INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 17, No. 6, p. 218-226, 2020

RESEARCH PAPER OPEN ACCESS

Experimental Investigation on the Developed Portable Biogas System utilizing Agricultural Biomass Wastes for Thermal Applications

Antonio-Abdu Sami M. Magomnang*, **Dianne Mae M. Asiñero**

Mechanical Engineering Department, University of Science and Technology of Southern Philippines - CDO Campus, CM Recto Avenue, Lapasan, Cagayan de Oro City, 9000, Philippines

Key words: *Anaerobic Digestion, Portable Biogas System, Thermal Applications.*

http://dx.doi.org/10.12692/ijb/17.6.218-226 Article published on December 12, 2020

Abstract

Woody biomass such as forest residues and fast-growing trees are used as a source of fuel for cooking and heating that contributes to deforestation and forest degradation. Not knowing, that this biomass can also be utilized as a source of energy when the organic material such as animal manure, agricultural biomass wastes decomposes under anaerobic conditions. This study aims to evaluate the performance of the developed portable biogas system using agricultural biomass wastes as a source of fuel for thermal applications. The developed system was modified to become portable making it ideal for transport in remote areas where fuel is not easily accessible. Then it is tested and deployed to rural and remote areas by conducting thermal experiments. The results show that the developed system is capable to produce and supply gaseous fuel for thermal regardless of the gas volume and time duration. Thus, the study could help to replace traditional wood-based cooking with a renewable energy system utilizing agricultural biomass wastes as a source of fuel that can be used in rural and remote areas.

* **Corresponding Author:** Abdu Sami M. Magomnang ✉ a_magomnang@yahoo.com

Introduction

In Mindanao Philippines, wood-based biomass is used for cooking and heating that contributes to deforestation and forest degradation, particularly in urban and rural areas, outskirts of refugee camps, and rural areas with high population densities (Jagger *et al.*, 2017). This issue contributes to the problem of global warming because trees which are a source of wood energy absorbs carbon dioxide from the atmosphere. Furthermore, fuelwood tends to be the dominant fuel for remote areas and some urban household energy use, particularly cooking. Residential solid fuels (e.g., wood, biomass coal) were burned for cooking and heating activities in developing countries, of which the smoke emissions are a leading human health risk factor (Jetter and Kariher, 2009). Wood is widely used as a source of fuel especially in remote areas where fossil fuels and other kinds of fuels are less accessible. With this, trees have been cut to produce wood fuel.

Since the utilization of wood coal is not feasible, this leads to the use of renewable energy such as biogas that has been considered as one of the alternative energy sources. Biogas is renewable energy that comes from agricultural biomass waste that we can use as a substitute such as animal manure to be used as fuel for cooking. Renewable energy is very essential and, in the future, sustainable sources of energy such as thermal, wind, coal, biogas, solar and other forms of energy. However, there is still a need to optimize and further development to these technologies for sustainability and availability depending on the area, and the community's needs.

Biogas production is one of the widely used conversion process for most wastewater treatment plants and including animal manure. A biogas digester is an airtight enclosed container designed to enhance the anaerobic digestion of biodegradable waste such as animal manure, domestic wastes, black water, or sludge and the collection of the produced biogas. A biogas digester is used to produce methane gas and biogas produced naturally when organic material such as animal manure, the agricultural waste decomposes under the anaerobic process. The size of the digester must be small size, which can be installed and moved at any place in every house with the help of minimum resources. People who live in poor conditions want to have a biogas digester at home for replacing the cooking gas as the ever-increasing price of cooking gas is adding to their problem.

Furthermore, researches from the Philippine Department of Agriculture - Western Mindanao Integrated Agricultural Research Centre led by Andrew M. Balili (Capareda, 2011) evaluated three (3) types of biogas digester to determine the design suited to the villages. It has been observed that the highest production of gas was made by the commercial type digester. Findings show that bio-gasification or the microbial conversion of organic matter in anaerobic conditions offers a systematic approach to manure treatment that does not only stabilizes the waste but also produces a significant amount of energy in the form of biogas.

With this, the researchers come up with the idea of portable biogas that could replace traditional wood-based cooking and heating, also it can be useful if utilized in rural and remote areas. Moreover, the use of biogas for cooking can help the environment.

The biogas system is a connection of anaerobic digester that is a portable biogas system that can be installed and easily moved at any place in every house with the help of minimum resources. The anaerobic digester servers to produce biogas such as fuel for cooking purposes. It is important to remove the impurities for health safety.

Likewise, the developed portable biogas system helps to supply the needs of the community through other renewable energy sources. It also involves the development and analysis of the portability of the digester to make it more efficient to produce methane gas. It mainly concentrates on the economic to weight ratio aspect and will also concern about the structure strength, durability, ergonomic factor, convenience, and flexibility of usage in different weatherconditions.

