BIOGAS PRODUCTION FROM KITCHEN WASTE/REFUSE

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ABSTRACT
The study was conducted in Laboratory (former rat house, biology department), Kyambogo University in 2008. Biogas refers to a gas made from anaerobic digestion of agricultural and animal waste. The gas is useful as a fuel substitute for firewood, dung, agricultural residues, petrol, diesel, and electricity.

The cost of energy (electricity, firewood and LPG) in Kyambogo University is of heavy charge to the University budget, the bigger part corresponding to the LPG balloon for cooking.

The objective of this work was to produce biogas in a Compact Water Plastic Tank with a Dome Fixed, using different organic waste from the kitchen in Kyambogo University.

It was realized through the Observation and Experimental Test using 500 ml bottles the rate of gas produced and retention time (with 24 hour biogas was produced). Fermentation of individual kitchen waste was done and cabbage leaves produces more gas after day 1 but on day 3, cooked posho had more gas. In phase two, a mixture of different kitchen waste was elaborated and later fermented, a mixture of cabbage leaves, matooke peelings and cooked posho had more gas after 24 hours.

In the experimental pilot and scale up tank, the formula was fermented and the 3 different types of digesters were tested, the old system with different inlet and outlet worked first, that is to say, the outlet system was able to let out the sludge. The other 2 news systems never let out the sludge due to the gas escape.

The designs for the different kitchens in Kyambogo University were obtained and they will be implemented when the university administration supports implementation process.

KEYWORDS: Biogas; Kitchen waste; Anaerobic digestion, fermentation.
1. INTRODUCTION

Biogas is about 20% lighter than air and has an ignition temperature in the range of 650°C to 750°C. It is odorless and colorless gas that burns with clear blue flame similar to that of LPG gas. Its caloric value is 20 Mega Joules (MJ)/m³ and burns with 60% efficiency in a conventional biogas stove.

Biogas refers to a gas made from anaerobic digestion of agricultural and animal waste. The gas is a mixture of methane (CH₄) 50-70%, carbon dioxide 30-40%; hydrogen 5-10%, nitrogen 1-2%, hydrogen sulphide (trace), water vapor 0.3%.

The gas is useful as a fuel substitute for firewood, dung, agricultural residues, petrol, diesel, and electricity, depending on the nature of the task, and local supply conditions and constraints.

Biogas systems also provide a residue organic waste, after anaerobic digestion that has superior nutrient qualities over the usual organic fertilizer, cattle dung, as it is in the form of ammonia.

Anaerobic digesters also function as a waste disposal system, particularly for human waste, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens.

The biogas technology is particularly valuable in agricultural residual treatment of animal excrement and kitchen residual.

The anaerobic reactor has a chamber where various chemical and microbiology reactions take place; it should be air and water tight.

In recent year varied modifications technological have been introduced to diminish the costs for the biogas production. Methods have been developed to increase the speed of fermentation for the bacteria gas producers, the reduction of the size of the digester, the use of materials for their production but durable, the modification of the feeding materials to ferment and the exit of the effluent for their best employment, as well as compacter the equipment to produce gas in the small housings, among others.

The equipment employed in housings was developed with success in India 2006, the compact digester using 2 plastic tanks one floating inside the other one. This drum uses with great efficiency and productivity the organic residuals with high contents of starch, coming from the preparation and waste of the foods.

This design is very cheap, and facilitates saving of space, manages few volumes of feeding flow and effluent but producing biogas quickly.
So this work focused on the objective of production of biogas using a Compact Water Plastic Tank with a Dome Fixed, with different organic waste from the kitchen in Kyambogo University. The system developed was economical and simple to operate.

2. METHODS AND MATERIALS

The study was conducted in Laboratory (former rat house), Kyambogo University in 2008.

The laboratory was step up in 3 stages, that is, 500 ml bottles as batch system, 20 L jerry can as a pilot system and finally a 100 L plastic tank as a scale up system.

Sources of Waste

The wastes use in this study were the peelings and food refuse from Kyambogo University East end kitchen, Public café in Kyambogo University and the cabbage leaves were got from Banda Market.

Preparation of the sample

It was ensured that foreign materials like earth, sand, gravel, sawdust, soap, detergents, etc. did not enter the digester. The slurry was prepared and later poured into 500 ml bottles. Tap water was added to the waste inside the 500 ml bottles. The slurry was fully stirred manually with a piece of wood until there were no lumps.

According to the objective, it was necessary to design and realize the construction of:

1. Batch system: For characterization of the different kitchen waste, 60 units of 500 ml digesters were built and then grouped into five with three of them having thermometers in the cover for measuring temperature into the gas chamber.

