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Production and purification of biogas from cassava peel using cow dung as inoculum

Production and purification of biogas from cassava peel using cow dung as inoculum

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Abstract. The study examined biogas production from cassava peel and cow dung due to the large quantity of cassava peel disposed at dumpsites in local cassava processing sites. A 200L biodigester was used for the experiment. It contained 25 kg of cassava peel, 25 kg of cow dung and 100 kg of water in the ratio of 1:1:4, respectively. A cumulative volume of 937.3L of biogas was generated after the 30 days digestion period. The biogas generated was pass through a combined absorption and adsorption pre-treatment process to reduce the concentration of impurities in the biogas. The procedure had a 91.5% CO_2removal efficiency and 88% H_2S removal efficiency. The biogas, after purification can be used for cooking. Also, the digestate from the anaerobic digestion process is rich in NPK, which can be used as fertilizer.

Keywords: biogas, anaerobic digestion, sustainability, adsorption and absorption, biogas treatment and pollution.

1. Introduction

Biomass technology is a clean and inexpensive energy source created by combining organic elements such as solid agricultural waste, municipal garbage, and animal waste[1–3]. Almost all developing countries, including Nigeria, have a problem with waste management[4–7]. This problem can be checked with biogas technology. Biogas can be produced from organic waste from cassava, yam, citrus and lime, rice, sorghum, cocoa etc[8] and [9].

Cassava being the most grown energy crop in Nigeria, generates a lot of waste during its processing[4]. Nigeria is currently the largest producer of cassava in the world, accounting for 60% of cassava produced in Africa and approximately 20% in the globe[9]. Cassava is processed into garri and fufu majorly by local cassava processor in Nigeria[10]. The three wastes generated from its processing are peel, solids and wastewater[4]. About 55% of cassava peel generated at cassava peel sites are disposed at dumpsite, causing a nuisance to the environment[4]. At the same time, the remaining percentage is used to feed livestock animals such as goats and pigs. The peels disposed at the dumpsite give off an unpleasant odour that causes air pollution in the neighbourhood[11] and [12]. Also, the peels can contaminate both ground and surface water after the acidic content in the peel gets washed by the rain and percolate into the ground. To avoid the indiscriminate disposal of cassava peels, the peels can be used as feedstock for biogas production. Studies have also shown that cassava peel can be mono-digested and co-digested[13]. Co-digestion of cassava peel with animal waste such as cow dung, swine waste, poultry droppings etc., have shown to produce more biogas than when cassava peel is digested alone[14] and [15]. The digestate from the anaerobic digestion process can be used as fertilizers to grow crops by the local farmers.

Figure 1: 200L Cassava planation near a cassava peel dump site in Ota, Ogun State.

Biogas is a colourless and flammable gas that contains 50-75Methane (CH_4), 25-50Carbon IV Oxide(CO_2), 0-10Nitrogen (N_2), 0-1Hydrogen (H_2), 0-3Hydrogen sulphide (H_2S) and 0-2Oxygen, (O_2)[10]. The essential component of biogas is methane because of its combustive properties. Biogas is formed through anaerobic digestion. Anaerobic digestion involves degradation of organic matter in the absence of oxygen. The process involves four stages[16]. The first stage is hydrolysis which is the slowest among the four degradation steps[16]. Bacteria's transform complex organic compounds into liquefied monomers and polymers. The second step is acidogenesis. That is where sugar and amino acids are converted into volatile fatty acid and alcohol. The third step is acetogenesis. That is where the substances formed in acidogenesis are converted into hydrogen, acetic acid and carbon dioxide. Finally, the fourth step is methanogenesis. The methanogenic bacteria convert hydrogen and acetic acid into methane and carbon dioxide[17]. During anaerobic digestion, parameters to be monitored are organic loading rate, pH, temperature, hydraulic retention time, carbon to nitrogen ratio, and particle size[18].

Biogas produced from anaerobic digestion can be treated with techniques such as biofiltration, pressurized water scrubbing, refrigeration/chilling and combined adsorption and absorption process. The four methods have benefits and drawbacks[19]. Water scrubbing and biofiltration

have excellent hydrogen sulphide, ammonia and volatile organic compound removal efficiency, while refrigeration is efficient for water vapour and ammonia removal[20]. Combined adsorption and absorption effectively remove water vapour, hydrogen sulphide, carbon dioxide and ammonia[19] and [20].
The aim of the study is to generate biogas from cassava peel using cow dung as inoculum and purifying the gas to get a higher methane concentration.