Methodology

This study addressed the development of the portable energy source and evaluates the performance of the constructed biogas unit. The study includes the design of the digester, carriage, agitator using Solidworks Education Edition Version 2018-2019. After the system is constructed and assembled it will undergo leak testing and then the pilot experiments.

Digester Design

A Batch mixture of 1:1½ weight to volume ratio of cow manure and water in a 40 liters plastic drum is designed in which almost a quarter of the volume is occupied by the substrate mixture. Furthermore, the design of the digester tank is intended for mono and co-anaerobic digestion for biogas production and biogas upgradings (purification) systems such as hydrogen sulfide and carbon dioxide as shown in Fig. 1.

The design is intended to exceed the internal pressure of the digester, enough to avoid the pressurized explosion. The carriage design is intended to include the biogas upgrading system, digester, and less weight are consider for its stability when it transfers from one place to another with consideration of the overall weight using the Ultra High Molecular Weight Polyethylene (UHMWPE) plastic as raw material.

Design of the portable biogas system components

A 24×12 inches polyethylene container, made from a 40-liter plastic drum was used as a digester as shown in Fig. 2 and Fig. 3. Wherein six (6) holes were drilled intended for the manure inlet, gas outlet, fertilizer outlet, for manure level, thermometer, and stirrer. For the manure inlet, a 3-inch diameter hole was drilled in the side of the digester. Then, a thirty (30) degrees elbow pipe is used to connect the two sizes of 1.5 and 3 inches PVC pipes was inserted in the hole of the container for the inlet purpose. A 1-inch diameter hole is for the 1 inch outside diameter PVC pipe was drilled at the top of the plastic container. Then, a 1-inch diameter was inserted in the PVC pipe down to a 10 inches distance. For the gas outlet, a 1-inch diameter PVC pipe is used with the 90° elbow, connect with it is the ball valve which serves to control the flow of gas. A manometer, as well as the tube going to the H_2S removal, were also connected with it. For the fertilizer outlet, a 2-in diameter hole was drilled at the side bottom of the plastic container.

A 2-in outside diameter cleanout pipe was inserted into it, where a cleanout pipe is used to trap the waste fertilizer. A Teflon tape and sealant epoxy must then have applied to the possible connection, like fittings so that the connection is more durable and avoid further leaking. Lastly, a 1 cm diameter hole was made at the middle side of the drum intended for a 1 cm diameter clear hose use to show the level of the manure inside the digester. Also, a 35 by 14 inches Carriage Base was used in a portable biogas system (Fig. 4) that must be lightweight but can stand the weight of the system components. The material used was a two-length 1×1×1/8" Aluminum steel angle bar and 1×1×1/4" Tubular aluminum steel.

The caster wheel is added to the design of the frame for it to be more convenient during transportation. It lessens the force needed in transporting the system. Anaerobic digestion is the process of breaking down the chemicals of the manure to produce the biogas. An agitator is a great help in the process for faster digestion of the manure and uniform digestion of the slurry inside the digester.

The designed agitator was a hand agitator type (Capareda, 2014). For the design of 1-in, the diameter round bar was used and connected with 1-in PVC blue pipe in the top that used to be the handle.

Testing and Commissioning on the Developed Set-up

To determine the functionality of the designed digester, bubble testing was used as a leak test method. This method consists of pressurizing the components, put a dissolve detergent in a basin of water then apply force by blowing the gas outlet. A leak in the component will produce a bubbling stream, which can be less or more intense depending on the size of the leak itself. The size of the bubble produce is depending on the leak that is present. Also, in the CO_2 and H_2S container, submerge leak testing was used to determine the leak. Also, the flame test will be conducted in this set-up, to know what kind of flame the system produces. In connection, it can help the researchers to determine its heating value because the bluer the flame it produces the higher the possibility of heat can be gathered. Lastly. Burner test limits only on three different experiments (boiling of water, and cooking rice), also to get the heating value that the biogas production.

Results and discussion

This study discusses and presents the designed portable gaseous fuel production system as well as the result of the data gathered during the testing and experimentation.

