International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Alternative Technology Solution for Cooking: Compact Biogas Digester

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Abstract:
This study is undertaken to prepare an alternative technology solution for cooking and to implement the design and set - up an operational of an onsite biodigester that will generate sufficient methane gas for cooking and probably other applicable uses. The biogas digester is simple to operate for everybody and effective option to save cost on power. It was found that a unit no smaller than 200 liters was needed to meeting the feedstock unit that gives a 2 hour per day cooking duration for a gas cooker run off one of these unit. Biodigester technology: Cow manure and kitchen waste feed produces more methane gas, and the reaction is completed in 7 days.

1.1 Introduction

1.1.1 Project Nature

One well-known organization committed to advancing environmentally friendly and sustainable technological solutions is the Centre for Appropriate Technology (GrAT). GrAT is an innovative organization dedicated to investigating and developing technologies that align with the values of environmental sustainability. Its goal is to identify workable solutions for a variety of environmental and social issues through a wide range of projects and activities. In addition to creating efficient technologies, they often develop eco-friendly solutions. One of GrAT's main strengths is its collaborative approach. To ensure that their initiatives have a significant and lasting impact, they work closely with a variety of stakeholders, including academic institutions, research organizations, and industry partners. Whether in the areas of waste management, renewable energy, or sustainable building, GrAT is continuously striving to improve how we interact with our environment and to prepare for a more sustainable future. Their commitment to sustainability and innovation has established them as a major force in the field of relevant technology. As a Technical Researcher at GrAT, my job was to manage the project efficiently and build a prototype biogas digester at Adamson University with a focus on safety. One of my main responsibilities was to thoroughly document the construction and operation of the Compact Biogas Digester System, while improving reporting, data analysis, and documentation skills. The potential of waste-to-energy technology was demonstrated when the focus shifted to examining the calorific value of gas generated from different substrates. The environmental impact was reduced by designing an affordable biogas digester using plastic barrels and related components, optimizing biogas consumption through networked systems and maintaining constant water levels. Composition analysis of the biogas revealed higher-than-average levels of carbon dioxide, and longer retention periods produced more gas, though with reduced combustibility. Experiments on co-digestion with various waste products highlighted energy efficiency and sustainability.

1.1.2 Objective

The main intent of this endeavor was to construct the compact biogas digester as an alternative technology solution for cooking purposes. Other secondary aims include:

- To attain the calorific values of the gas manufactured from household and animal wastes.
- To enhance the effectiveness of the proposed digester system by increasing the production of gases.

1.1.3 Work Nature

During my internship at the Centre for Appropriate Technology (GrAT), I conducted an extensive inspection of the construction and operation of a Compact Biogas Digester System. Throughout this endeavor, my primary focus was on ensuring the safety and effective functionality of the system, while maintaining open communication with the GrAT team for issue reporting. I took a proactive approach to document all activities comprehensively, aiming to uncover the energy potential of different waste materials and their role in sustainable energy generation.To facilitate biogas production and storage, I utilized three 200 L plastic drums along with various materials, carefully measured for precision. I designed the biogas digester to be cost-effective and environmentally friendly compared to traditional systems. Additionally, I conducted an in-depth analysis of gas production and composition, which revealed a predominantly carbon dioxide-rich composition with lower methane content.

1.1.4 Duties

- To implement the technical research of the biogas digester system prototype.
- To document all the activities linked with operation and construction of the compact biogas digester system.
- To calculate the calorific value of the produced gas from several combinations of substrate.
- To produce and store biogas through the experiment.
- To develop the plan layout of the proposed project.
- To examine the composition of average biogas by mixing carbon and methane.
- To determine the outcomes from the experiments and compare them to check the consistency.

