

## ORIGINAL RESEARCH ARTICLE

## Production, Purification and Compression of Biogas from Cow Dung

Mohammad, A.<sup>1</sup>, Garga M.A.<sup>2</sup>, Bawa, M.Y.<sup>2</sup>, Bako I.<sup>2</sup> and Shuaibu, I. M.<sup>1</sup><sup>1</sup>Department of Pure and Applied Chemistry, Faculty of Science, Usman Danfodiyo University, Sokoto, Nigeria<sup>2</sup>National Biotechnology Research and Development Agency, Bioresources Development Centre, Katsina, Nigeria

### ABSTRACT

Biogas has been widely recognized as a viable alternative energy source; however, its commercial use remains limited due to challenges with storage and transportation. This study elucidates the processes involved in the production, scrubbing, compression, and storage of biogas derived from cow dung, with the aim of enhancing its portability and combustion efficiency. A total of 385 kg of fresh cow dung was anaerobically digested in a 1 m<sup>3</sup> floating-dome digester for a retention period of seven days to generate raw biogas. The raw biogas was subsequently purified through a three-stage scrubbing system: carbon dioxide (CO<sub>2</sub>) was removed by chemical absorption using 100 g/L calcium oxide (CaO) slurry, hydrogen sulfide (H<sub>2</sub>S) was eliminated using 863 g of iron filings via adsorption, and water vapor was extracted using 498 g of silica gel crystals. The purified biogas was compressed to an absolute pressure of 4 bar using a refrigerant compressor and stored in a 23.7 L compressed natural gas (CNG) cylinder. The compression process was completed within 4.54 minutes, with direct proportional relationships observed between compression time, cylinder pressure, and compressor surface temperature. The performance of the compressed biogas was evaluated through water boiling and food cooking tests and compared with raw biogas and conventional fuels (kerosene, firewood, charcoal, and butane gas). The scrubbed and compressed biogas boiled 1 liter of water in 7 minutes and 49 seconds, representing a 33% reduction in boiling time compared to raw biogas (11 minutes and 37 seconds). Similarly, cooking 1 kg of rice required 30 minutes with purified biogas, compared to 45 minutes with raw biogas, indicating a 33% improvement in cooking efficiency. These findings demonstrate that the sequential scrubbing of CO<sub>2</sub>, H<sub>2</sub>S, and water vapor using locally available materials significantly enhances the calorific value and combustion performance of biogas, while compression facilitates its storage and transportation. The study establishes a replicable low-cost system for producing portable high-energy biogas suitable for domestic applications.

### ARTICLE HISTORY

Received August 15, 2025

Accepted December 17, 2025

Published December 30, 2025

### KEYWORDS

Biogas, cow dung, anaerobic digestion, scrubbing, compression, calcium oxide, iron filings, silica gel, calorific value



© The Author(s). This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 License [creativecommons.org](https://creativecommons.org/licenses/by-nc/4.0/)

### INTRODUCTION

Energy remains an essential input to all aspects of modern society, serving as the life wire for industries, transportation, and conventional power generation (Al Mubarak et al., 2024). Global energy consumption has approximately doubled in recent decades, with 82% of primary energy derived from fossil fuels and 18% from renewable sources, including 11% from bioenergy (Kizilkaya et al., 2024). However, rising concerns over the consequences of climate change threaten to limit future access to fossil fuels, as carbon dioxide (CO<sub>2</sub>) accumulation, the inevitable product of fossil fuel consumption, creates an irreconcilable conflict between energy security and environmental protection, potentially precipitating a major economic crisis, environmental crisis, or both (Shindell and Smith, 2019).

The energy crises of the 1970s, coupled with population growth and growing public awareness of the costs of conventional energy, have driven a sustained search for renewable energy alternatives, which are available in significant quantities in both developed and developing countries (Kizilkaya et al., 2024). Among these, biomass, derived from renewable biological sources such as plants, animals, and microbes, has emerged as a promising carbon dioxide-neutral alternative that can be converted into fuels through various methods (Onyeaka et al., 2025). Another approach to biomass utilization involves the production of gas from organic materials such as animal manure or sewage, with biomass resources including cattle dung, agricultural wastes, and other organic residues serving as fundamental energy sources since the dawn of civilization

**Correspondence:** Ahmad Mohammad. Department of Pure and Applied Chemistry, Faculty of Science, Usman Danfodiyo University, Sokoto, Nigeria. ✉ [tjachmad@hotmail.com](mailto:tjachmad@hotmail.com).

**How to cite:** Mohammad, A., Garga, M. A., Bawa, M. Y., Bako, I., & Shuaibu, I. M. (2025). Production, Purification and Compression of Biogas from Cow Dung. *UMYU Scientifica*, 4(4), 301 – 309. <https://doi.org/10.56919/usci.2544.027>

(Huang, 2024), offering considerable scope for conversion into biogas (Ozor et al., 2014).

Biogas, primarily composed of methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>), with trace amounts of hydrogen sulfide (H<sub>2</sub>S) and water vapour, offers a renewable alternative to conventional fossil fuels (Bagudo et al., 2011). Despite its recognized potential as a viable alternative energy source, the widespread commercial adoption of biogas remains unrealized due to two interrelated challenges: impurities that reduce its calorific value and cause corrosion, and difficulties associated with its storage and transportation (Kapdi et al., 2007). Raw biogas typically contains 40–45% CO<sub>2</sub>, which significantly reduces its energy density, along with H<sub>2</sub>S, which corrodes equipment, and water vapour, which compromises combustion efficiency (Vinayak and Katti, 2015). Furthermore, in its uncompressed state, biogas is bulky and impractical for transportation, limiting its application to locations close to production sites (Ray et al., 2016).