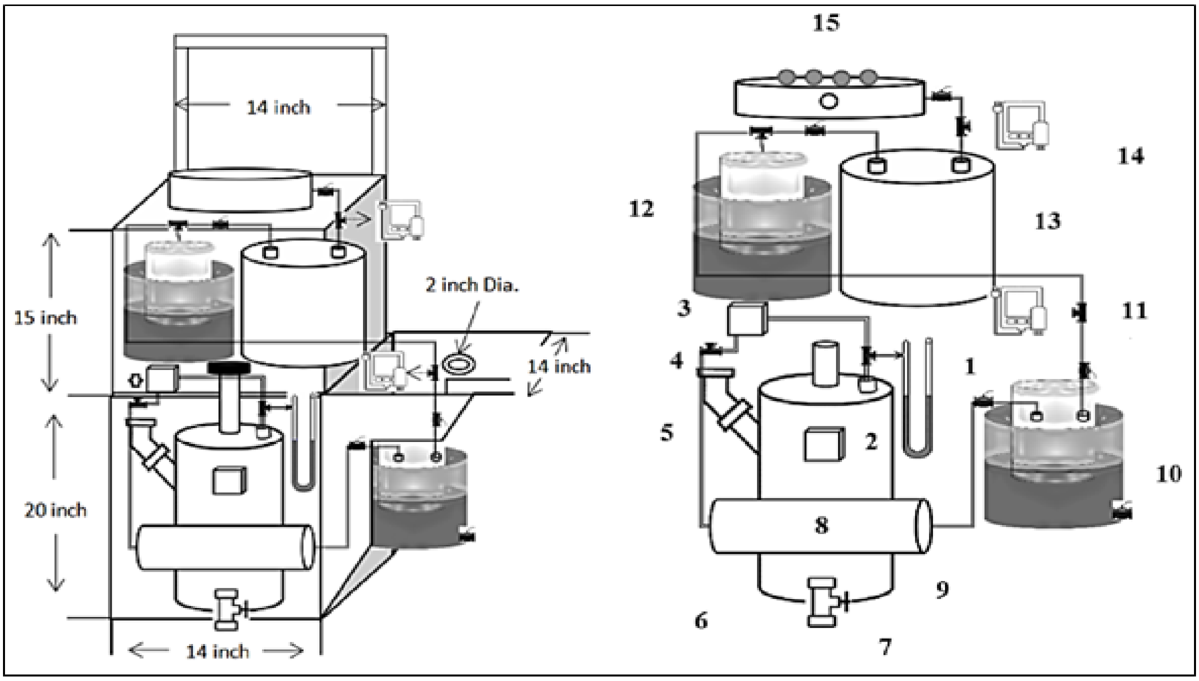

Fig. 1. Designed Portable Gaseous Fuel Production System.

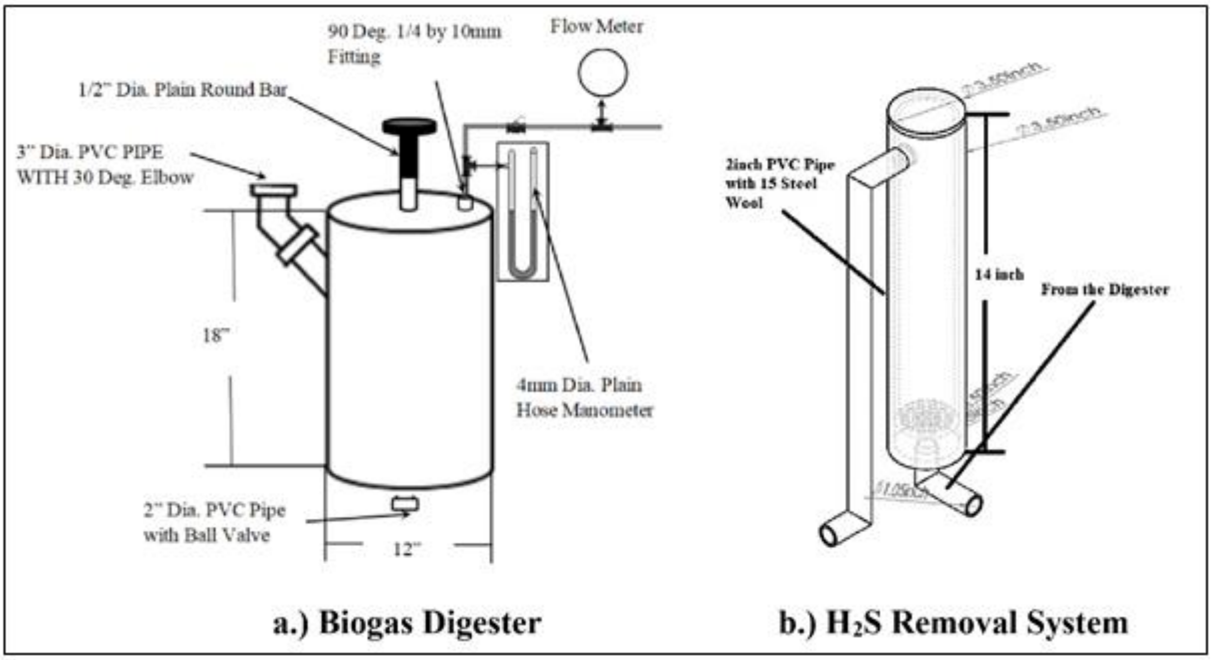

Fig. 2. Portable Gaseous Fuel Production System Components (Digester and H_2S Removal System).