2. Materials and methods

2.1Biodigester

A 200L plastic drum was used as the biodigester. The digester had an inlet chamber and two outlet chambers. The inlet chamber is an opening where the feedstock will be poured through to enter the digester. After loading, the inlet chamber is sealed to avoid gas leakages and contamination from the environment. The outlet chamber at the bottom of the tank is for draining the digesterwhen the digestion process is complete. Also, the second outlet chamber at the middle of the digester collects slurry samples for pH test.
The digester was connected to a tire tube for collecting the biogas produced daily. The gas from the tube was then later transferred to a larger storage unit for safekeeping. The digester was also agitated manually everyday of the week to prevent the slurry from caking in the digester. Figure 2 shows the design drawing of the experimental setup.

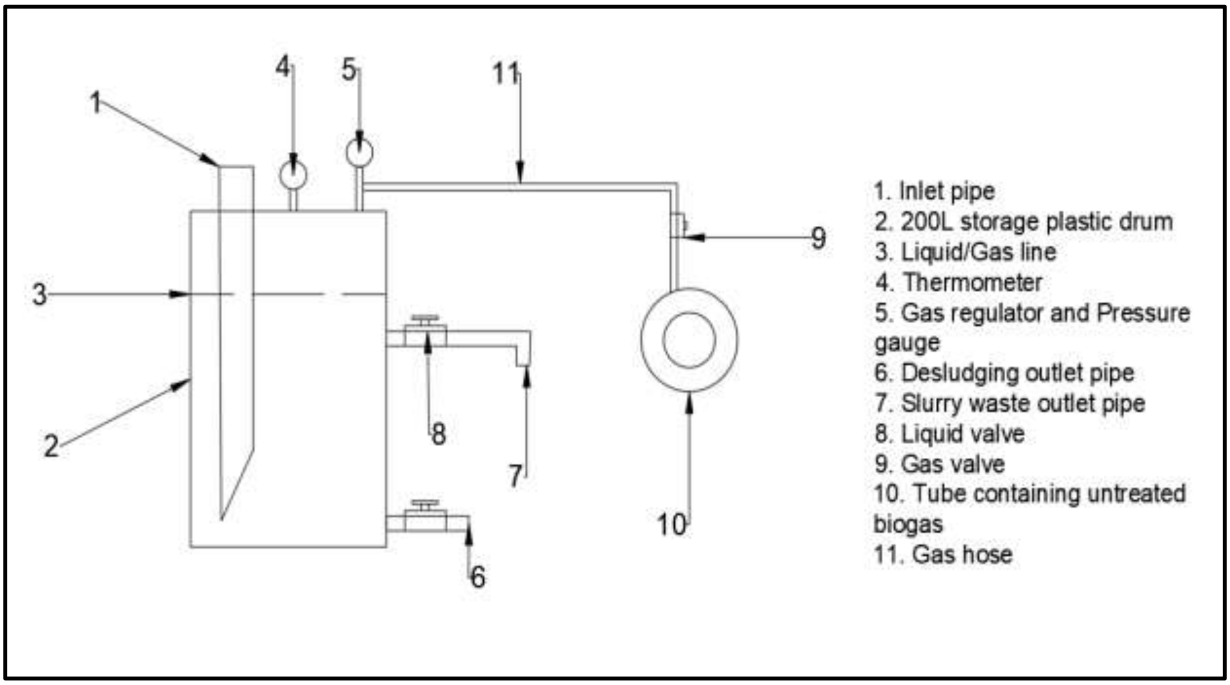

Figure 2: 200L Biodigester experimental setup.

2.2 Feedstock

The feedstock used for this experiment are cassava peel, cow dung and water. The cassava peel was gotten from a local cassava farm in Atan, Ogun State (Figure 3), while the cow dung was gotten from an abattoir in Ota, Ogun State. The water used for the experiment was fresh tap water obtained from the civil engineering department, Covenant university. The cassava peel was soaked for two days to reduce the cyanide content present in the peel. Cassava peel is naturally acidic, and the acidity affects the productivity of the microorganism that will digest and convert the peels into biogas. So, it’s necessary to soak the peel to reduce the acidity to an acceptable level. After soaking, the peel was dried under the sun to reduce its moisture content. The peels were then grinded into small pellets to aid digestion and increase biogas yield.

