Small Scale Bubbling Fluidized Bed Gasifier for Syngas Extraction from Napier grass

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Abstract. For some farmers, Napier grass is non-beneficial since it may compete for growth area and nutrients for common agricultural crops. However, this grass has the potential to become biomass energy source. It is known that Napier grass is a candidate source of syngas or synthetic gas which can be utilized in different applications. To extract synthetic gas, the Napier grass must undergo gasification process. This study focuses on the design and testing of a small-scale bubbling fluidized bed gasifier for Napier grass. The reactor chamber is made up of low carbon steel while the inert bed material used is silica. The materials for the gasifier were chosen by using the quantitative method of material selection. The temperatures at the inlet, sections of the reactor and exhaust of the reactor were monitored. The maximum furnace temperature of the gasifier was 473°C and observed after 170 minutes due to increased furnace and reactor heating surface area. The syngas extracted from the gasifier was tested and analyzed that there is 21.23 ppm of Carbon Monoxide (CO) and low Volatile Organic Compound (VOC) content. The composition of syngas conformed with the standards and can be used for cooking applications.

1. Introduction
Napier Grass or Pennisetum purpureum is one of the considered highly perennial grasses that can be a source of biomass. It is also considered potential source of biofuel which can provide 3.5 times more amount of biomass compared to sugar cane trashes since it has high productivity, can use water more efficiently compared to root crops and withstand diseases and insect problems [1,2]. It estimated to produce 90m³ of compressed biogas by utilizing 1 ton of Napier grass which can be used as alternative for LPG [3]. It is necessary to increase production of significant amount of biofuel and biomass, it is evident to investigate further biomass conversion technologies. The most common biomass conversion technologies for grasses is gasification. Gasification is the process of biomass conversion which involves high temperature heating to produce synthetic gas or syngas [4]. There are several gasification technologies that are considered expensive with complex gasifier designs but less efficient in biomass conversion [5]. One of the gasifiers considered for improvement is the bubbling fluidized bed gasifier. This study highlights the improvement on the heat transfer furnace area design and air flow distribution, testing and analysis of a small scale bubbling fluidized bed gasifier showing temperature distribution and syngas composition using Napier grass as feedstock.

2. Methodology
2.1. Gasifier Design
The gasifier design as shown in Figure 1 consists of a reaction chamber where the combustion process take place with fuel feed system where the biomass is being placed via the hopper to aid in combustion. The reactor is made up of low carbon steel while the inert material used as bed is silica. The furnace is located at the bottom part of the reaction chamber which uses coconut shell as feedstock as seen in Figure 1a. The furnace is modified as seen in Figure 1b such that there is an increase in its surface area seen in Figure 1c hence inducing heat transfer in the process. A cyclone is included in the design to remove other solid particles in the syngas [6]. A blower is installed via the blower inlet in the system to distribute the air inside the reaction chamber.

![Figure 1. Schematic Diagram of the Small-Scale Bubbling Fluidized Bed Gasifier Design](image)

- (a) Previous Design
- (b) Modified design
- (c) Modified furnace surface area

2.2. Napier Grass
The Napier Grasses to be used were obtained from the fields along the Pulo Diezmo Road, Cabuyao City. The abundance of these grass can be observed as in Figure 2.
2.3. Testing
To produce syngas from the gasifier, 50-100 grams Napier grass samples were fed up with the rate 0.1 kg/hr into the hopper. The coconut shell is used as feedstock in the furnace. During the combustion process, temperatures at the exhaust, points 1, 2, 3 and the furnace were monitored as shown in Figure 3 and were monitored for ten-minute intervals in three hours. The syngas was collected in the syngas collector whereas the solid particles were gathered in the ash collector to be used as soil amendment.

![Figure 2. Napier Grass](image)

**Figure 2.** Napier Grass

![Figure 3. Temperature monitoring points in the gasifier](image)

**Figure 3.** Temperature monitoring points in the gasifier
3. Results and Discussion

3.1. Temperature Monitoring Points in the Gasifier
As seen Figure 4, the maximum temperatures recorded for Point 1, Point 2, and Point 3 were 226°C, 189°C and 187°C, respectively. The maximum temperature at the furnace reached up to 473°C while the exhaust temperature observed to have 144°C. After pre-heating the reactor, there is evidence of white gas after one hour of combustion signalling that the Napier grass has been gasified [7]. In general, there is an increase trend in the temperature monitoring points with respect to time.

![Figure 4. Temperature monitoring points in the gasifier with respect to time](image)

3.2. Syngas Composition
The syngas collected was tested in Ostrea Mineral Laboratory Inc. A direct gas analyzer and non-dispersive infrared was used in identifying the amount of CO, O₂ and VOC (Volatile Organic Compound) present in syngas produced from the gasification of Napier grass. As seen in Table 1, the maximum amount for CO is about 21.23 ppm and all samples have very low amount of volatile organic compound. The VOCs for all the samples are less than 0.1 ppm.

| Sample ID | Mass (g) | CO (ppm) | VOC (ppm) |
|-----------|----------|----------|-----------|
| SG-1      | 50       | 21.23    | <0.1      |
| SG-2      | 100      | 18.96    | <0.1      |
| SG-3      | 50       | 20.92    | <0.1      |

4. Conclusion
A small-scale bubbling fluidized bed gasifier was designed and tested to produce syngas from Napier grass. The combustion process took only an hour to reach gasification temperature of 473°C. The maximum CO content was observed to 21.23 ppm with low VOC content. It can be observed that there must be a continuous feeding of feedstock for continuous production of syngas. The syngas produced by the gasifier can be used for heating and cooking applications.
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