Previous studies have explored various methods for biogas purification, including chemical scrubbing, water scrubbing, pressure swing adsorption, and membrane separation (Nallamotheu et al., 2013; Zhao et al., 2010). However, many of these technologies remain economically prohibitive for small-scale and rural applications, requiring sophisticated infrastructure and technical expertise (Divyang and Hemant, 2015). Similarly, efforts to compress biogas have been documented, but integrated systems combining purification and compression using locally available materials have received limited attention (Shah et al., 2016; Ray et al., 2016). While individual components of biogas production, purification, and compression have been investigated, there is a paucity of studies that integrate these processes into a cohesive, low-cost system suitable for rural and semi-urban contexts in developing countries. Specifically, the sequential application of calcium oxide (CaO) for CO<sub>2</sub> removal, iron filings for H<sub>2</sub>S adsorption, and silica gel for moisture extraction, all materials readily available in local markets, has not been comprehensively evaluated as an integrated scrubbing train preceding biogas compression. Furthermore, the performance of biogas purified and compressed by such a system relative to conventional cooking fuels has not been empirically validated under controlled experimental conditions.

This study is justified by the pressing need to develop appropriate technologies that bridge the gap between biogas production and practical utilization, particularly in Nigeria and similar developing nations where cattle rearing generates vast quantities of dung that remain underutilized or mismanaged, contributing to environmental pollution while energy poverty persists (Godi et al., 2013). The conversion of this abundant waste resource into portable, high-energy biogas could simultaneously address waste management challenges, provide clean cooking energy, reduce deforestation from firewood collection, and mitigate greenhouse gas emissions. Moreover, the development of a purification and compression system

utilizing locally available materials, hydrated lime from water treatment facilities (for CaO production), iron filings from metal workshops, and silica gel from commercial suppliers, ensures technological accessibility and sustainability, enabling communities to maintain and replicate the system without external expertise.

Therefore, this study aims to develop and evaluate an integrated system for the production, purification (scrubbing), compression, and storage of biogas derived from cow dung, using calcium oxide, iron filings, and silica gel as scrubbing media, and to assess the combustion performance of the resulting compressed biogas through comparative water boiling and food cooking tests against conventional fuels.

## MATERIALS AND METHODS

### 2.1 Sample Collection and Treatment

The cow dung was procured from the residence of Malam Umaru Mai-awaki, situated in Gidan Yunfa Village, adjacent to the Department of Pure and Applied Chemistry at Usmanu Danfodiyo University, Sokoto. He maintains a herd of cattle within a yard on his property. A total of 500 kilograms of relatively fresh cow dung was gathered for this research and subsequently stored in various sacks. These were placed in the biogas demonstration room at the Sokoto Energy Research Centre, Permanent Site. Samples for slurry preparation were extracted from the stock (Ransirini et al., 2024).

### 2.2 Generation of Biogas

A total of 385 kg of cattle dung was meticulously introduced into a 1m<sup>3</sup> digester (Plate 1) in successive increments, followed by the addition of water and thorough agitation until the slurry occupied two-thirds (2/3) of the digester's capacity, thereby reserving the remaining one-third (1/3) for biogas production. An inverted 1 m<sup>3</sup> plastic tank was positioned within the slurry-filled plastic tank to serve as a floating gas holder.



Plate 1: 1m<sup>3</sup> Biogas Digester

The biogas production commenced after a period of five (5) days, achieving its peak volume by the seventh (7th) day. Daily ambient temperatures, along with the slurry temperature, were recorded utilizing a digital thermometer with a range of -50 to 1300°C. The pH of the slurry was

also monitored daily using a TestWest pH meter, as micro-organisms are highly sensitive to pH fluctuations, which directly influence the volume of biogas generated (Kabeyi *et al.*, 2024). The produced gas was subsequently conveyed to the scrubbing and compression units via a 9.1-meter-long ½-inch PVC pipeline.

### 2.3 Scrubbing of Biogas

The purification of biogas was conducted utilizing three units, as depicted in Plate 2, to eliminate the impurities inherent in the biogas. The removal of contaminants such as water vapour, carbon dioxide, and hydrogen sulfide is imperative prior to their use as fuel for diverse applications (Georgiadis *et al.*, 2020).



Plate 2: Biogas scrubbing units set-up

#### 2.3.1. Scrubbing of Carbon Dioxide using Calcium Oxide

Five-hundred-gram (500 g) of hydrated lime, Ca (OH)<sub>2</sub>, obtained from the Sokoto State Water Board's water treatment facility at Tashan Illela, was subjected to thermal treatment at 600°C in a furnace for a duration of one hour to yield CaO, which was subsequently allowed to cool in a desiccator containing silica gel crystals. A precise quantity of 100.0 g of the resultant CaO was mixed with 1000 cm<sup>3</sup> of distilled water in a volumetric flask (Shah *et al.*, 2016) and subsequently transferred into the fabricated CO<sub>2</sub> scrubber (Plate 3).