Since a 200L digester is used for the experiment, the feedstock should not exceed the 75% of the size of the digester, which is 150L[21]. To this end, 25 kg of cassava peel, 25 kg of cow dung and 100 Kg of water will be used for the study with a ratio 1:1:4, respectively. The ratio was selected based on recommendations from previous studies. Adelekan and Bamgboye[13]recommended a cassava peel to animal waste ratio of 1:1, while Olaniyi[22]recommended feed to water ratio of 1:2. The cassava peel, cow dung and water were uniformly mixed before being loaded into the digester. A retention time of 30 days was considered for the experiment.

2.3 Biogas treatment.

The combined adsorption and adsorption process was used for the purification of biogas to obtain a higher concentration of methane. The materials used are powdered activated carbon, silica gel and calcium hydroxide. The silica gel and calcium hydroxide were ground into powdery form to increase the surface area. Also, the calcium hydroxide was mixed with water to form an aqueous solution. The experiment was carried out as recommended by Muhammed and Shuichi[23]. The experimental setup is displayed in figure 4.

The untreated biogas was passed through the first flask containing an aqueous solution of calcium hydroxide to remove Carbon IV Oxide(CO_2). After removal, the gas flows into the second flask. The pipe connecting the first flask to the second flask contained powdered activated carbon, which removed hydrogen sulphide present in the biogas. The gas then flows to the third flask for water vapour removal by the silica gel. The concentration of the gas before and after treatment was tested with a gas analyzer. The limitation to using a gas analyzeris that it only tests for four components: Methane CH_4, Carbon IV Oxide CO_2, Hydrogen Sulphide H_2S and Carbon monoxide CO.

Figure 3: Cassava processing farm at Atan, Ogun State.

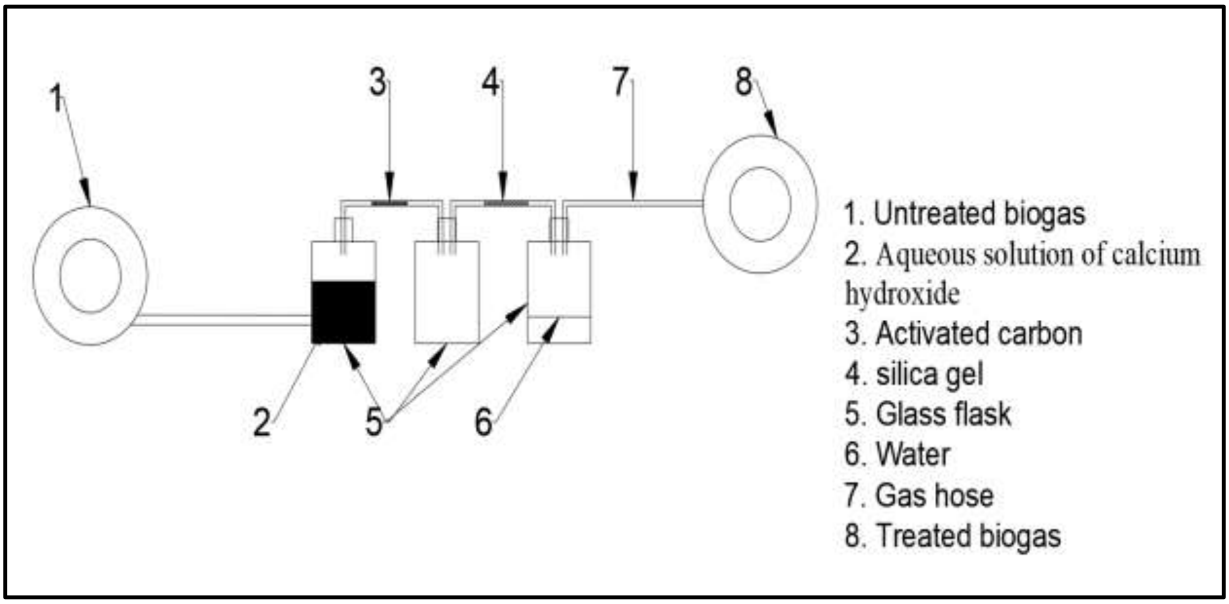

Figure 4: Biogas purification experimental setup.