   Photo 1 shows the batch system

The digester was stirred manually by shaking the 500 ml bottles. A pH tape was used to measure the pH before the food refuse was added into the bottles and after the digestion period. It ranged from 6 -8. The temperature of the slurry was read daily using a thermometer that was inserted into the digester. The ambient temperature was not measured. The pressure of the gas produced was recorded daily using manometer filled with colored water. The pressure of biogas produced was measure and recorded as the displaced water in the manometer column. The biogas generated was measured by downward displacement of water. The volume of water displaced was measured daily. The highest volume for given day of the experiment was over 708 mm on the 4th day.
2. **Pilot plant**: 6 tanks of 20 L capacity were grouped into 3 systems, with the traditional system and 2 new system with combined inlet and outlet but with different elbow angles; that is, 45° and 90°. The systems have gas storage tanks in order to obtain the characteristic of the formula running in the continuous process.

![Photo 2 shows the pilot plant](image)

3. **Scale up tank**: two tanks of 100 L were built and were to work in the conditions similar to the kitchen in Kyambogo University.

![Photo 3 shows the Scale up tank](image)

Additionally, it was necessary to build 3 types of manometers; the last one was developed urgently for the high biogas pressure in the tested formula.

**Experiment realized:**

1. Evaluation of the individual waste (in the batch system) were selected
   1.1 Raw vegetable peelings: matooke, sweet potato, cassava and Irish potato.
   1.2 Raw leafy vegetable: cabbage leaves
   1.3 Fruit peelings: sweet banana, pineapple, papaya
   1.4 Cooked food: rice and posho

    Additionally, the hand machine type, milling characteristics and dilution of the waste (to be fermented with the inoculum) with water was evaluated.

    The fruits were analyzed because we did not know the gas production rate using the vegetable alone.

2. Evaluation of the mixed waste in the batch system

   According to the first experiment, matooke (M) was mixed with the following:

   - M + Sweet potato peelings
   - M + Cassava peelings
   - M + Irish potato peelings
M + Cabbage leaves
M + Cooked posho
M + Cooked rice
M + Sweet banana peelings
M + Pineapple peelings
M + Papaya peelings

Finally, M + cabbage leaves + Cooked Posho

**Data collection**
The volume of biogas produced was recorded on a daily basis. The mean daily gas yielded was recorded as shown in graph 1 and 2. The daily temperature inside the digesters recorded and $21^0C$ was the least and $25^0C$ was the highest see table 1.

1. **Results:**
1. As the pressure was measure, the temperature was read using a thermometer (0-100$^0$ C), the readings are recorded in table 1

2. Evaluation of the waste alone, batch system and the fruits are not reported because Kyambogo University kitchen do not produce the necessary amounts for biogas production this is shown in table 2.

**Table 1 shows average temperature readings in degrees centigrade of individual food waste**

<table>
<thead>
<tr>
<th>Day</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
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<tbody>
<tr>
<td>Food waste Type</td>
<td>Cabbage leaves</td>
<td>21</td>
<td>22</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Irish Potato peelings</td>
<td>21</td>
<td>22</td>
<td>20</td>
<td>20</td>
<td>22</td>
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<tr>
<td>Sweet Potato Peelings</td>
<td>22</td>
<td>23</td>
<td>22</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Matooke peelings</td>
<td>21</td>
<td>23</td>
<td>21</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Cassava peelings</td>
<td>22</td>
<td>24</td>
<td>22</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Cooked posho</td>
<td>22</td>
<td>24</td>
<td>21</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Cooked rice</td>
<td>22</td>
<td>25</td>
<td>22</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2 shows average manometer readings (in mm) of individual food waste**

<table>
<thead>
<tr>
<th>Day</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste Type</td>
<td>Cabbage leaves</td>
<td>249</td>
<td>507.3</td>
<td>469</td>
<td>461.3</td>
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<tr>
<td>Irish Potato peelings</td>
<td>110</td>
<td>286</td>
<td>480.5</td>
<td>481.5</td>
<td>455</td>
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<tr>
<td>Sweet Potato Peelings</td>
<td>164.25</td>
<td>385.25</td>
<td>528.75</td>
<td>503.3</td>
<td>634.67</td>
</tr>
<tr>
<td>Matooke peelings</td>
<td>95.5</td>
<td>236.5</td>
<td>289</td>
<td>399.75</td>
<td>555</td>
</tr>
<tr>
<td></td>
<td>142.25</td>
<td>271</td>
<td>284.75</td>
<td>313</td>
<td>390</td>
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<tr>
<td>------------------</td>
<td>--------</td>
<td>------</td>
<td>--------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Cassava peelings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooked posho</td>
<td>26</td>
<td>241</td>
<td>462</td>
<td>708</td>
<td></td>
</tr>
<tr>
<td>Cooked rice</td>
<td>6</td>
<td>166</td>
<td>258</td>
<td>289</td>
<td></td>
</tr>
</tbody>
</table>

Graph 1 shows pressure reading for individual food waste against days of fermentation

![Graph](image)

From the graph 1, it is possible to see that the variables obtained were; time, temperature and gas pressure (measured using a manometer). It was assumed that the measured pressure was like biogas produced during waste digestion.