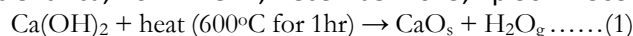


Plate 3: Calcium oxide container for scrubbing CO<sub>2</sub>

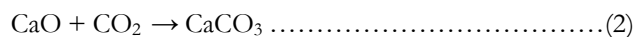
The inlet tube of the scrubber unit is affixed to the outlet of the 1m<sup>3</sup> biogas digester.

The equation for the calcination of Ca (OH)<sub>2</sub> is:

<https://scientifica.umyu.edu.ng/>

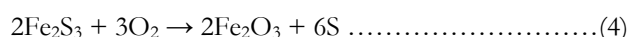
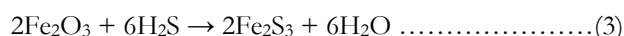


The equation for the scrubbing of CO<sub>2</sub> is:



#### 2.3.2. Hydrogen Sulphide Separating Unit

Iron fillings, 863g, (Plate 4) was put inside the fabricated hydrogen sulphide scrubbing unit which has both inlet and outlet channels. The inlet channel is linked to the CO<sub>2</sub> scrubber, while the outlet channel leads to the inlet channel of the moisture scrubber. When the gas enters the container, the iron fillings react with H<sub>2</sub>S according to the following equations (Ray *et al.*, 2016):



Lead acetate paper was used to detect hydrogen sulphide before and after scrubbing.



Plate 4: Iron filings for scrubbing H<sub>2</sub>S

#### 2.3.3. Water Vapour Scrubbing Unit

The moisture content of the biogas was trapped using 498g of silica gel crystals contained in a 2 L transparent plastic container (Plate 5), used as the scrubbing unit.



Plate 5: Silical gel Crystals for scrubbing water vapour

The inlet channel of the scrubbing unit receives biogas from the H<sub>2</sub>S scrubber, while its outlet channel is connected to a pressure gauge, which is also attached to

the inlet of the compressor. The outlet channel of the compressor delivers purified, compressed biogas to the CNG Cylinder. The change in colour of the silica gel crystals from pink to blue was used to monitor the efficiency of the scrubber, as described by Kumar et al. (2025), Nallamothe et al. (2013), Vinayak and Katti (2015), and Ray et al. (2016).

### 2.3.4 Compression and Storage

The fully active 1m<sup>3</sup> biogas digester (gas outlet closed) was connected to the Carbon (IV) Oxide, Hydrogen Sulphide, and Moisture scrubbers, which were also connected to the compressor inlet channel (switched off) via a pressure gauge. The outlet channel of the compressor was then connected to the inlet port of the fabricated G.I. Pipe adaptor, which was welded to the CNG Cylinder, which was fitted with a gas tap valve and pressure gauge

(Sibanda, 2021). The experimental set-up is shown in Plate 6.

The set-up was checked for leakage and compression was commenced by opening the outlet tap of the biogas digester to allow the flow of biogas, switching the compressor (Plate 7) on from electrical switch, opening the gas tap valve on the CNG cylinder to allow the compressed purified biogas into the cylinder and starting the stop watch for monitoring the compression at the following pressure; 0, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 bars. The process was monitored by measuring the following parameters at the specified pressure (i) time taken to attain the pressure, (ii) the corresponding height of the gas holder and (iii) the surface temperature of the compressor. Once a pressure of 3.0 bars is obtained, the biogas digester outlet tap is closed, the compressor is switched off, the cylinder tap valve is closed, and the cylinder is weighed (Talia, 2018).



Plate 6: Experimental Set-Up for Biogas Compression



Plate 7: Reciprocating Compressor with Pressure Gauge

For storing gas after compression, a CNG cylinder with a volumetric capacity of 23.7 L and a net weight of 12.5 Kg was used, as shown on Plate 8. The whole scrubbing, compression and storage systems were captured on Plate 8.

### 2.4 Water Boiling Test

This was carried out to compare the heating efficiency of the scrubbed and compressed biogas with other heating sources, including raw biogas, kerosene, firewood, charcoal, and cooking gas (butane) (Yusuf et al., 2020).

The compressed biogas was stored in a CNG cylinder connected to a burner fabricated by SERC, while raw biogas was stored in the gas holder of the 1 m<sup>3</sup> digester, which was connected directly to a burner. A 10-Wick double burner domestic kerosene stove for kerosene, an improved wood stove for firewood, a fabricated charcoal stove for charcoal, and a scanfrost double burner gas cooker for cooking gas (butane) were used, as shown in Plate 9.



Plate 8: Compressed Natural Gas (CNG) Cylinder with Pressure Gauge

The experiment measured the time taken for each heating source to boil an equal volume of water under similar

conditions. 1000 cm<sup>3</sup> of water was first placed in a stainless-steel pot on a compressed biogas stove fabricated by SERC. The initial water temperature and the ambient temperature were recorded. Heating water started after igniting the stove. A digital thermometer was used to check the temperature of the water in the pot, and a stopwatch was used to monitor the time of heating every 3 minutes. The change in temperature of the water was observed until the boiling point was reached, when the stove was turned off. The same procedure was repeated for the remaining fuels, and their heating values were evaluated as indicated in Tables 2.10 (a-f). However, charcoal and firewood were determined to be lit when enough charcoal and firewood were burning, such that the fire would not die out with the addition of a pot set on it to heat (Yusuf *et al.*, 2020).