3. Results and Discussion

3.1 Biogas production.

A cumulative volume of 937.3L of biogas was produced after the 30 days digestion period, as seen in figure 5. The digester did not produce any biogas on the first day of digestion.Similar occurrence was recorded from previous studies[3] and [15]. Biogas production started on the second day and had a peak on the 10^{th} and 12^{th} day of digestion with a volume of 48.9L. A sharp decline in biogas production can be noticed on the 12^{th} and 17^{th} days of digestion. This can be attributed to a temperature drop in the slurry as a result ofa reduction in the ambient temperature. Biogas production depends on the ambient temperature. On sunny days, biogas production increased, while it reduced on rainy and cold days. Biogas production started to decline after the 25^{th} day because of the reduction of the methanogenic bacteria present in the digester. After the 30 days of digestion, the biogas produced had methane, carbon dioxide, hydrogen sulphide and carbon monoxide concentration of 33.6%, 64.1, 1100ppm and 645ppm, respectively. The methane concentration was low because the slurry did not include any buffer for pH stabilization[10].

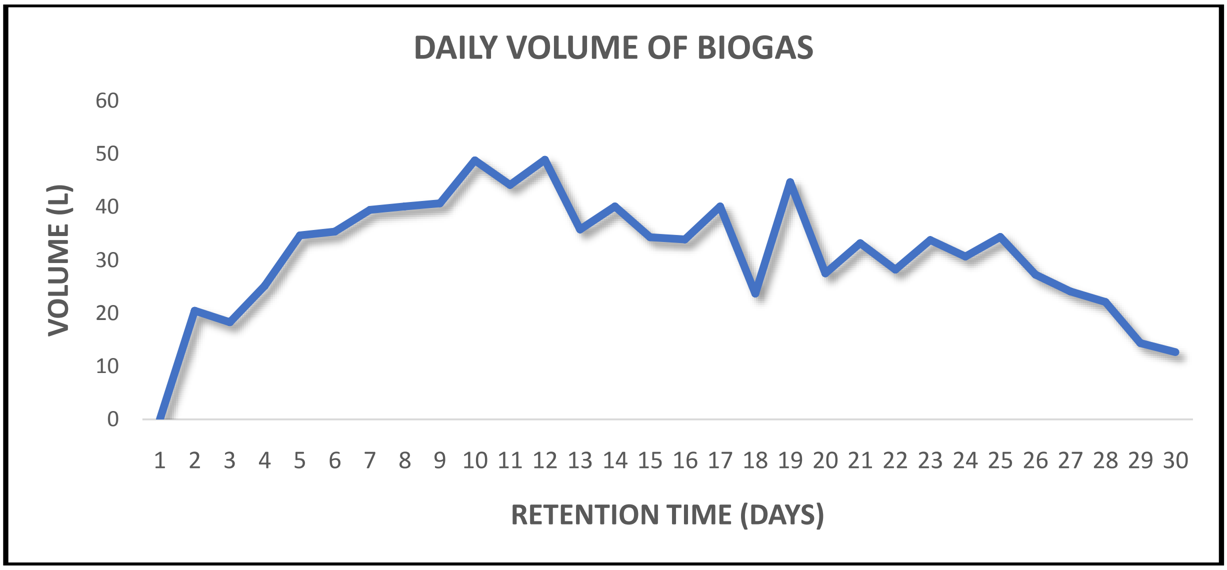

Figure 5: Daily Volume of biogas produced.

3.2 Temperature and pH.

The temperature and pH of the digester were monitored daily. The digester had a slurry temperature range of 29.2 to 35.8°C,which is between the acceptable mesophilic temperature range (30 - 40°C). An ambient temperature range of 27 to 32°C was recorded for the study, as seen in figure 6. The ambient temperature was directly proportional to the slurry temperature. An increase or decrease in the ambient temperature directly affected the temperature of the slurry. The study noticed that sunny day with a temperature of 30°C and above increased biogas production significantly compared to rainy days.

