Research article

Effects of Air Injection and Iron Oxide Pellet Addition on Hydrogen Sulfide Removal and Biogas Production

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Abstract Hydrogen sulfide (H_2S) in biogas resulting from anaerobic digestion process is unwanted trace compound, because it is toxic and can corrode biogas engine. This study aimed to compare the 2 desulfurization methods, air injection and iron oxide pellets addition, on H_2S removal and quantity and quality of biogas. The experiment was carried out with two floating drum digesters (1 m^3 each) constructed at Royal University of Agriculture, Phnom Penh, from January to August 2020. Three levels of air injection at 2%, 4%, and 6% of O_2 regarding the daily biogas production and iron oxide pellets application at 1 kg, 2 kg, and 4 kg per m^3 of biogas were applied to remove H_2S in biogas from different raw materials of pig manure and food waste. The amount of daily biogas production was quantified by gas flow meter, also gas quality was measured using a GEM5000 gas analyzer. The experimental results indicated that food waste had higher daily biogas production comparing to pig manure in both desulfurization methods. Biogas from food waste increased from 544 L d^{-1} without iron oxide pellets addition (0 kg) to 657 L d^{-1} with 4 kg iron oxide pellets addition; and to 566.5 L d^{-1} with 2% of injected O_2. To the contrary, desulfurization for pig manure with 2% of O_2 and 1 kg of iron oxide showed high daily biogas yield of 348 L d^{-1} and 340 L d^{-1}, respectively. For raw materials of pig manure, in both desulfurization methods, had higher CH_4 content than food waste. Air injection was more effective in H_2S removal than iron oxide for both substrates, but higher level of H_2S reduction was observed with pig manure. Accordingly, it was concluded that desulfurization methods with air injection and iron oxide pellets addition were effective in biogas production as well as H_2S removal, but a clear trend appeared in the raw material of food waste.

Keywords floating drum digester, anaerobic digestion, food waste, pig manure, H_2S removal

INTRODUCTION

Biogas is a product generated from the anaerobic digestion of organic substances by appropriate microorganisms through four metabolic stages; namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Dumont, 2015). It is considered one of the renewable energy sources that can provide both heat and electricity for use in households, in farms, or in industries. Gas compositions contained in biogas include methane (CH_4), carbon dioxide (CO_2), and other trace elements such as ammonia (NH_3), water vapor (H_2O), and hydrogen sulfide (H_2S). The majority of them are CH_4 (60-70%) and CO_2 (30-40%) (Okoro and Sun, 2019), but the only energy source is CH_4, which has both benefits and drawbacks. If released into the atmosphere unused, CH_4 is a greenhouse gas which has 28 times more powerful than CO_2, which actually accelerates global warming (National Geographic, 2019). When burned or used for internal combustion engine, its harmful effects are reduced and at the same time, its beneficial energy can be harnessed. Nevertheless, the presence of H_2S in biogas may causes problems in terms of health hazard and economic aspects (Pinate et al., 2017).

H_2S is an unwanted gas mixed in biogas because it is toxic to humans at low concentrations and corrosive to engines. High concentrations of H_2S can corrode engines or metal parts, and lead to faster degradation of engine lubricant oil. A maximum recommended level for generator operation ranges from 200 to 500 ppm (Rodrighez et al., 2014). If it is used without treatment, oil lubricants must be changed more often, or the lifespan of a generator is reduced, resulting in high investment and operating costs. Furthermore, H_2S limits for gas heating boilers, combined heat and power (CHP), fuel cells, and national gas upgrade are 1,000, 1,000, 1, and 4 ppm, respectively (Choudhury et al., 2019). However, different substrates used for biogas production produce different concentrations of H_2S. Substrates that contain high-level protein produce higher H_2S content than those contain carbohydrate and lipid due to the presence of more sulfurous elements in it. Biogas produced from organic waste may contain H_2S in the range of 10-20,000 ppm, but about 10-40 ppm is found in biogas produced from sewage and 50-300 ppm from landfill (Dumont, 2015). Moreover, Huertas et al. (2020) stated that H_2S produced from organic waste such as pig manure can be as high as 30,000 ppm.