## 2.5 Rice Cooking Test

The efficacy of the purified and compressed biogas was further tested by comparing the time required to cook food with different heating fuels. In this study, 1kg of rice was cooked under the same condition by the five different heat sources (Castellanos-Sánchez *et al.*, 2024). The rice was washed as is done locally, then placed into a pot, which was placed on the already-ignited compressed biogas burner and allowed to cook until it was confirmed cooked. Cooking time was measured with a stopwatch, and the burner was turned off at the end of the test. The experiment was repeated for the remaining five heating sources, namely raw biogas, kerosene, firewood, charcoal, and cooking gas. Time of cooking was observed (Rimantho *et al.*, 2025).



A: 30 X 30cm Compressed /Raw Biogas Stove



B: 84 X 42cm Improve wood Stove



C: 23 x 23cm Charcoal Stove



D: 55 X 30cm Kerosene Stove



E: 60 X 60cm Gas Cooker

**Plate 9: Different Heating Stoves**

## RESULTS AND DISCUSSION

### 3.1. Scrubbing CO<sub>2</sub> using CaO

The use of biogas as a viable alternative energy source is predominantly dependent on its methane concentration. Consequently, biogas scrubbing is imperative to enhance the energy yield per unit volume of compressed biogas and to mitigate the corrosive effects of hydrogen sulfide (H<sub>2</sub>S). This can be accomplished by compressing the gas into cylinders, a process that necessitates the prior removal of carbon dioxide (CO<sub>2</sub>), hydrogen sulfide (H<sub>2</sub>S), and water vapour (Bagudo *et al.*, 2011). The presence of carbon dioxide diminishes the calorific value of biogas, and its

removal not only increases the heating value but also reduces greenhouse gas emissions (Francisco López *et al.*, 2024). Scrubbing CO<sub>2</sub> was performed using 100 g/L CaO. The results of our findings are in conformity with Vinayak and Katti (2015), Shah *et al.* (2016), and Ray *et al.* (2016). It indicated that CO<sub>2</sub> was reduced to the minimum level as observed during the water boiling test.

### 3.2. Scrubbing Hydrogen Sulphide using Iron Fillings

Lead acetate paper was used to detect H<sub>2</sub>S before and after scrubbing. Before scrubbing, raw biogas was passed over the surface of the lead acetate paper, which changed

colour from white to black. Similarly, after scrubbing, the gas was passed onto the surface of the lead acetate paper, but the colour remained unchanged. This observation remained unchanged throughout the compression period. It was observed that iron fillings have scrubbed H<sub>2</sub>S from the biogas, which agrees with the method and results obtained by Vinayak and Katti (2015) and Ray et al. (2016).

### 3.3. Scrubbing Water Vapour using Silica Gel Crystals

Water vapour was the last impurity to be scrubbed from the biogas, and silica gel was used. The container of the silica gel was transparent, so it was physically observed as it absorbed moisture; the colour of the silica gel changed from pink to blue. Replacement of the gel crystals was performed according to Nallamotheu et al. (2013), Vinayak and Katti (2015), and Ray et al. (2016). Silica gel crystals should be replaced after a specific time, depending on the purification rate.

### 3.4. Variations of Height, Volume, Time, Pressure and Temperature during Compression

During compression of the scrubbed biogas, the compressor showed the ability to suck the gas (suction pressure), compress and send it to the storage tank with much pressure (discharge pressure). Using the compressor reduces the problem of weight displacement, thereby increasing the pressure and flow rate of biogas from the digester. The result also indicates a direct proportional relationship between the height of the gas collector and the volume of the gas, as shown in Figure 1 during the compression process. As the height of the gas collector reduces from 0.69m to 0.65m with frequent compression, the calculated volume of biogas contained in the collector decreases from 0.46m<sup>3</sup> to 0.43m<sup>3</sup>. The second compression time at a height of 0.65m reduces to 0.62m, corresponding to a reduction in the biogas volume in the dome from 0.43m<sup>3</sup> to 0.41m<sup>3</sup>. The downward trend continued for the remaining replications of compression.

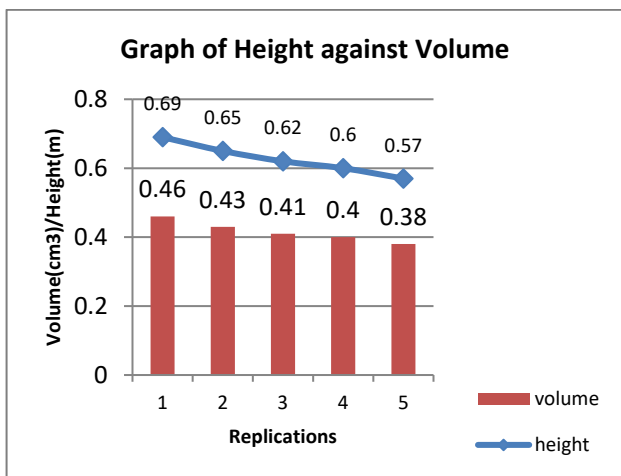


Fig. 1: Relationship between Height and Volume during Compression

Also, the relationship between the time of compression, the pressure in the cylinder, and the compressor <https://scientifica.umyu.edu.ng/>

temperature during compression was established, as shown in Figure 2. The result indicates that the time of compression increases with increasing pressure in the cylinder, while the compressor temperature began to rise at a point.