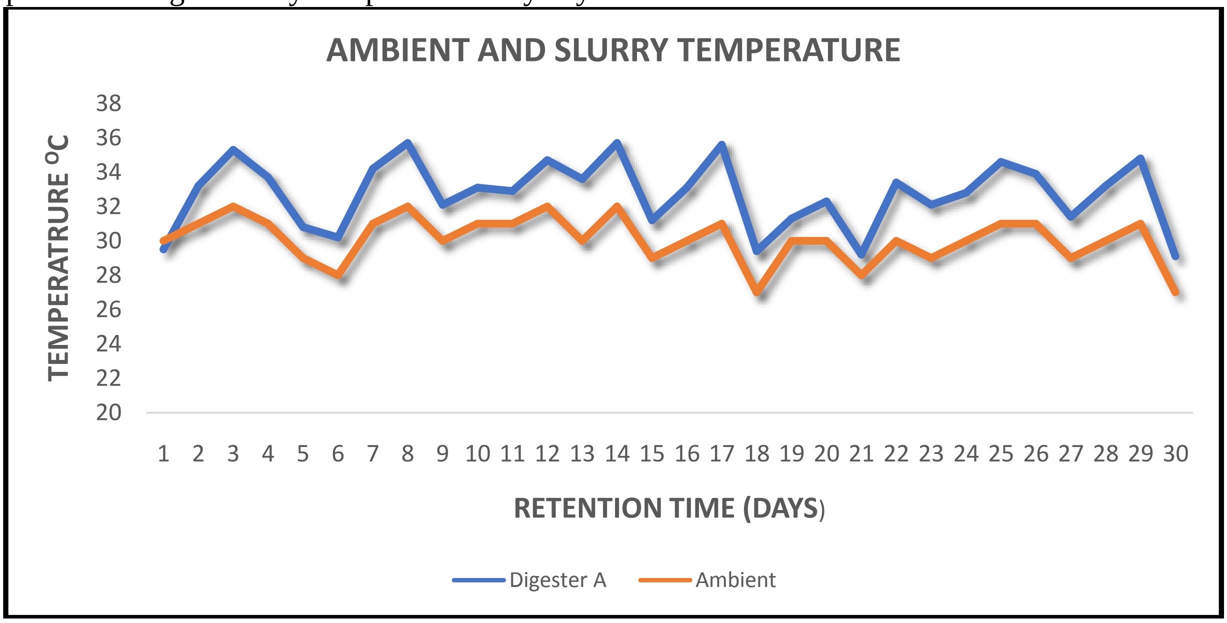

Figure 6: Ambient and slurry temperature

The average pH of the slurry in the digester was 5.5, which showed the slurry was acidic. This could have impacted the volume of biogas produced because acidic and basic slurries reduce biogas production. pH within the range of 6.5-7.5is acceptable for optimum biogas production. Chemical buffers such as NaOH, KOH, $NaHCO_3$, $Ca(OH)_2$ have been used to stabilize the pH of cassava slurries to increase biogas production[10]. The pH over the 30 days digestion time is shown in figure 7.