Evaluation of the developed biogas system

The selection of digester material was important since it needs to hold the internal pressure of the digester to avoid the pressurized explosion. With this, an Ultra High Molecular Weight Polyethylene (UHMWPE) plastic was used for digester and gas holder along with its fabricated steel containers. Also, a plastic pneumatic hose was used to connect the digester to the gas holder and as well as to the biogas upgrading system as it ensures durability and safety. Likewise, it can withstand the pressure inside the digester.

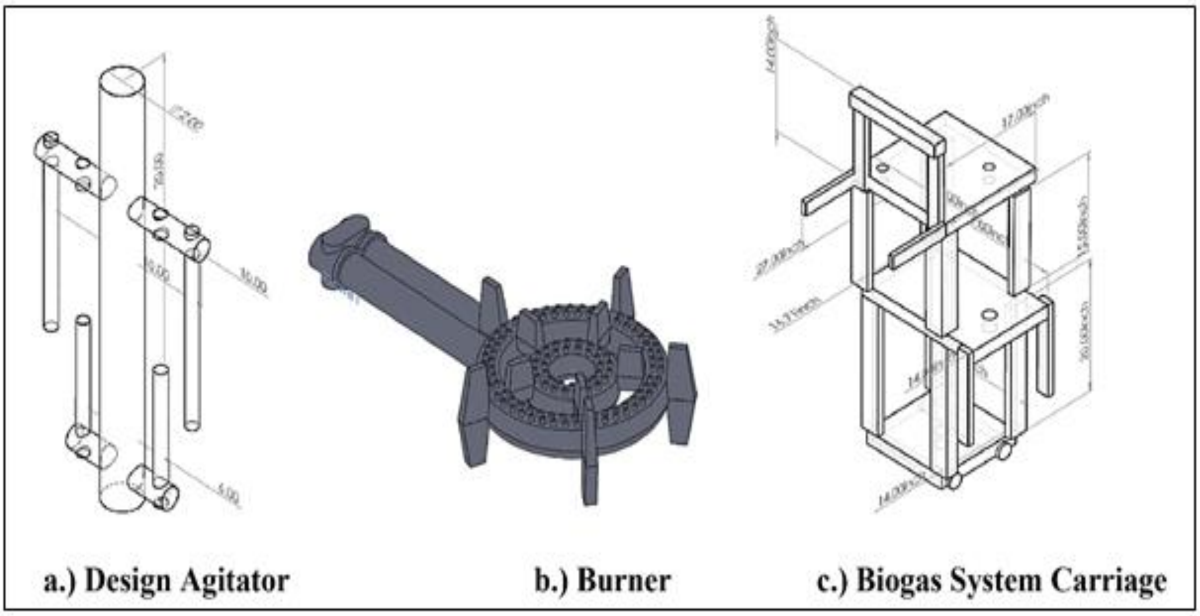

Fig. 3. Portable Gaseous Fuel Production System Components (Agitator, Burner, and Carriage).

Fig. 4. Actual Set-up of the Portable Biogas System.

The developed system was portable and easy to transfer and uses less weight material like aluminum steel. Lastly, the developed carriage system can withstand the overall weight of the biogas system by using angle steel bars.Fig. 5 shows that the temperature throughout the hydraulic retention time of ambient and slurry temperature of the cow manure was in the mesophilic temperature range (20°C–40 °C) (Philippines National Standards, 2001). With a maximum slurry temperature of 33°C.