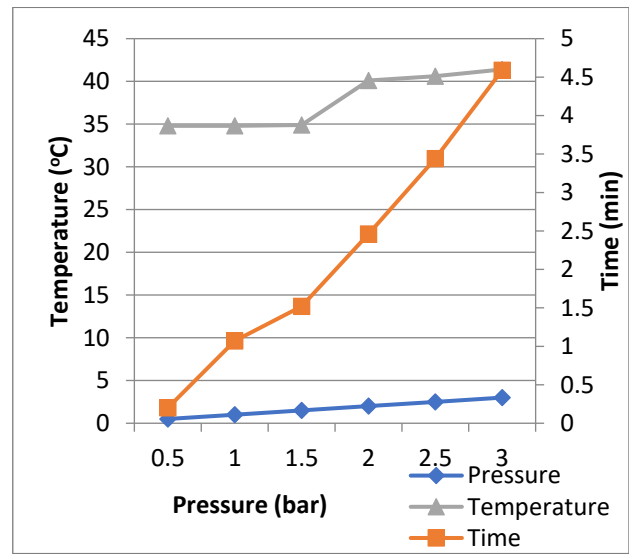


Fig 2: Variation of Time, Temperature and Pressure

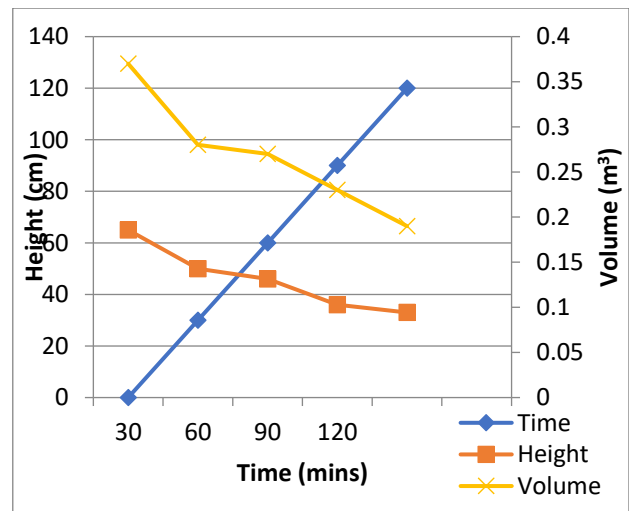


Fig. 3: Relationship between Pressure and Time

Figure 3 depicts the correlation between the height of the biogas holder and the associated calculated gas volume, revealing a decreasing trend as gas was consumed. The height of the gas holder diminished from 0.65 m to 0.33 m, while the biogas volume correspondingly decreased from 0.37 m<sup>3</sup> to 0.19 m<sup>3</sup>. This inverse correlation indicates a steady decrease in stored gas throughout the compression cycles. The initial gas volume of 0.37 m<sup>3</sup> at a holder height of 0.65 m effectively facilitated four compression cycles into a CNG cylinder, achieving an absolute pressure of 3.0 bar at 30-minute intervals. This illustrates effective gas recovery and storage capabilities, aligning with earlier research indicating that biogas volume and pressure are directly affected by gas holder displacement and methane content (Akinola et al., 2025; Abanda et al., 2025).

### 3.5. Water Boiling Test

### 3.6 Food Cooking Test

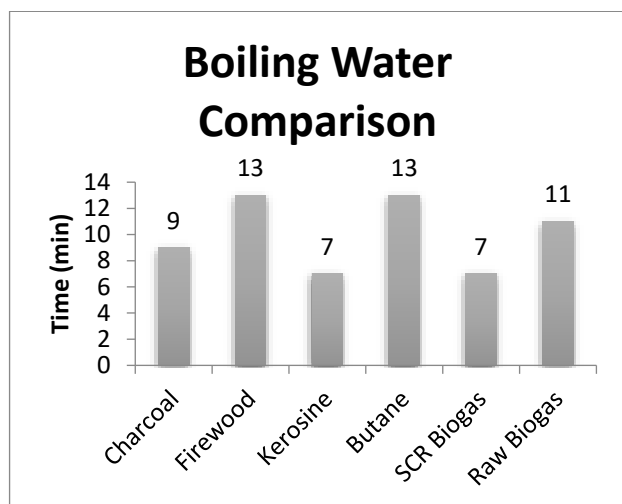


Figure 4: Comparison of water boiling test using different sources

A water-boiling test was conducted with raw and scrubbed biogas, kerosene, firewood, charcoal, and cooking gas (butane). The time to boil 1 L of water with raw biogas was 11:37 minutes, while 1 L was boiled with scrubbed and compressed biogas in 7:49 minutes. However, kerosene, firewood, charcoal, and cooking gas boiled the same quantity of water at 7 min, 11 min, 9 min, and 13 min, respectively. It indicates that the purified biogas had a shorter heating time, as its calorific value was higher than that of raw biogas. This is because only methane contributes to combustion, while the other scrubbed gas mixtures were toxic or harmful. The result also shows heating time with different heating sources. As a result, it is essential to scrub CO<sub>2</sub> and other impurities from raw biogas to raise its calorific value and enable its use in several applications.