2.1 Personal Engineering Activities

2.1.1

I was assigned my first task as a Technical Researcher intern at the Centre for Appropriate Technology (GrAT): building a prototype of a biogas digester system. Under GrAT's guidance, I meticulously adhered to the design and constructed the prototype at Adamson University. I was responsible for conducting the demonstration in a specific space provided by the university, ensuring that GrAT supplied all the necessary equipment.In addition to constructing the prototype, my primary responsibility was to prioritize safety throughout the process. I ensured that the system functioned effectively and safely within the allocated space. I promptly informed the GrAT team of any issues that arose during the development stage and sought their advice and support.In this official research context, I gained valuable knowledge about technological construction, project management, and effective communication.

2.1.2

During my internship, I had the significant responsibility of meticulously documenting all activities related to the construction and operation of the Compact Biogas Digester System. Using report writing, videography, and other relevant methods, I ensured that every aspect of the project was appropriately and promptly recorded. I prepared a technical paper that included several important components. I thoroughly compared various substrates and their properties, providing insightful analysis on their suitability for the digester. Additionally, I collected comprehensive data on gas production, including temperature, pressure, methane content, and the presence of other gases. To understand the system's overall benefits and maintenance needs, I also conducted a thorough cost-benefit analysis. In this role, I not only honed my skills in data analysis and documentation but also came to appreciate the significance of comprehensive reporting in research and development projects.

2.1.3

During my time as a Technical Assistant and Researcher at GrAT, I was tasked with a project that involved determining the calorific value of the gas produced from various substrate combinations. I worked with a range of substrates, including pure cow dung, combinations of cow dung and kitchen waste, mixtures of cow dung, kitchen waste, and vegetable waste, as well as a composite of cow dung, kitchen waste, vegetable waste, and paper waste. I conducted experiments to ascertain whether there was a notable discrepancy in methane production and calorific value between using cow dung in isolation and when it was blended with kitchen waste as a substrate. I found this research to be a captivating exploration of the potential energy outputs of various waste materials and their contribution to sustainable energy generation. I calculated the lowest calorific value of cow dung as 5.3 kWh/kg and the highest as 5.8 kWh/kg using the corresponding formulas. Similarly, I calculated a high calorific value (HCV) of 9.7 kWh/kg and a low calorific value (LCV) of 9.46 kWh/kg for kitchen waste, with a molecular weight of 84 g/mol. For vegetable waste, which had a molecular weight of 256 g/mol, I estimated the HCV and LCV as 6.8 kWh/kg and 6.03 kWh/kg, respectively. Finally, I calculated the calorific values for paper waste, with the highest at 6.2 kWh/kg and the lowest at 5.8 kWh/kg. I then computed a total of 7.39 MJ of heat from the different waste materials, considering the lower calorific values for all substrates.

Determination of Calorific value of Cow dung:

With 180g/mol

Mole fraction of C = 72/180 = 0.4

Mole fraction of H = 10/180 =0.06

Mole fraction of O = 80/180 =0.5

Mole fraction of N = 1

Mole fraction of S =1

From the modeling equation 6:

HCV = 34.91(0.4) + 117.83(0.06) – 10.34(0.5) – 1.51 X 1 + 10.05 X 1 – 2.11(92.4)

= -170.45G/t

Since is a negative answer, the modeling equations 8 and 9 are appropriate (Rachel N. et al., 2011).

HCV = 34.91(0.4) + 117.83(0.06) – 10.34(0.49) – 1.51 X 1 + 10.05 X 1

= 20.74 GJ/t = 20.74 X 1000 / 3600 = 5.8 kWh/kg

LCV = 20.74 – 22.36 (0.06)

= 19.40 = 5.3 kWh/kg

2.1.4

In the research, I used three 200 L plastic drums for biogas production and storage. I also acquired materials such as screws, PVC sockets, a biogas desulfator, a gas and water separator, a burner, PVC tees, PVC pipes, and hose clamps, along with their respective measurements. I designed the biogas digester, which incurred an estimated cost of about PHP 11,670, including the tanks used as the gas holder system. I developed a biogas digester that was more cost-effective, easier to construct, and environmentally friendly compared to traditional biogas plants. I positioned the three plastic drums next to each other on a smooth surface alongside the digester tank drum. Alternatively, I could place the digester tank drum on a higher surface to facilitate better gas flow into the gas holder tanks, which were filled with 200 L of water through one of the original caps on the storage drums and sealed securely. I ensured that the tanks were interconnected at the bottom, maintaining a consistent water level in the second gas storage drum. I then allowed the gas to flow through the biogas desulfator and gas-water separator, ultimately connecting it to the burner or other applications.