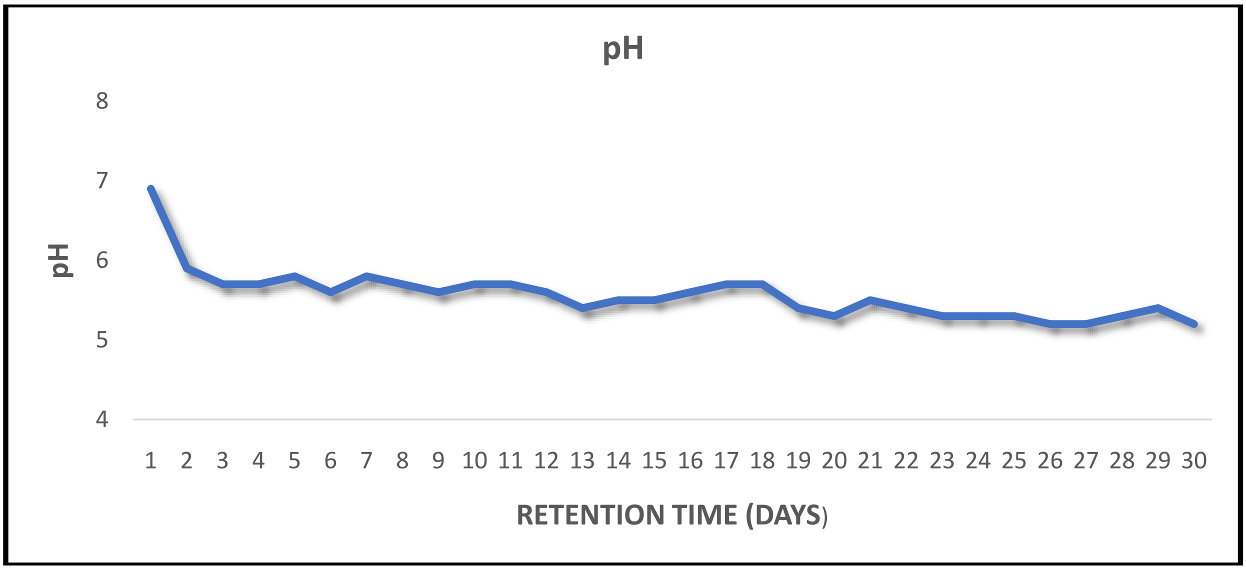

Figure 7: Variation of pH with retention time

3.3 Biogas treatment.

The flask containing the $Ca(OH)_2$ aqueous solution was observed to gradually remove high proportion of CO_2 (approximately 91.5% removal efficiency), resulting in methane-rich biogas. However, this was a time-dependent process. Gaseous concentration was found to decrease with time as seen in Figure 8. Initially, the liquid solvents reacted rapidly with and almost completely absorbed CO_2 after 240 min. The concentrations at the outlet stream were essentially very small compared to their original values. As the absorption process progressed, the CO_2 was continuously stripped into the solution. The corresponding curve obtained is presented in Figure 8, showing the variation of the CO_2 concentration changes with time. It was found that $Ca(OH)_2$ became saturated in about 150 min. It can be seen that the CO_2 concentration reduced sharply in the experiment up to 180 min, agreeing with the work done by Muhammed and Shuichi[23] and Mamun and Torii [19]. The reducing trends decreased gradually and almost remained stable at 150 to 240 min. CO_2, being an acidic gas, reacts with $Ca(OH)_2$ to produce a white precipitate of calcium carbonate, $CaCO_3$.
Hence, for the absorption of CO_2 gas, appropriate bases such as $Ca(OH)_2$ must be used to produce an acid-base neutralization reaction thereby, absorbing and reducing the CO_2 content in biogas.

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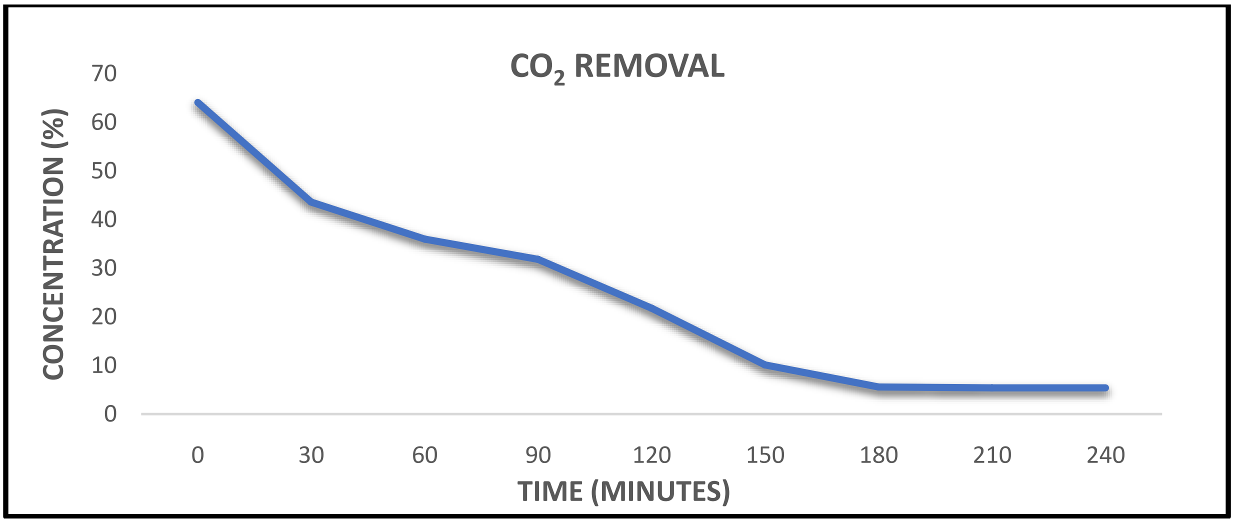