The water boiling test demonstrated that 1 litre of water reached boiling point in 11 minutes and 37 seconds with raw biogas, while it took only 7 minutes and 49 seconds with scrubbed and compressed biogas. In comparison, kerosene boiled the water in 7 minutes, firewood in 11 minutes, charcoal in 9 minutes, and butane gas in 13 minutes. The reduced heating time of purified biogas suggests a higher calorific value, attributed to the increased methane (CH<sub>4</sub>) concentration resulting from the removal of carbon dioxide and other impurities. Methane is the sole component of biogas that contributes positively to its calorific value, whereas CO<sub>2</sub> and H<sub>2</sub>S diminish energy density and combustion efficiency (Abanda et al., 2025; Zhang et al., 2018). Akinola et al. (2025) reported similar results, noting enhanced flame temperature and reduced cooking time after purification of biogas. The 33% reduction in boiling time observed in this study corresponds with documented increases in calorific value, rising from 26 MJ/kg in raw biogas to over 34 MJ/kg post-scrubbing (Zhang et al., 2018). These findings show that upgrading biogas significantly improves its heating performance, positioning purified biogas as a feasible alternative to traditional fuels such as kerosene or LPG for both domestic and industrial applications.

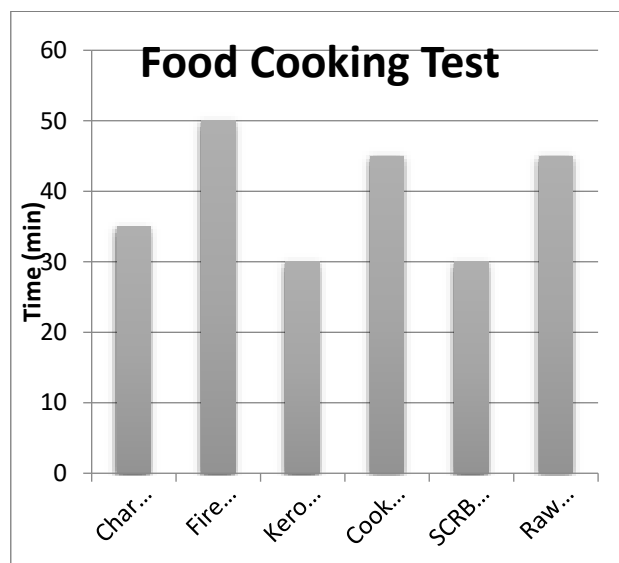


Figure 5: Food cooking test with various sources

In the current research, the results from the cooking tests clearly illustrate the impact of fuel quality (i.e., calorific value) on thermal efficiency: cooking 1 kg of rice with raw biogas took 45 minutes, while using scrubbed and compressed biogas reduced the cooking time to 30 minutes, and the same was observed with kerosene. The other heating sources, butane (cooking gas), charcoal and firewood took 45, 35 and 50 minutes respectively to cook the same quantity of rice. The enhanced performance of the scrubbed/compressed gas can be attributed to the elimination of diluent gases (such as CO<sub>2</sub>, H<sub>2</sub>S, and water vapor) and the increase in methane (CH<sub>4</sub>) concentration, which raises the heating value, as reported by Prajapati et al. (2015); Agori et al. (2023). Furthermore, Prajapati et al. (2015) noted that the typical calorific value of raw biogas ranges from approximately 21–24 MJ/m<sup>3</sup> (55–80% CH<sub>4</sub>) and that upgrading through CO<sub>2</sub> removal significantly enhances the energy density. Similarly, Agori et al. (2023) demonstrated that purified biogas could boil 500 mL of water in about 3.9 minutes, compared to roughly 7.4 minutes with raw biogas, indicating nearly double the heating effect post-scrubbing. This is consistent with the findings of this study that indicated scrubbed/compressed biogas reduced cooking time compared to raw biogas by approximately 7–12 minutes (30–48% reduction), which aligns with the increased calorific value. Moreover, the longer cooking time with kerosene suggests that even raw biogas may outperform conventional liquid fuels under specific conditions.

### CONCLUSIONS

This study documented that biogas can be compressed and made portable after removing traces of impurities, including CO<sub>2</sub>, water vapour, and H<sub>2</sub>S, before using it as fuel for several applications. The setup for scrubbing, compression, and storage was established and demonstrated. It was shown that CO<sub>2</sub> scrubbing was performed using CaO as the chemical absorber. Biogas compression was performed to an absolute pressure of 3

bars in a CNG cylinder over a total of 4.54 minutes. The use of iron fillings was found to be very effective for removing H<sub>2</sub>S, while silica gel was effective for moisture absorption. It was also found that the methane concentration in the purified biogas was higher than that in raw biogas, as determined by the water boiling test and food cooking test.

It can be concluded that high-energy biogas can be produced from locally available raw materials such as cow dung and compressed into cylinders after scrubbing for easy handling and transportation.