2.1.5

After that, I developed the layout plan for the proposed project. I set up the biodigester using various parameters and materials to ensure the effective execution of the experiment. I followed the measurements precisely and began the experiment by removing the drum's top cover and one side. Using a power drill or an angle grinder, I converted the drum into the biogas digester as assigned. I carefully attached a 3" (7.62 cm) PVC male threaded adaptor (MTA) to the side hole of the drum and connected a 3" (7.62 cm) PVC female threaded adaptor (FTA) to the MTA's threaded end. I applied epoxy A and B meticulously to ensure the connection was tight and secure. Then, I took two metal sheets, cut them to the specified size, and drilled precisely eighteen holes for the screws. I made sure the metal sheets were perfectly aligned before placing them on top of the biogas digester. After finishing the metal plate, I painstakingly assembled the mixing system as directed, ensuring that PVC solvent cement was used to securely bond all the PVC parts. Next, I connected the digester drum's biogas output to the biogas storage drums, using PVC solvent cement to seal the joints for a perfect seal. I ensured that all connection points were properly sealed to maintain the integrity of the system. Finally, the gas pipe was connected to the stove, a gas and water separator, and an H2S separator (also known as a biogas desulfator). I understood that the digester's raw biogas contained H2S, which is toxic to humans and can corrode biogas equipment, in addition to producing unpleasant odors. Furthermore, the gas and water separator effectively reduced the amount of water in the biogas stream present in the raw biogas.