All the waste evaluated produced biogas after 24 hours; this was corresponding to temperature increase. The better biogas producers were, cooked posho, sweet potato peelings, Irish potato peelings, matooke peelings followed and cooked rice grains performed poorly.

Cabbage leaves increased the pressure after 24 hours; the pressure was still high after 48 hours, Matooke peelings increased progressively in pressure after 2 days.
3. Evaluation of mixed food waste (the fruit waste are not considered).

Table 3 shows average manometer (in mm) readings of individual food waste

<table>
<thead>
<tr>
<th>Food waste Type</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matooke + Posho</td>
<td>77</td>
<td>439</td>
<td>656</td>
<td>708</td>
<td>708</td>
</tr>
<tr>
<td>Matooke + Rice</td>
<td>92</td>
<td>435</td>
<td>684</td>
<td>708</td>
<td>462</td>
</tr>
<tr>
<td>Matooke + Sweet Potato Peelings</td>
<td>55</td>
<td>217</td>
<td>492</td>
<td>680</td>
<td>671</td>
</tr>
<tr>
<td>Matooke + Irish potato peelings</td>
<td>27</td>
<td>97</td>
<td>556</td>
<td>449</td>
<td>193</td>
</tr>
<tr>
<td>Matooke + Cassava peelings</td>
<td>32</td>
<td>123</td>
<td>633</td>
<td>708</td>
<td>569</td>
</tr>
<tr>
<td>Matooke + Cabbage leaves</td>
<td>36</td>
<td>205</td>
<td>390</td>
<td>522</td>
<td>484</td>
</tr>
<tr>
<td>Matooke + Posho + cabbage leaves</td>
<td>176</td>
<td>447</td>
<td>689</td>
<td>646</td>
<td>345</td>
</tr>
</tbody>
</table>

Graph 2 shows pressure reading for mixture of different food waste against days of fermentation

![Graph showing pressure readings over days for different food waste mixtures.](image)
The result in graph 2 shows that the mixture of matooke peelings + cabbage leaves + cooked posho produced gas after 1 day and the pressure was stable in the second day.

The mixture of matooke + cooked posho and matooke + cooked rice are very good too, the pressure increased after 2 days; this is shown in graph 2.

According to this result and the criteria used to mix the waste

According to this result and basing on the criteria that the mix of waste is better, we decided to test in the pilot plant and in the scale up tank the use of matooke peelings + cooked posho + Cabbage leaves to obtain fermentation parameters.

Quality of the produces Gas:
The carbondioxide content by syringe – protocol was used to test the quality of the gas. A syringe body fitted with dome flexible tube and dilute sodium hydroxide (NaOH) solution was used to estimate carbon dioxide percentage, as NaOH absorbs carbon dioxide not methane; 60-70 % was not absorbed by the solution.

4. CONCLUSION
In developing countries like Uganda, more than 80% of the population lives in the rural areas where more than 90% of the energy being consumed comes from non-commercial sources, the major one being fuel wood. The increasing cost of conventional fuel in urban areas necessitates the exploration of other energy sources. Animal and plant wastes are abundant especially in rural areas. Biogas can be produced from food wastes/refuse and peelings as a substitute for fossil fuels.

The generation of biogas from food waste/refuse or peelings produces an energy resource. The process also creates an excellent residue that retains the fertilizer value of the original waste products.

The search for alternative source of energy such as biogas should be intensified so that ecological disasters like deforestation, desertification, and erosion can be arrested.

5. RECOMMENDATIONS
Utilization of biogas technology is no longer in doubt. For effective utilization of biogas technology the following recommendations are made:

a. Awareness of the technology: Encourage the use of biogas an awareness campaign for potential users should be undertaken.

b. Education/Training: There is need to evaluate the present institutional framework for renewable energy education in Uganda (and other developing countries) and make suggestions for a shift in policy toward increasing its adoption rate.
c. Government: Government agencies should take an active part in biogas projects and researches as is done in other countries like India and Nepal.

d. Kyambogo University as an institution should put up a biogas plant which can be used as a study plant for the nation, this will facilitate in promoting biogas technology.

6. ACKNOWLEDGMENTS
This research was supported by the Kyambogo University through the Research and Grants Committee, we are grateful for the financial support.

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