Figure 8: Graphical representation of concentration of CO_2 removed with time

The removal efficiency of H_2S was based on the measurement of the inlet and outlet H_2S concentrations of biogas produced from the digester and the retention time in the pipe containing the activated carbon. The activated carbon was chosen because it has a high surface area, promising for H_2S removal. H_2S concentration remained stable between the time range of 120 - 240 min. After a contact time was 30 min, the concentration of H_2S in the digester was reduced to 769.2 ppm as seen in figure 9. At the end of 240 min, the concentration of H_2S in the digesterwas 124.2 ppm. It had a removal efficiency of 88%, which shows the activated carbon is efficient for the removal of H_2S from biogas.
The maximum concentration of H_2S acceptable for running internal combustion engines is 50 ppm (Muhammad & Shuichi, 2015). The digester had a concertation of 124.2ppm after 240 mins. This shows that the biogas from the digester cannot be used for combustion engines unless the biogas undergoes two phases of H_2S removal. The high concentration of H_2S in the digester can be attributed to the absence of a buffer in the slurry before digestion.
It is normal that the adsorption is increased if the time of experiments increases; however, it is evident that the adsorbent has a H_2S adsorption capacity limit. The result agreed with the work done by Mamun and Torii[19] and Muhammad and Shuichi[23].

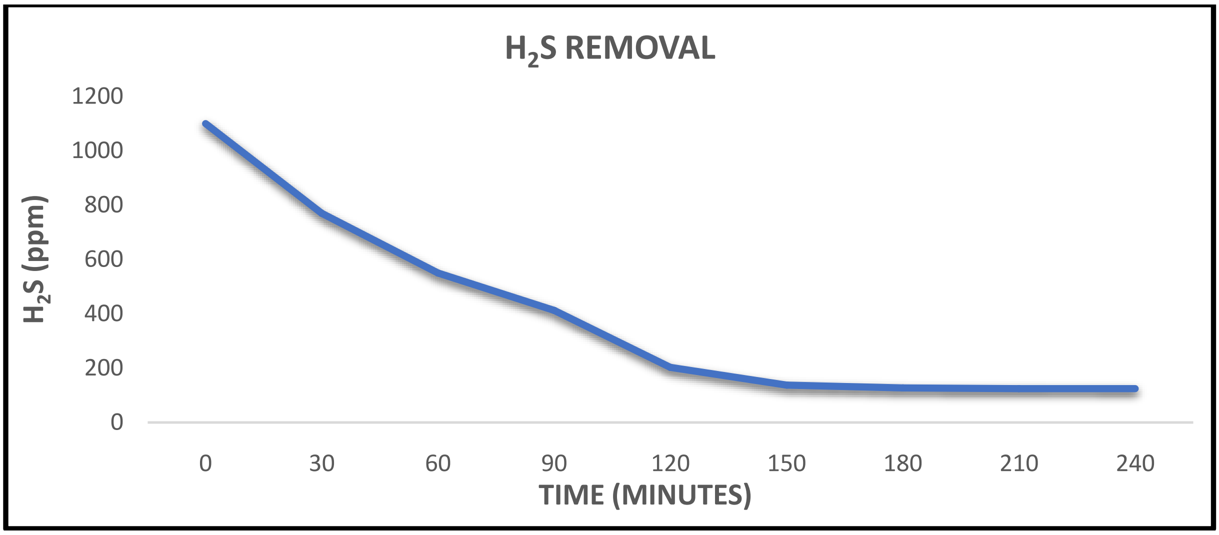

Figure 9: Graphical representation of concentration of H_2S removed with time

4. Conclusion and Recommendation

This work showshow biogas can be generated from cassava peel using cow dung as inoculum. The biogas produced could be used as replacement for firewood used by local cassava processor to produce garri and lafu. The volume of biogas and concentration of methane can be increased by pre-treating the cassava peels and including a buffer in the slurry that will be loaded into the digester. It is also recommended that the digester is placed outside and not indoor if no special heating system will be provided. The sun rays on the digester increase the temperature of the slurry which leads to biogas production.

The Combined absorption and adsorption process proved effective for biogas treatment to remove the major impurities. The biogas can be used for household daily cooking but cannot be used to power engines because of the high concentration of H_2S. This can be resolved by making the biogas undergo the pre-treatment process twice to effectively eliminate all the impurities present in the gas. Also, the digestate after the 30 days digestion time can be used as fertilizer to grow crops. This will reduce the cost of purchasing chemical fertilizers by the cassava famers if they utilize biogas technology. The authors also beckon on the government to empower local cassava farmers with biodigester so that they can turn their waste into wealth.

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