## REFERENCES

- Abanda, T., Takam, N. W., Edoun, M., Tientcheu, M., & Kuitche, A. (2025). Numerical modeling and performance evaluation of a new biogas purification system. *Applied Engineering*, 9(1), 45-58. [Crossref]
- Agori, J. E., Iwemah, E. R., Oba, J., & Eseha, E. A. (2023). Purification and compression of biogas: Effect on calorific value and cooking time. *Advance Journal of Science, Engineering and Technology*, 8(10).
- Akinola, A. B., Akinnagbe, A. E., Kolade, B. T., Olanrewaju, O. O., & Adeyemo, A. J. (2025). Purification of biogas using low-cost locally available materials for off-grid power applications. *Journal of Energy Research and Reviews*, 17(10), 57-73. [Crossref]
- Al Mubarak, F., Rezaee, R., & Wood, D. A. (2024). Economic, societal, and environmental impacts of available energy sources: A review. *Eng*, 5(3), 1232-1265. [Crossref]
- Bagudo, B. U., Garba, B., Dangoggo, S. M., & Hassan, L. G. (2011). The qualitative evaluation of biogas samples generated from selected organic wastes. *Scholars Research Library*, 3(5), 549-555.
- Baki, A. S. (2004). *Isolation and identification of microbes associated with biogas production at different retention time using cow dung* [MSC dissertation, Usmanu Danfodiyo University Sokoto].
- Biswas, T. D., & Kartha, A. R. S. (1977). Removal of carbon dioxide from biogas. In *Proceedings of the National Symposium on Biogas Technology and Uses*. IARI.
- Bloch, H. P., & Hoefner, J. J. (1996). *Reciprocating compressors, operation and maintenance*. Gulf Professional Publishing. [Crossref]
- Castellanos-Sánchez, J. E., Aguilar-Aguilar, F. A., Hernández-Altamirano, R., Venegas Venegas, J. A., & Raj Aryal, D. (2024). Biogas purification processes: Review and prospects. *Biofuels*, 15(2), 215-227. [Crossref]
- Cheng, J., & Liu, B. (2002). Swine wastewater treatment in anaerobic digesters with floating media. *Transactions of the ASAE*, 45(3), 799-805. [Crossref]
- Dangoggo, S. M., Zuru, A. A., & Sambo, A. S. (2000). *Mechanism of biogas production from cattle, camel and donkey dungs* [Paper presentation]. National Solar Energy Forum (NASEF2000).
- Divyang, S., & Hemant, N. (2015). Low cost biogas purification system for application of bio CNG as fuel for automobile engines. *International Journal of Innovative Science, Engineering and Technology*, 2(5). (ISSN 2348-7968)
- Elhalwagi, M. M. (Ed.). (1986). *Biogas technology, transfer and diffusion* (pp. 295-301). Elsevier Applied Science Publishers.
- Francisco López, A., Lago Rodríguez, T., Faraji Abdolmaleki, S., Galera Martínez, M., & Bello Bugallo, P. M. (2024). From biogas to biomethane: An in-depth review of upgrading technologies that enhance sustainability and reduce greenhouse gas emissions. *Applied Sciences*, 14(6), Article 2342. [Crossref]
- Georgiadis, A. G., Charisiou, N. D., & Goula, M. A. (2020). Removal of hydrogen sulfide from various industrial gases: A review of the most promising adsorbing materials. *Catalysts*, 10(5), Article 521. [Crossref]
- Godi, N. Y., Zhengwuvi, L. B., Abdulkadir, S., & Kamtu, P. (2013). Effect of cow dung variety on biogas production. *Journal of Mechanical Engineering Research*, 5(1), 1-4. [Crossref]
- Habib, M. A. (1996). A text on energy forecast [Review]. *International Journal of Renewable Energy*, 3(1), 130-131.
- Huang, W. (2024). Resource utilization of agricultural waste: From biomass energy to organic fertilizer. *Journal of Energy Bioscience*, 15. [Crossref]
- Kabeyi, M. J. B., Olanrewaju, O. A., & Akpan, J. (2024). Biogas production and process control improvements. In *From biomass to biobased products*. IntechOpen. [Crossref]
- Kaparaju, P., Serrano, M., Thomsen, A. B., Kongjan, P., & Angelidaki, I. (2009). Bioethanol, biohydrogen and biogas production from wheat straw in a biorefinery concept. *Bioresource Technology*, 100(9), 2562-2568. [Crossref]
- Kapdi, S. S., Vijay, V. K., Rajesh, S. K., & Rajendra, P. (2007). *Biogas scrubbing, compression and storage: Perspective and prospectus in Indian context*. Centre for Rural Development and Technology, Indian Institute of Technology.
- Kasisira, L. L., & Muyiyya, N. D. (2009). Assessment of the effect of mixing pig and cow dung on biogas yield. *Agricultural Engineering International: The CIGR Ejournal*, XI(Manuscript PM 1329).
- Khurmi, R. S., & Gupta, J. K. (2006). *A text book of refrigeration and air conditioning* (1st ed., pp. 320-403). Eurasia Publishing House.
- Kizilkaya, A. C., Rothenberg, G., & Gitis, V. (2024). The future of fossil fuels. In *Handbook of energy, environment, and the circular economy* (pp. 1-98). World Scientific. [Crossref]
- Kumar, R., Singh, B., Kakkar, R., Mittal, A., & Pani, B. (2025). Rhodamine-based turn-on fluorescent and colorimetric chemosensor for selective Pb<sup>2+</sup> detection: Insights from crystal structure, molecular docking, real sample analysis, and logic gate applications. *Analytical Methods*, 17(23), 4812-4830. [Crossref]

