



Biogas Generation from Rice Cooking Wastewater

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Abstract

Rice is the staple of all families of South Asia and South East Asia. The process of cooking rice involves boiling the rice in water which leaves a byproduct of decanted liquid. The research showed that the wastewater generated from cooked rice could be used to generate biogas with a biogas generation potential of 190 ± 46 mL/g BOD₅ (5.38 ± 0.75 L of biogas/per L of Maar) with the methane content of 78 %. First order reaction defines the kinetics of biogas production with the intent of fitting between modelled and observed data (r^2) of 0.961. The first order kinetics constant “k” was determined to be 0.2 d^{-1} . Further a family of four produces 1.0 L of starch rich wastewater per day that has the potential to produce 5.38 L of biogas with 78 % methane content. Further a household reactor was built out of recycled plastic chemical drum seeded with cow dung fed with waste rice cooking wastewater handling the wastewater decanted from the daily rice cooking for a family of five. The biogas generated was used as demonstration to fire a biogas household burner. The experimental program shows the potential for the use of starch rich wastewater in an urban setting to augment the energy needs for cooking.

Keywords: Biogas generation potential, Cooked rice decant wastewater, Kinetics

1 Introduction

Bangladesh is a country whose economy is natural gas driven. Natural gas is used for electricity generation, fertilizer production, process heating, electricity generation, and household cooking. About 70% of Bangladesh's energy demand is met through natural gas but in recent times, the demand of natural gas has been exceeding the supply (1). The government has started to put in place measures that limit supply. Natural gas supply has been limited for domestic use placing an undue burden to the urban population. However, amidst all the crisis, we may have found a simple potential solution from a very unlikely source in the form of wastewater generated from rice cooking that serves as the substrate for biological methane generation. Rice is a staple food in Bangladeshi households. People rely on it as the chief source of their dietary needs at least twice per day. The process of preparing rice involves boiling it in water and this process gives off a white starchy liquid which is referred to as “Bhaather Maar”, and in this study this rice rich wastewater was used to conduct a Biological Methane Potential (BMP) study (2) to ascertain how much biogas can be produced from waste water generated from rice cooking. In a controlled experimental program wastewater generated from cooking rice was characterized, using methane generating reactors at the bench scale a BMP study was conducted to ascertain the quantity and quality of the biogas generated from Maar. The study was further expanded to actual application where a waste acetone empty plastic drum was converted to a biogas generator and installed in a urban house as a field trial. The generated biogas was used to fire a household level cooking burner to demonstrate the practical efficacy of using waste cooked rice water to produce biogas for domestic use.

The overall intention of the experimental program was to introduce domestic rice wastewater in the energy diversification to stride for sustainable development of South Asian and East Asian countries future and to identify a source which is readily available can produce a positive sustainable solution at the household level.

2 Materials and Methods

Raw wastewater: The rice cooking wastewater was obtained from actual wastewater generated from cooking rice in a typical household of urban Bangladesh, in average 1.0 L of rice wastewater is generated per day from a family of 4 persons. A seven-day composite sample was used to characterize the wastewater used in the study.

Seed: The BMP study seed was seven-day old cow dung and for the pilot reactor the seed source was fresh cow dung.

Analysis: The rice cooking wastewater was analyzed for COD, BOD₅, TS, and pH as per standard methods (4). The biogas generated was measured using the piston displacement method where the piston in the syringe reactor moves up with daily biogas production the displacement volume is noted by reading off the graduation lines existing in the syringes used as the BMP reactors (3).

BMP Reactor Configuration: The bench scale BMP reactor were 150 ml plastic disposable syringes with a liquid volume of 20 ml (Figure 1). The BMP syringe reactors were operated as batch reactor with an incubation period of 34 days. In the BMP study the rice wastewater was fed directly to the reactor at the initiation of the study. The food to microorganism ratio (F/M) for the BMP study was 0.02. The daily biogas production was

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monitored and noted and at the end of the study the biogas quality was measured in terms of methane and carbon dioxide percentage. The data generated was plotted and modelled using Spreadsheet in accordance to established protocols modelling anaerobic transformation substrates (4, 5, 6, 7, 8).



Figure 1: Syringe reactor used in the BMP study

Field Trial: The field trial reactor was a 100 L waste acetone drum with two ports retrofitted to be the feed port which had a feed tube going to the bottom of the drum (Figure 2). The biogas was vented through a line in the cap of the second port and directly connected by a quarter inch gas hose pipe to a biogas home burner. The reactor was operated in a batch feed mode with daily feeding of the rice starch wastewater. The initial seed volume was 15 L of 5% solids cow dung slurry. The reactor was operated till the methane content of the biogas was sufficiently high enough to sustain the flame in the burner.



Figure 2: Field trial biogas reactor and burner

3 Results and Discussion

In line with research trends of using easily biodegradable wastewater to produce bioenergy (9, 10), the research program investigated the use of rice cooking wastewater rich in starch to produce biogas for cooking in domestic houses. The composite rice cooking wastewater characterized and used in the study is given in Table 1. This is a highly biodegradable wastewater with high BOD₅, wastewater and should be very suitable for methane generation an anaerobic process. The BMP study conducted using the rice cooking starch wastewater using syringe reactor seeded with cow dung at an F/M ratio of 0.02 at a BOD₅ loading rate of 0.5 Kg BOD₅/m³ within the range of operation of low rate reactors for anaerobic wastewater treatments currently being designed and constructed (2).