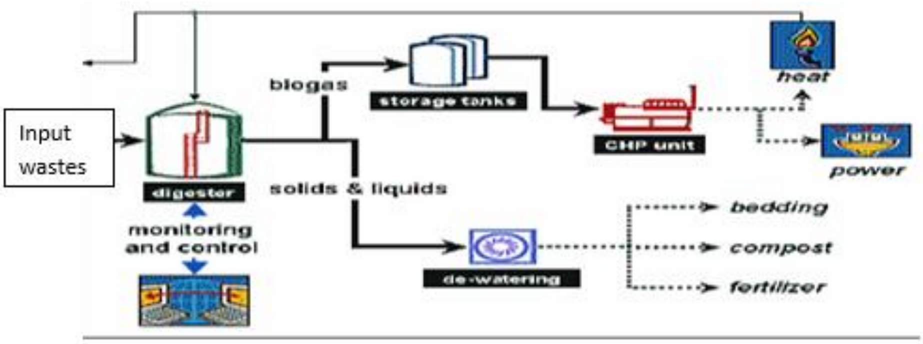

Figure 1 Plan Layout for the experiment

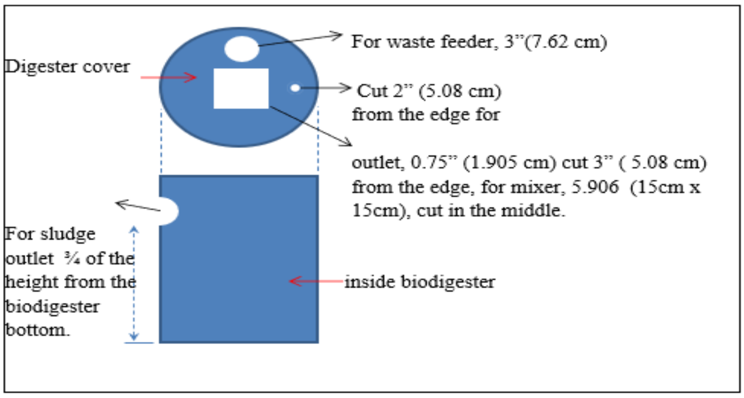

Figure 2 Biodigester setting

Figure 3 Drum cutting

Figure 4 Insertion of thread

2.1.6

I analyzed the average biogas composition by finding it primarily composed of over 68% carbon dioxide with methane, the key biogas component, at a relatively low 22%. I conducted an incubation experiment at 38-47°Cover 7 days which produced approximately 3930 milliliters of biogas. I observed that longer retention times increased gas production, but slow-reacting methane-generating methanogens led to non-combustible gas due to high carbon dioxide proportions. In another experiment, I added 1 kg of kitchen waste (KW) after 7 days of cow dung (CD) digestion without removing biodigester sludge. I conducted the study with the aim of investigating biogas generation through the co-digestion of KW and CD, with the goal of reducing digestion time by enhancing methanogenic activity. I mixed the waste with appropriate volumes of water according to a 4gVS/L/d organic loading rate aiming to dilute organic substances and promote microorganism breeding. In a different trial, I introduced 1 kg of vegetable waste (VW) without removing biodigester sludge to explore biogas generation from co-digestion of KW, CD, and VW by emphasizing an environmentally friendly compact biogas digester. I monitored the setup and stirred the reactor daily for 6 days. In a paper waste co-digestion experiment, I ran the trial for 5 days resulting in a biogas composition with 55% methane and 35% carbon dioxide making the gas barely flammable.

2.1.7

From the experiment with cow dung, I got 68% carbon dioxide and 22% methane as biogas along with the 1000ml gas production in 6 days at 47 degrees Celsius with a pH value of 7.5. Furthermore, I calculated 3400ml of gas produced in 6 days of time with a pH value of 6.8. With that, I found 55% methane gas and 35% carbon dioxide from the 1 kg of kitchen waste. Following that, for the vegetable waste only, I attained the maximum gas produced of 3600ml in just 5 days with a pH 6.9 with greatest production of methane gas of 70%. From the paper waste, I produced only 2000ml gas at a temperature of 44 degrees Celsius in 5 days with 55% methane gas and 35% carbon dioxide. From that, I concluded that the highest production of gas was obtained from the 1kg vegetable waste with 3600ml in which methane gas produced was found to be 70%. I attached the results for gas production from each waste below.

Cow Dung:

Table 1 Experimental Data

pH	Temperature (°C)	Time (day)	Gas production in ml
7.65	38	1	500
7.56	40	2	500
7.29	39	3	600
7.5	42	4	630
6.90	42	5	700
7.5	47	6	1000

