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Analysis of the Influence of Internal Pressure Control to the Total Gas Production in Anaerobic Digester

Faatihatur R. Silmi[a], M. Ramdlan Kirom[a], A. Qurthobi[a]*

[a]*Department of Engineering Physics, Faculty of Electrical Engineering, Telkom University, Bandung, 40257, Indonesia*

Abstract

Production of bio-hydrogen from stale rice was conducted in an aerobic digester. It was applied 3 types of pressure control range to the digester, they are (0-3/3 %), (0-2/3 %), (0-1/3 %) of maximum pressure during the production of bio-hydrogen in mesophilic (35 ^{o}C) condition which is equal to (0-10 psi), (0-6 psi), (0-3 psi), and as small as possible pressure in the digester. This research shows that the optimum pressure control range to increase total gas production is (0-2/3 %) or (0-6 psi), with total production of 19 liters biogas.

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Keywords: Bio-hydrogen; organic waste; anaerobic digester; mesophilic; pressure control;

1. Introduction

The process of hydrogen separation can be done through various processes, such as the process of steam reforming, water electrolysis, or biology. Hydrogen production by biological methods is more efficient in energy and more environmental friendly than other methods [1,2]. One of biological hydrogen production methods is the anaerobic fermentation. Hydrogen can be produced by anaerobic bacteria from carbohydrate-rich substrate into organic acid, H_2 and CO_2 [3]. Three main stages of anaerobic fermentation in the anaerobic digester: (1) Hydrolysis; (2) Acidogenesis; (3) Methanogenesis [4]. The optimum hydrogen production can be obtained from acidogenesis phase. Some environmental conditions for anaerobic digester that affect bio-hydrogen production are pH, temperature, HRT, and partial pressure [5]. Increased pressure inside the digester is considered as a waste product and inhibits the metabolism of anaerobic bacteria [6], but by lowering the partial pressure of hydrogen can increase the production of hydrogen [5].

The purpose of this research is to utilize stale rice as a substrate to produce bio-hydrogen, with focus on the analysis of internal pressure control range to increase the production of hydrogen gas in a laboratory scale anaerobic digester. This research is a part of bio-hydrogen production research at Engineering Physics Department, Telkom University.

2. Materials and methods

2.1. Reactor design

The reactor used in this research is a type of anaerobic digester with a total volume of ± 11 liters. This reactor is made of stainless steel, it was designed so that the reactor can be used for temperature control and can withstand pressure of 11 to 14.5 psi. The reactor is composed of two layers of stainless pipes; there is a gap between the pipes that used as a chamber of heating fluid (water). Table 1 is a table that describes the dimensions of the reactor used in this study.

* Corresponding author. Tel.: +62 87722793305; fax: -.
E-mail address: silmifaatihatur@gmail.com

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Table 1. Dimension of anaerobic digester

Description	Dimension
Volume capacity	± 11 liters
Diameter of inner tube	25.4 cm
Diameter of outer tube	27.9 cm
Width of water heating gap	2 cm

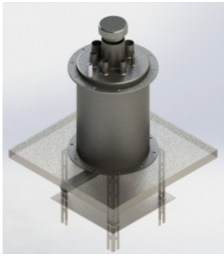

Fig. 1. Design of anaerobic digester.

2.1.1. Reactor Testing

Reactor was tested to determine the state of the reactor. This test should be done to ensure that the reactor can be used as an anaerobic environment for anaerobic facultative and anaerobic obligate bacteria alive. The testing is done by injecting pressurized air using a compressor into the reactor, after closing all channels of sensors and valves. The tests carried out in stages, ranging from the 8, 9, 10, 11, up to 14.5 psi. From the test results, when the reactor is pressurized to 14.5 psi reactor is safe and does not explode. But slowly after 2 hours the gas pressure inside the reactor started to fall, it indicates that there is a gas leak in the reactor. The leaks are at the gate of substrate disposal valve, gate of one-way valve of pH input, and gate of gas output solenoid valve. Similar things happened to the test reactor with pressurized air injection at 12 and 13 psi. Further is reactor testing at a pressure of gas 8, 9, 10 and 11 psi; at these four pressure points the reactor is able to maintain the gas pressure over 2 hours. Thus, it can be known that the maximum capacity of the reactor is 14.5 psi and 11 psi for maximum ability of the reactor to maintain gas pressure. Based on preliminary test, 10.4 psi was selected as a safe point of the reactor to maintain gas pressure. It shows that, the reactor is able to maintain 10.4 psi for 28 hours. Hence, during the bio-hydrogen production in this research, it was avoided to use the reactor until the maximum limit of the reactor (11 psi), and always under the gas pressure of 10.4 psi.

2.2. Pressure control design

In the production process of bio-hydrogen, generally it was given temperature and pH control to create optimum environmental conditions for anaerobic bacteria [7,8,9]. But in this research pH control is not applied to the system, because in pH control system the pH liquid must be injected into the reactor using pump, which is make sudden increase of internal pressure. This sudden increase is considered as a disturbance, because it creates unclear relationship between the increase of internal pressure digester and gas production of anaerobic bacteria. So the environmental control applied in this research is temperature control. Temperature is one of the most affecting factors in bio-hydrogen production [10]. The temperature control refers to a research that has been done by Pratiwi [11], but by re-adjusting the temperature set point to mesophilic range (35 ^oC). Two reasons for selecting mesophilic control due to: first, the anaerobic bacteria used in this research is the bacteria that has been found in stale rice or without any addition of thermophilic bacteria inoculum. Second, thermophilic experiment consumes more energy compared to a mesophilic experiment, and the different between yields in thermophilic and mesophilic is not always highly significant considering the difference in the amount of consumed energy [10]. While, to support the main purpose of this research, which is analyzing the optimum pressure control range, here is the design of the hardware and software or a program for pressure control and data acquisition.

2.2.1. Hardware

The design of the hardware to support this research is consist of the addition of solenoid valve, shut off the gas valve, and gas storage made of a balloon. During the production, the produced gas is stored in the reactor until internal pressure of the digester reaches the desired set point. Solenoid valve is required to regulate the volume of gas that comes out of the reactor, in order to control the internal pressure within the reactor, with the assistance of microcontroller and relay driver. Hardware design for pressure control system can be seen at figure 2.