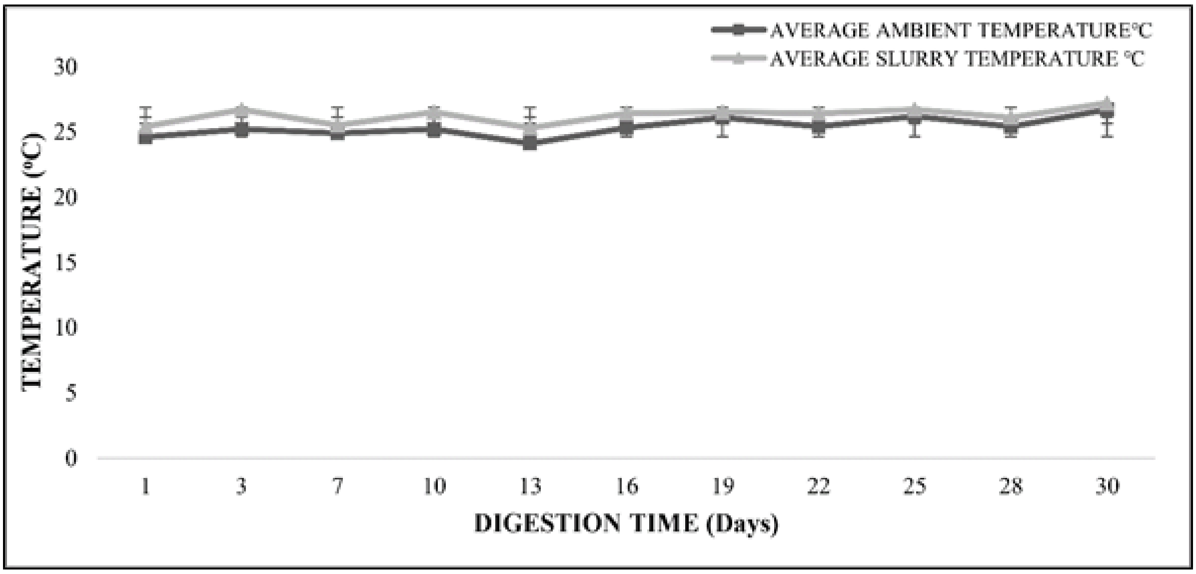

Fig. 5. Average Temperature inside the Biogas Digester.

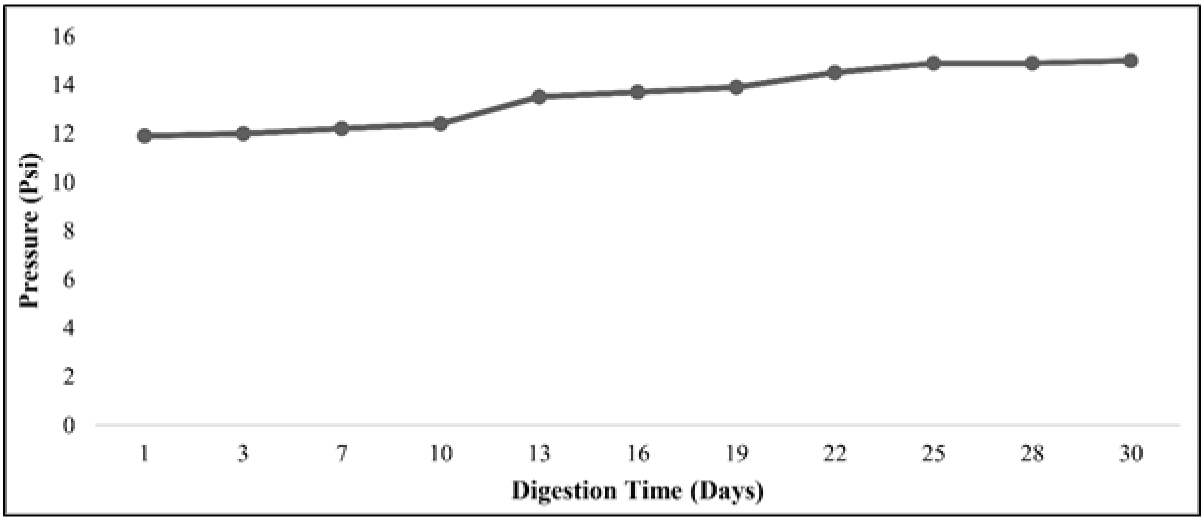

Fig. 6. Average Digester Pressure.

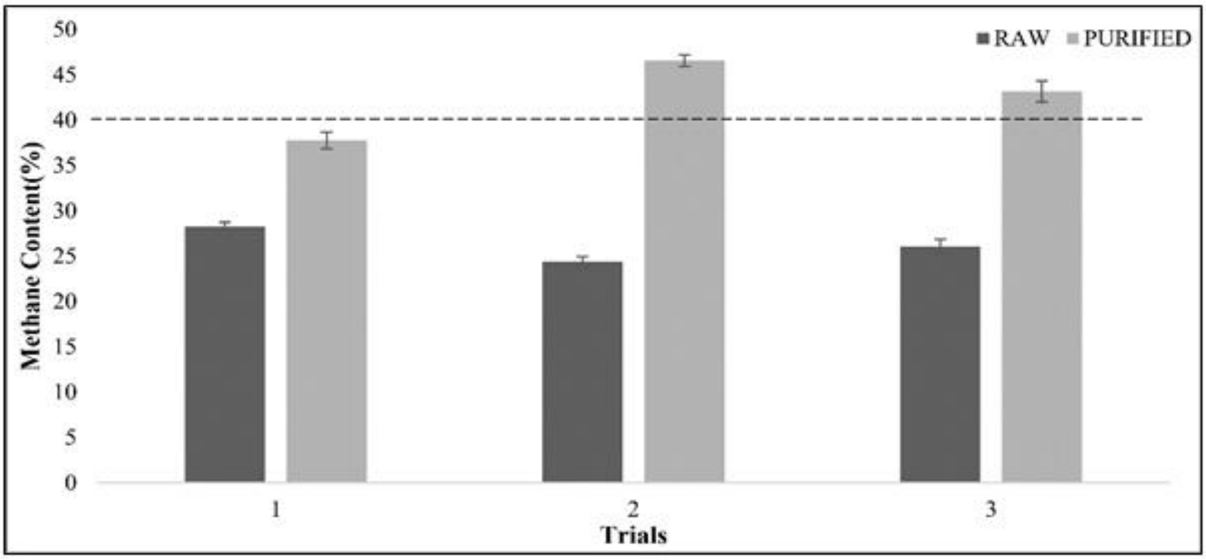

Fig. 7. Gas Analyzer Reading of Raw and Purified biogas in every test.