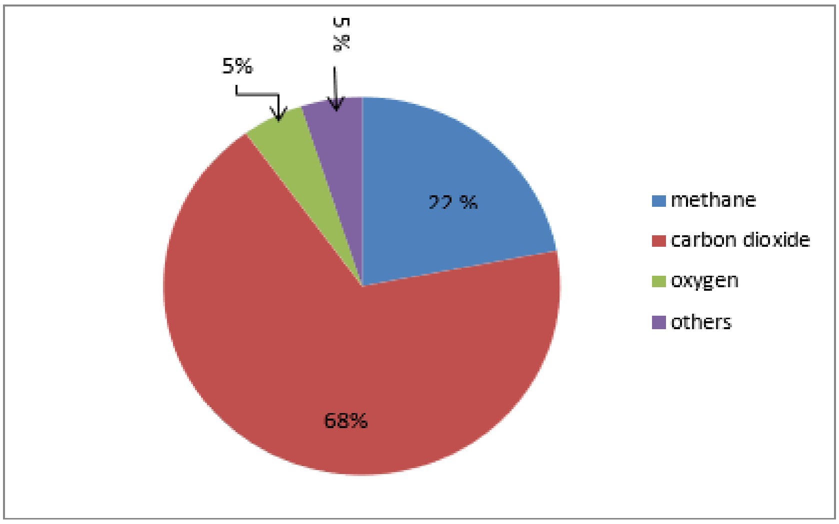

Figure 5 Biogas Composition

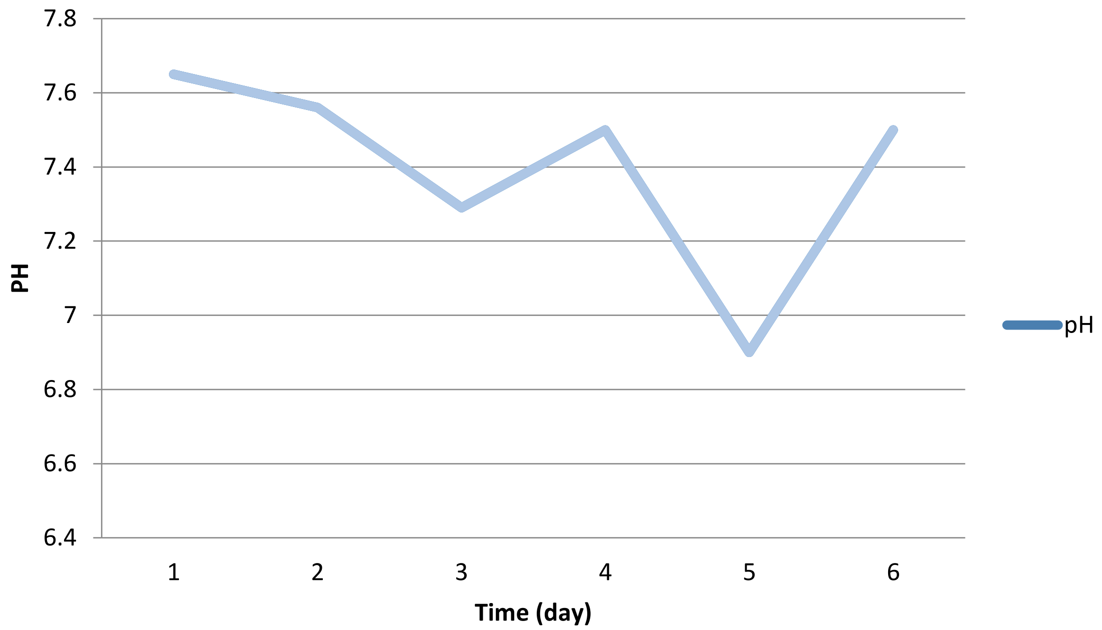

Figure 6 pH vs Days.

Kitchen waste:

Table 2 Exp Data

pH	Temperature °C	Time (day)	Gas produced in ml
7.6	45	1	600
7.5	43	2	700
7.5	38	3	800
7.4	40	4	820
7.0	44	5	950
6.8	47	6	3400