To reduce its concentration to an acceptable level, desulfurization techniques can be applied physically, biologically, and chemically. Biologically removal is done by air injection into digester with regulated amounts of oxygen (O_2) between 0.3 and 3% of produced biogas; however, this reaction may result in sulfur build-ups in the digester space (Hines et al., 2019). Many kinds of chemical methods have been studied. Pinate et al. (2017) proposed a small batch test for H_2S removal by absorbent granules soaked in ferric chloride ($FeCl_3$) and in sodium hydroxide solution (NaOH), the removal efficiency was around 90%. Zulkeflia et al. (2016) stated that H_2S removal could be done by activated carbon soaked in NaOH, potassium hydroxide (KOH), and potassium carbonate (K_2CO_3), but added that the last chemical element was the most effective. Biological H_2S removal methods are also increasing popular and considered highly effective. Those biological methods include biofilters, biotrickling filters, bioscrubbers, and activated sludge (Barbusiński and Kalemba, 2016). However, H_2S removal techniques are limited, or have not been well documented in Cambodia, which makes it difficult for promotion of biogas use inside the country. Therefore, proposing an applicable desulfurizing technique is highly valuable for economic reasons.

Pig manure is a major waste from animal productions in Cambodia. According to MAFF (2020), the number of pigs was around 2.18 million heads in 2019 of which more than half raised in commercial farms. On the other hand, kitchen waste amounted from 63.30% to 80.46% of all solid wastes from households (Sour, 2017). Proper management of these two wastes by converting them to biogas will provide both environmental and economic benefits.

OBJECTIVE

The objectives of this study were (1) to compare the effects of air injection and iron oxide pellets on H_2S removal and quantity and quality of biogas produced from two different substrates, food waste and pig manure; and (2) to identify relations between biogas production with CH_4 content in the two substrates.

METHODOLOGY

This research was conducted at the pilot biodigesters belonging to the Biogas Technology and Information Center (BTIC), at the Royal University of Agriculture, Cambodia, starting from January to August 2020. Two floating drum biodigesters (1 m^3 each) were used for this experiment. Two different substrates, food waste and pig manure, were daily fed into the systems. At its full production, biogas was then treated by two desulfurizing methods: air injection and iron oxide pellets. Air injection was applied directly into the gas holders (the floating drum) on top of the digesters at O_2 levels of 2%, 4%, and 6% of daily produced biogas. Meanwhile, iron oxide pellets were placed in a gas treatment container through which raw biogas was passed through and treated before being quantified. The levels of iron oxide pellets were applied at 1, 2, and 4 kg m^{-3} of daily produced biogas. Effectiveness of the desulfurizing methods was also determined by comparing the results with raw untreated biogas.

Materials

Two floating drum biodigesters used in this experiment had concrete bases and walls constructed under the ground. The whole volume was 1 m^3, one third of which was for gas storage. The gas holders were high-grade polyethylene plastic water tanks that were cut in half and used as covers for the digesters. They can move up and down, depending on the biogas pressure produced inside.

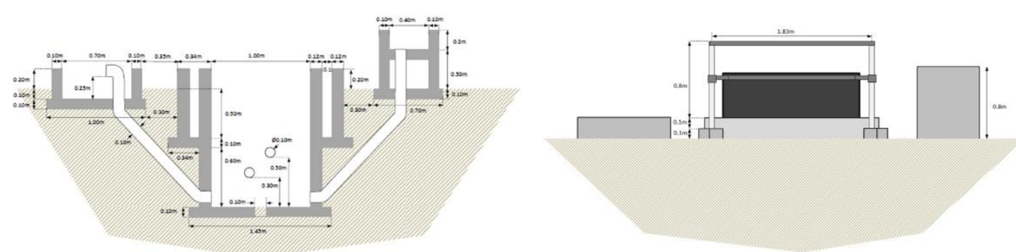

Fig. 1 Technical drawing of a floating drum biodigester used in this experiment

Substrates used in this experiment were food waste and pig manure. Their physical and chemical properties were analyzed in advance. Still, there might be some variations due to everyday fresh collection of the substrates. To reduce errors, substrate collection was done at the same place throughout the experimental period.

Food waste was daily collected from the university canteen. It contained 21.9% dry matter, 1.4%