Further, Fig. 6 shows a consistent pressure of approximately way above the atmospheric pressure of 14.7 psi. It was almost the same for the entire experiment since the water inside the manometer has a minimal rise in height. Thus, the pressure inside was not accumulated because of the developed gas port which leads to the release of excess pressure inside the digester. Likewise, Fig. 7 shows the percent methane content of raw and purified biogas of 3 trials.

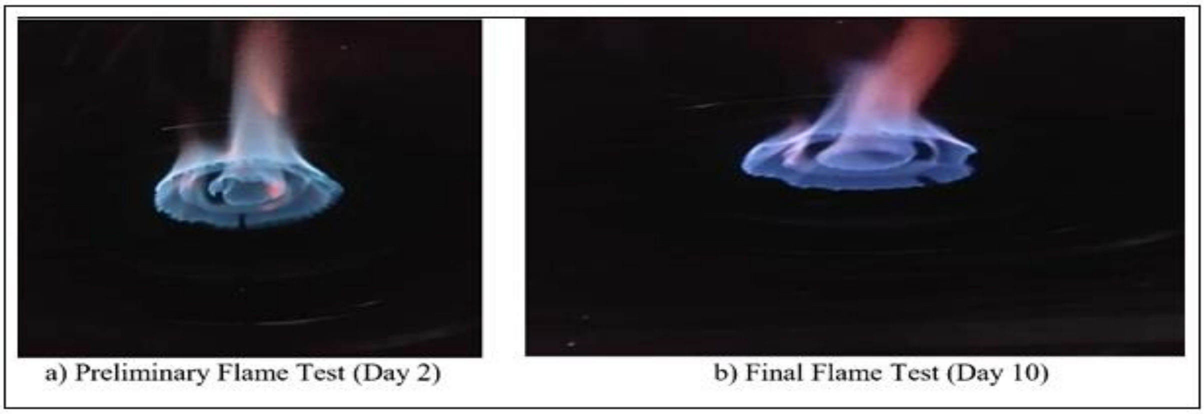

Fig. 8. Biogas Flame Test.