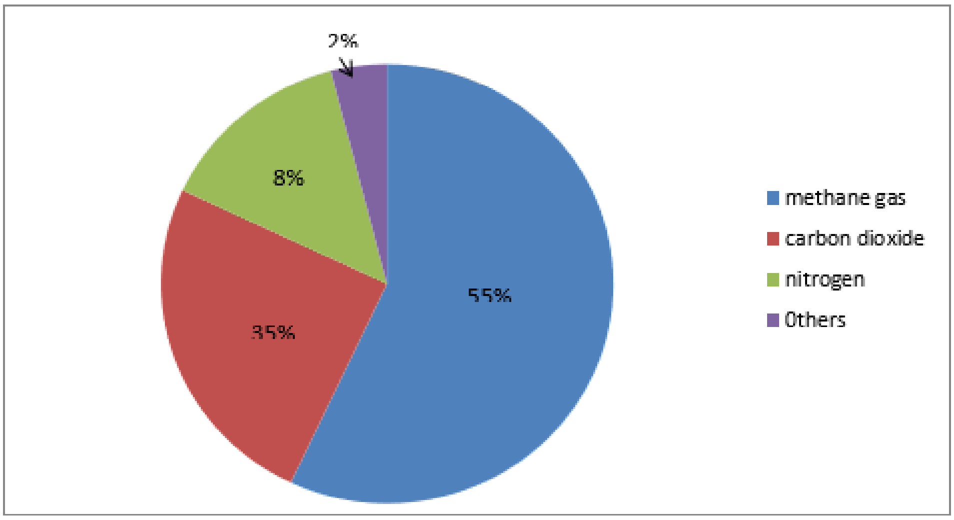

Figure 7 Biogas composition

Vegetable waste:

Table 3 Experimental Data

Table 6 Experimental Data of the Mixed Substrate (Vegetable wastes)

pH	Temperature °C	Time(day)	Gas obtained in ml
7.5	42	1	1450
6.9	38	2	1450
7.4	40	3	2000
7.4	42	4	2500
6.9	37	5	3600

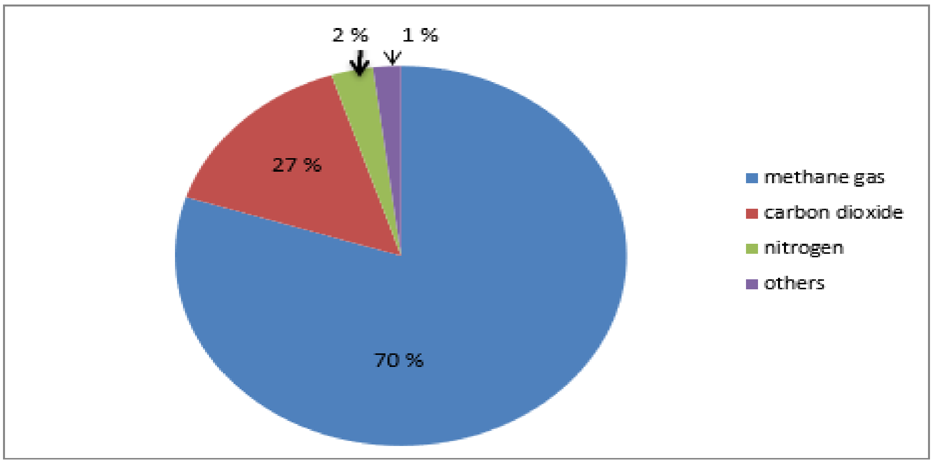

Figure 8 Composition of Biogas

Paper waste:

Table 4 Experimental Data

pH	Temperature °C	Time (day)	Gas Produced in ml
7.5	45	1	500
6.5	40	2	600
6.4	40	3	1200
6.5	43	4	1400
6.4	44	5	2000

