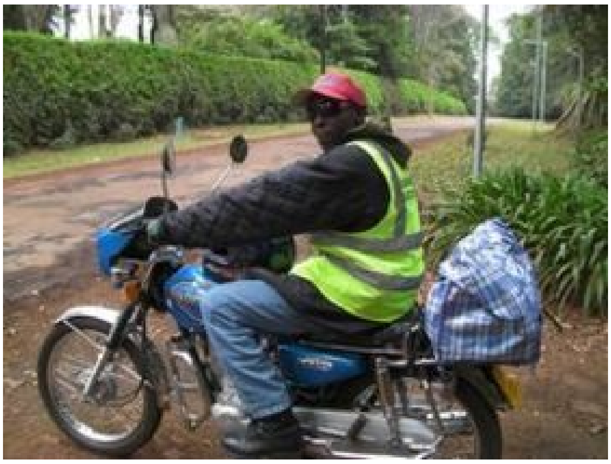
Simplicity

- The plants are fabricated from reinforced long lasting UV resistant plastic
- All components can be recyclable after use
- User serviceable components are widely locally available

Portability

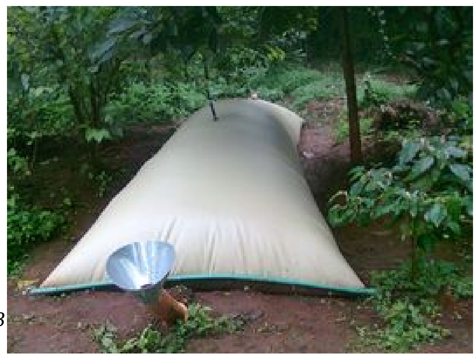
When packed the kit is compact and lightweight, and can be transported on a motorcycle *boda-boda*. When up-scaling, you can sell current system and install a larger capacity system and when moving house you just roll it up and take it with you.





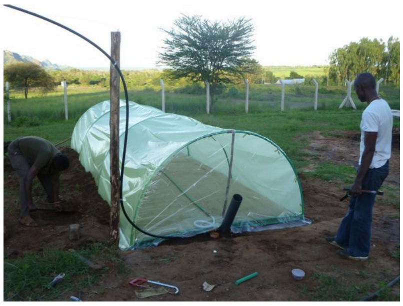
Installation - The system is surface mounted and in most scenarios, can be installs in one or two days

- No construction, digging, masonry, building etc
- No heavy transport costs
- No contractors and fundi's No hassle

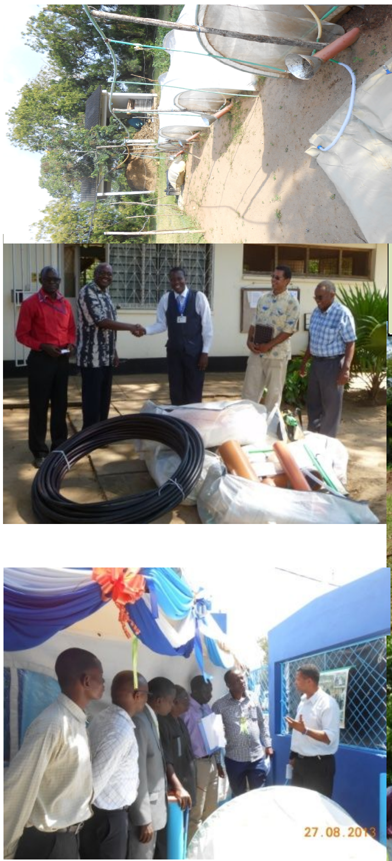


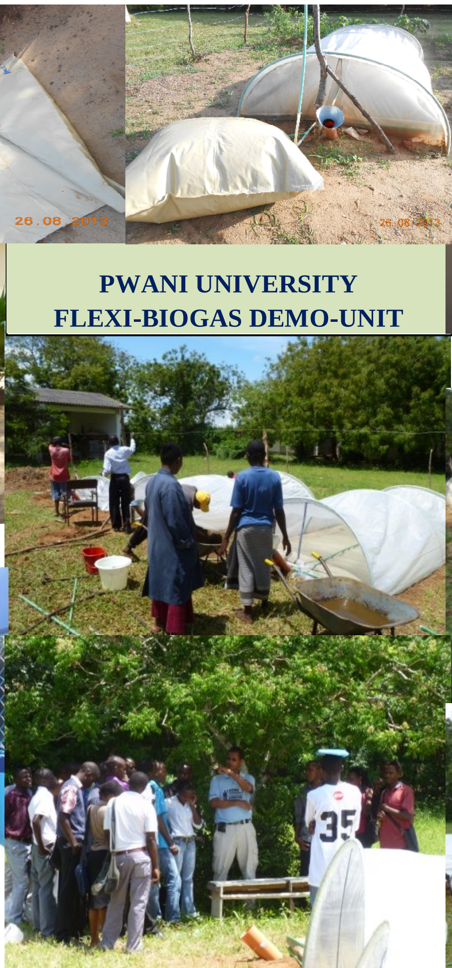
Continuous-flow, CF - Batch Combo - Large domestic 9m^3

Biogas International have recently super upgraded the digester design branding it the Continuous-Flow Batch Combo or 'CF Batch Combo'. As well as being used as a continuous flow system, the new system design also very simply allows for large volume batch digestion of periodic bulk inputs such as mass market waste, water hyacinth, agro processed waste etc



The new digester has Zip-like seals across either end of the envelope so using bulky inputs, and emptying the digester can be achieved very simply. Synchronising more than one digester with a scheduled input supply will continuously produce large volumes of both gas and fertilizer.





A selection of events

from the inception of the PU-BIL Flexi-Bio Project to date….