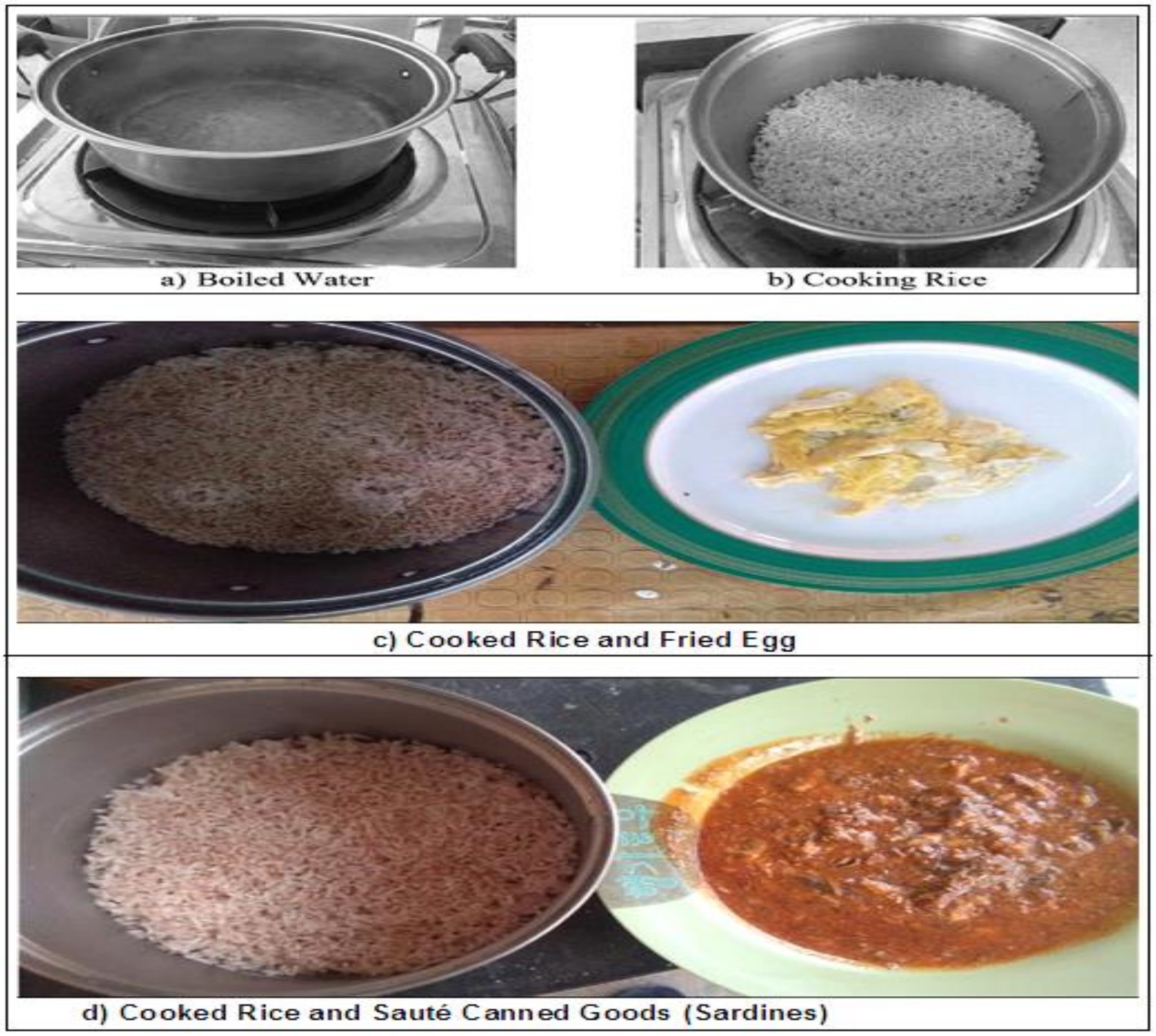

Fig. 9. Cooking Test Experiments.

The data indicate that the methane content of the scrubbed/ purified biogas was increasing from 23.7% to 47.3% due to the reduction of Carbon dioxide and Hydrogen Sulphide. This result identifies with the values obtained by Olugasa *et al.* (2018) for upgrading biogas which is 58-82% CH_4 and 31-14% CO_2.

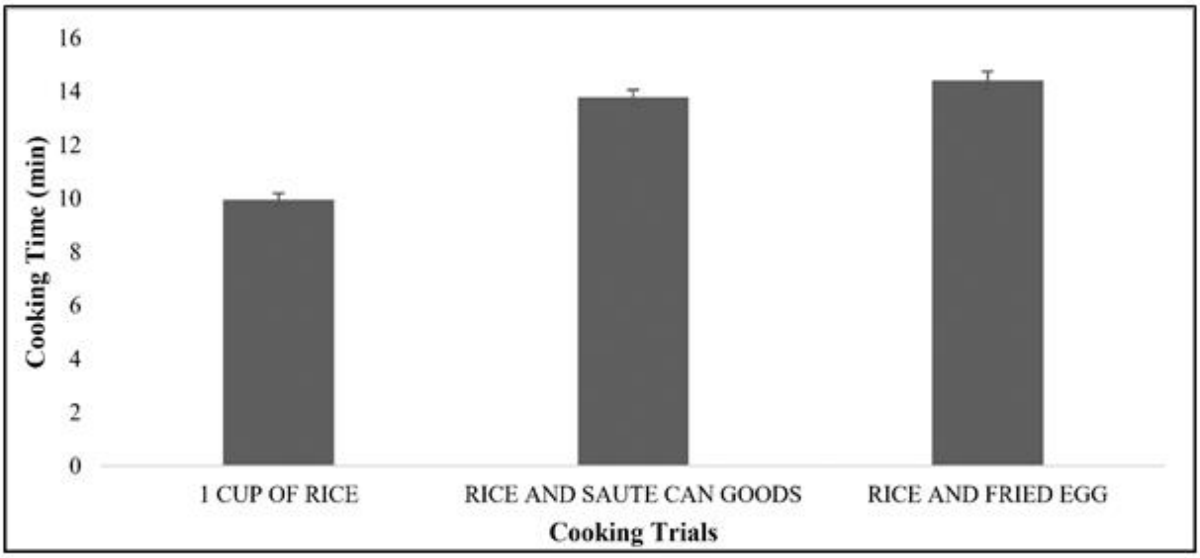

Fig. 10. Cooking time in three (3) Cooking trials.

Evaluating the Cooking Capability on the developed portable gaseous fuel system unit

Before the cooking test, gas samples were analyzed using the gas analyzer. The results of all the biogas samples were found at 47.3% (Rathod *et al.,* 2018). After this, a flame test was conducted to determine the feasibility of the developed portable biogas system to boil water and cook rice. The test shows in Fig. 8 that the developed design has a dark blue flame, which has a similar flame if using liquefied petroleum gas (LPG's).