Table 1: Characteristics of the rice cooking wastewater used in the BMP study

pH	BOD ₅ (mg/L)	Density (g/ml)	TS (mg/L)	VS fraction (%)
8.3 ± 0.1	23450 ± 796	0.95 ± 0.01	0.47 ± 0.01	98.7

The biogas production trends for the BMP reactors are shown in Figure 3. From the onset the BMP reactors producing biogas and gas production was completed within 15 days of operation. The mean ± Standard Deviation total biogas production for the four reactors in the BMP test was 190 ± 46 mL/g BOD₅ (5.38 ± 0.75 L of biogas/per L of Maar). Also the biogas production trend showed that the system did not require any period of acclimation prior to achieve the high degree of waste stabilization shown by rapid biogas production indicating that Maar is easily degradable by the anaerobic culture. The kinetics of biogas production by the degradation of Maar by the anaerobic microorganism is defined by Figure 4. The Figure shows that first order kinetics curve fitting of predicted verses observed biogas production using Equation 1 to calculate the theoretical biogas production trend using the optimized by curve fitting of the first order rate coefficient “k” value of 0.2 day⁻¹. The goodness of fit data between the modelled data and the experimentally observed data showed a very good fit (r² = 0.961).

$$\text{Biogas}_t = \text{Biogas}_{\text{max}} \times (1 - e^{-kt}) \quad (1)$$

where Biogas_t is biogas at any time in ml biogas/gBOD₅, Biogas_i is maximum biogas production in ml biogas/gBOD₅, t is time in days, and k is rate constant, day⁻¹. The time to reach max biogas production was 2.4 days a short time frame indicating that the Maar is easily anaerobically biodegradable and the system has the microorganism to readily degrade the rice cooking wastewater and produce biogas. The methane content of the biogas measured in the end of the test was 78% showing that the biogas generated from Maar has high methane content close to that of methane gas supplied to household the gas supply companies. In the field trial reactor, the gas production was observed within three days of feeding after reactor startup but the gas produce would not be burn. It was suspected that the methane content of the biogas was low for we had used fresh cow

dung to seed the reactor and that the methanogenic population was not sufficient to produce a high quality biogas with respect to methane content. After a month of sustained operation, the biogas produced would burn in a blue flame (Figure 5) indicating that the produced biogas had methane content sufficient enough to combust.

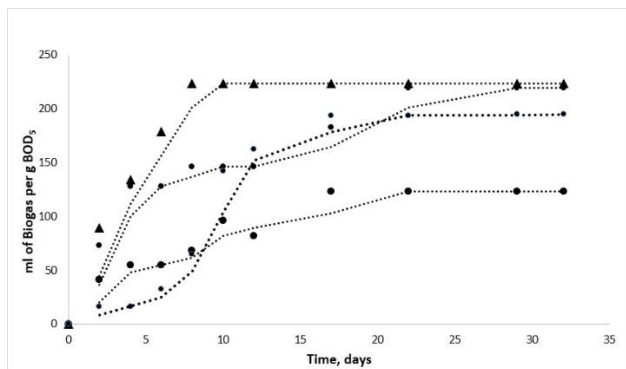


Figure 3: Cumulative biogas production with days of operation

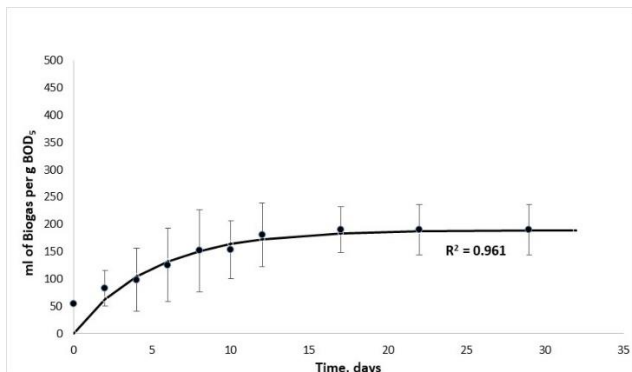


Figure 4: First order modeled profile of biogas product to observed data



Figure 5: A blue flame indicating produced biogas had methane content

In an overall prospective the result of the BMP study and the field trial showed the potential of Maar a substrate for biogas production producing a biogas with high methane content. A waste product such as Maar that is dumped down the drain can be used in the energy mix to as a source of renewable energy in the context of south Asia and South East Asia.

4 Conclusions

The research showed that the wastewater generated from cooked rice could be used to generate biogas with a biogas generation potential of 190 ± 46 mL/g BOD₅ (5.38 ± 0.75 L of biogas/per L of Maar) with the methane content of 78 %. First order reaction defines the kinetics of biogas production with the intent of fitting between modelled and observed data (r^2 of 0.961). The first order kinetics constant “k” was determined to be 0.2 d^{-1} . Field trial showed the viability of the concept at applied level.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses. Manuscript writing was done by Nadim Reza Khandaker.

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