- Li, R., Chen, S., & Li, X. (2009). Anaerobic co-digestion of kitchen waste and cattle manure for biogas production. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 31(20), 1848-1856. [\[Crossref\]](#)
- Nallamothe, R. B., Teferra, A., & Appa Rao, B. V. (2013). Biogas purification, compression and bottling. *Global Institute for Research and Education*, 2(6), 34-38. (ISSN 2319-7293)
- Onyeaka, H., Hart, A., & Obileke, K. (2025). Enhancing carbon neutrality: The role of biomass in CO<sub>2</sub> uptake. In *Advances in sustainable applications of microalgae* (pp. 73-93). Elsevier. [\[Crossref\]](#)
- Ozor, O. C., Agah, M. V., Ogbu, K. I., Nnachi, A. U., Udu-ibiam, O. E., & Agwu, M. M. (2014). Biogas production using cow dung from Abakaliki abattoir in south-eastern Nigeria. *International Journal of Scientific & Technology Research*, 3(10). (ISSN 2277-8616)
- Prajapati, D. D., Mevada, D. D., & Patel, A. (2015). A review on upgrading calorific value of biogas from the digester. *Technix International Journal for Engineering Research*, 1(7), 109-115.
- Ransirini, A. M., Elżbieta, M. S., Joanna, G., Bartosz, K., Wojciech, T., Agnieszka, B., & Magdalena, U. (2024). Fertilizing drug resistance: Dissemination of antibiotic resistance genes in soil and plant bacteria under bovine and swine slurry fertilization. *Science of the Total Environment*, 946, Article 174476. [\[Crossref\]](#)
- Ray, N. H. S., Mohanty, M. K., & Mohanty, R. C. (2016). Biogas compression and storage system for cooking applications in rural households. *International Journal of Renewable Energy Research*, 6(2). (ISSN 2348-7968)
- Rimantho, D., Pratomo, V. A., Pane, E. A., & Noywuli, N. (2025). Quality function deployment method for cooking stove design using *Hermetia illucens* oil. *Mathematical Modelling of Engineering Problems*, 12(1). [\[Crossref\]](#)
- Shah, D. R., Nagarsheth, H. J., & Acharya, P. (2016). Purification of biogas using chemical scrubbing and application of purified biogas as fuel for automotive engines. *Research Journal of Recent Sciences*, 5, 1-7. (ISSN 2277-2502)
- Shindell, D., & Smith, C. J. (2019). Climate and air-quality benefits of a realistic phase-out of fossil fuels. *Nature*, 573(7774), 408-411. [\[Crossref\]](#)
- Sibanda, T. N. (2021). *Design of an anaerobic digester for electricity generation using a small reciprocating engine* [Doctoral dissertation, Stellenbosch University].
- Speece, R. E., & McCarthy, P. L. (1964). Nutrient requirements and biological solid accumulation in anaerobic digestion. In *International Conference on Water Pollution Research*. Pergamon Press. [\[Crossref\]](#)
- Stocker, T. F., Qin, D., Plattner, G.-K., Alexander, L. V., Allen, S. K., Bindoff, N. L., Bréon, F.-M., Church, J. A., Cubasch, U., Emori, S., Forster, P., Friedlingstein, P., Gillett, N., Gregory, J. M., Hartmann, D. L., Jansen, E., Kirtman, B., Knutti, R., Krishna Kumar, K., ... Xie, S.-P. (2013). Technical summary. In T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (Eds.), *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
- Talia, L. (2018). Biogas plants: Design and fabrication. In *Biogas: Fundamentals, process, and operation* (pp. 51-93). Springer. [\[Crossref\]](#)
- Vinayak, R. G., & Katti, P. K. (2015). Biogas compression and bottling: A solution to energy crises. *International Journal of Computer Applications*, (National Conference on Role of Engineers in Nation Building (NCRENB-15)), 28-31. (ISSN 0975-8887)
- Yolanda, A., Criado, M. A., & Carlos, J. A. (2011). Kinetics of the CaO/Ca(OH)<sub>2</sub> hydration/dehydration reaction for thermochemical energy storage applications. Instituto Nacional del Carbón, CSIC-INCAR.
- Yusuf, S. S., Ismail, M., & Abdullahi, J. (2020). Comparative study on the rate of flammability of biogas and firewood. *American Journal of Energy Engineering*, 8(3), 26-33. [\[Crossref\]](#)
- Zhang, X. (2018). Implementation of packed column for biogas upgrading. In *Proceedings of IMEETMCON 2018* (pp. 55-60).
- Zhao, Q., Leonhardt, E., MacConnell, C., Frear, C., & Chen, S. (2010). Purification technologies for biogas generated by anaerobic digestion. *Journal of Bioscience and Bioengineering*, 101, 309-314.
- Zuru, A. A., Dangoggo, S. M., Birnin-Yauri, U. A., & Tambuwal, A. D. (2004). Adoption of thermogravimetric kinetic models for kinetic analysis of biogas production. *Renewable Energy*, 29(1), 97-106. [\[Crossref\]](#)
- Zuru, A. A., Saidu, H., Odum, E. A., & Onuorah, O. A. (1998). A comparative study of biogas production from horse, goat and sheep dungs. *Nigerian Journal of Renewable Energy*, 6(1 & 2), 43-47.