Furthermore, the system was tested for its functionality to boil water under 12-18 mins time duration. In cooking rice, this was conducted using a cup of rice and it takes 8-9mins to boil and 4-5mins cooking time with the cooked rice as shown in Fig. 9 and Fig. 10. Also, it was noticed that there was no scent of the substrate (cow manure) was observed even after cooking.

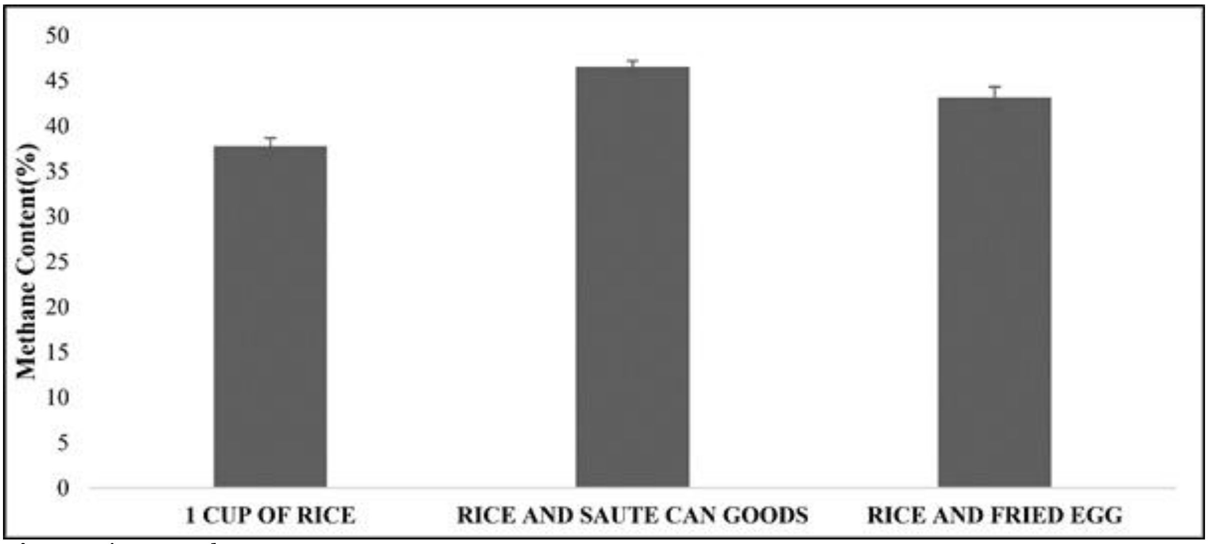

Fig. 11. Biogas Methane content.

Fig. 11 shows the Methane content (%) of the portable biogas in 3 trials. The results show that the methane content (%) of biogas can affect the cooking time of the rice and the viand. Therefore, the portable biogas system can be cooked at a time of 8-15mins in a complete meal of a person.

Conclusions

It has concluded that the designed portable biogas system met the following design purposes, which are lightweight, portable, and convenient. Given 37.5kg of slurry (1:1.5 ratio mixture) the digester was able to produce 14 Liters of gas in 4 days, sufficient enough to cook 1 cup of rice in approximately 9 min. and viand in around 5 min. Also, the constructed portable biogas system has produced a total of 95-100 Liters of gas during a period of 30-day retention time. Some sets of meals comprise of rice and viand can use up to 15 liters of gas. The portable biogas system can cook a maximum of 6 complete sets of meals during digestion time.

References

Jagger P, Pedit J, Bittner A, Hamrick L, Phwandapwhanda T, Jumbe C. 2017. Fuel efficiency and air pollutant concentrations of wood-burning improved cookstoves in Malawi: implications for scaling-up cookstove programs. Energy for Sustainable Development **41,** 112-120. https://doi.org/10.1016/j.esd.2017.08.007

Jetter JJ, Kariher P. 2009. Solid-fuel household cookstoves: characterization of performance and emissions. Biomass and Bioenergy **33(2),** 294-305. https://doi.org/10.1016/j.biombioe.2008.05.014

Capareda SC. 2011. Biomass energy conversion. Sustainable growth and applications in renewable energy sources **(1),** 19.

Capareda SC. 2014. Introduction to Biomass Energy Conversions, CRC Press.

Philippine National Standards. 2001. Build a Biogas Plant - Home. Retrieved March 29, 2020, from https://www.build-a-biogasplant.com/PDF/pns.413.2003.pdf

Olugasa TT, Odesola IF, Oyewola MO. 2018. Biogas Purification and Compression for use in Spark Ignition Engines. In International Conference of Mechanical Engineering (Vol. 2018).

Rathod VP, Bhale PV, Mehta RS, Harmani K, Bilimoria S, Mahida A, Champaneri H. 2018. Biogas Production from Water Hyacinth in the Batch type Anaerobic Digester. Materials Today: Proceedings **5(11),** 23346-23350. https://doi.org/10.1016/j.matpr.2018.11.072