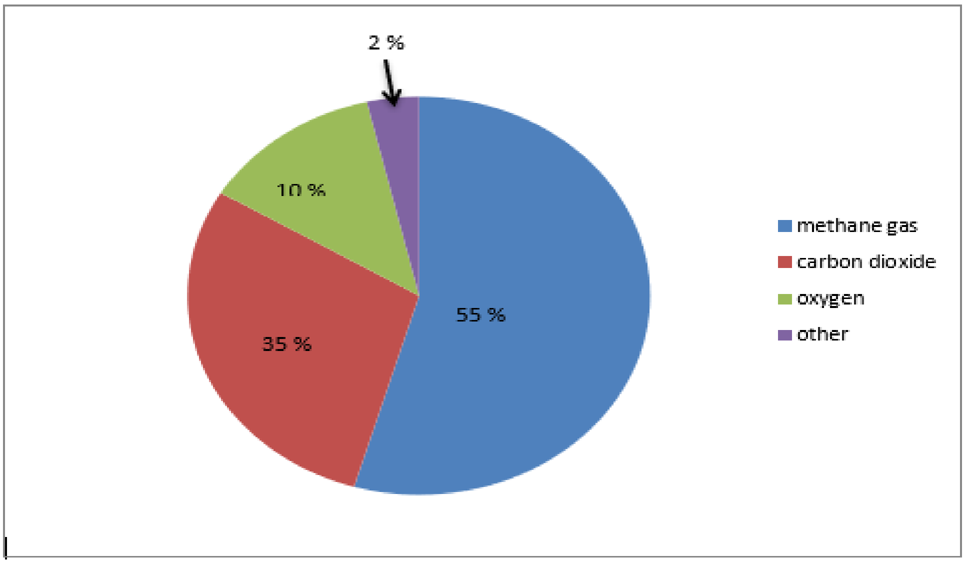

Figure 9 Biogas composition

2.2 Problem and Solution

2.2.1

I encountered the initial challenge of finding a suitable location for the research prototype plant. After meticulous evaluation, I determined that the best course of action was to install the prototype plant in the rear section of Adamson University's school bus parking area in Manila. I made this choice based on careful consideration and a well-thought-out strategy.I selected this site because it was conveniently located near the industrial wastewater area, which was important for the goals of the study. By choosing this location, I ensured easy access to industrial wastewater, a crucial resource for the study's success. This strategic decision not only streamlined the logistical aspects of the project but also expedited the research process.

2.2.2

I encountered another technical challenge which revolved around assessing the site's conditions. I focused on various environmental factors such as drainage, groundwater, and flood risks. I aimed to discover an ideal site that would not only reduce site preparation costs but also protect the plant from excessive sunlight exposure. I concluded that the best option was a level, shaded area. I calculated that the plants in the project needed an area that was around 500 cm × 2 m and 1 m high. I took this decision to ensure that the site will precisely meet the demands and specifications of the project. By considering those factors, I successfully addressed this challenge. Finally, I played a pivotal role in creating a favorable environment for the project which ultimately led to a more cost-effective and efficient research process.

2.3 Creative Work

I painstakingly designed a schematic and inventive process flow for the little biodigester that I used for this project. At that point, I implemented my design which was a big step forward for the project.

2.4 Team management

I ensured that each team member's strengths and expertise aligned with the project's objectives. I organized an initial project kick-off meeting to introduce the team to the project's goals and objectives. During this meeting, I defined roles and responsibilities, emphasizing each member's contribution to the project's success.I led the development of a comprehensive project plan, outlining the steps required for designing, building, and testing the Compact Biogas Digester. I delegated tasks to team members to conduct in-depth research on biogas technology, materials, and design options. Collaboratively, we designed the Compact Biogas Digester, considering factors such as size, materials, and environmental impact. I oversaw the construction of the prototype, ensuring that the team adhered to safety and quality standards.

2.5 Codes and Ethics

I shadowed the code ISO 12814-1:2008 for the specification of the biogas. I also came across the ethics of the college for other inspections.

2.6 Conclusion

An inspection of the construction and operation of a Compact Biogas Digester System was conducted during my internship at the Centre for Appropriate Technology (GrAT). The project involved meticulously adhering to the design and building the prototype at Adamson University under GrAT's guidance. Safety and effective system functionality were prioritized, with close communication and issue reporting to the GrAT team. Activities were thoroughly documented through report writing and videography, including analyses of substrates, gas production parameters, and cost-benefit assessments. The calorific value of gas produced from various substrate combinations—such as cow dung, kitchen waste, vegetable waste, and paper waste—was determined. The research aimed to explore the energy potential of different waste materials and their contribution to sustainable energy generation. Three 200 L plastic drums were utilized for biogas production and storage, along with various materials and measurements. A cost-effective and environmentally friendly biogas digester design was developed. Gas production and composition were analyzed, indicating a primarily carbon dioxide-rich composition with lower methane content. Experiments revealed the impact of retention times and substrate combinations on biogas production and combustibility.

I modified the approach to implementing the project's alternative technology solution for cooking with the compact biogas digester. I also gained valuable insights into supervising, managing, leading, directing, and communicating throughout the project.

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