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Short Communication

Potential development of compressed bio-methane gas production from pig farms and elephant grass silage for transportation in Thailand

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HIGHLIGHTS

- We developed an anaerobic co-digestion process of pig manure with grass silage.
- We set up an industrial scale experience to utilize biogas.
- Compressed bio-methane gas (CBG) to be used as automotive fuel.
- Potential developments of CBG gas production deliver to transport.

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ABSTRACT

This research project evaluated biogas production using anaerobic co-digestion of pig manure and elephant grass silage in large scale to delivered transportation directly for cars. Anaerobic co-digestion was estimated in three full-scale continuously stirred tank reactors (CSTRs) at 40 °C. In the form of compressed bio-methane gas (CBG) production was 14,400 m^3/day (CH_4 60–70%) amount of CBG was 9600 m^3/day. The procedure was enhanced by using molecular sieve, activated carbon for removal of moisture and CO_2 membrane H_2S and CO_2 respectively. The results were demonstrated the amount of CO_2, H_2S gas was reduced along with CH_4 was improved up to 90% by volume and compressed to 250 bar tank pressure gauge to the fuel for cars. The CBG production, methane gas improvement and performance were evaluated before entering the delivered systems according to the energy standards. The production of CBG is advantageous to strengthen the Thailand biogas market.

1. Introduction

Renewable resources of energy are a part of the Asian region fight against climate changes, at the same time they contribute to economic growth, increasing the number of employed people and provide energetic safety. Biogas production and use are generally regarded as a sustainable practice that can guarantee high greenhouse gas savings (Weiland, 2010). The biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits and is an additional source of income for farmers. Consequently, biogas technology is becoming increasingly popular throughout the world, particularly in countries where governments promote domestic biogas systems.

Thailand is one of the fastest growing, energy intensive economies in Southeast Asia. Energy demand required to meet the economic growth of Thailand is high and growing every year. Currently, energy is one of most sensitive issues in Thailand, where almost 50% of the total commercial energy supply was imported (Aggarangsi et al., 2013). Thailand is an agricultural country with around 34% of the households throughout the country working in agriculture and 93% of them located in rural areas. The two major activities in the agriculture area are the cultivation of crops (54%) and integrated crop–livestock farming (35%). The major forms of livestock in Thailand are pigs, chicken and cattle (Charoensook et al., 2013). Accordingly, Thailand, as the country has the potential biogas as a country with a lot of agriculture; including raw materials from crops and livestock, it can be used to develop renewable energy in the form of biogas is methane gas caused by the decomposition of organic matter in the system. And the biogas resources are from industrial wastewater and live stock manure, which have potential of 7800 and 13,000 TJ/year, respectively (Tippayawong and Thanompongchart, 2010). In Thailand, biogas is mostly derived from domestic pig manure used as fuel. Recently, most of the agricultural biogas plants digest manure with the addition co-substrates to increase the content of organic material for achieving a higher gas yield (Álvarez et al., 2010). For these reasons co-digestion is commonly practiced and most recommended co-substrate was manure.

Co-digestion has been defined as the anaerobic treatment of a mixture of at least two different substrates with the aim of

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improving the efficiency of the anaerobic digestion process. At present, there are an increasing number of full-scale co-digestion plants treating manure and industrial organic wastes. Co-digestion of mixed substrates offers many advantages, including ecological, technological, and economic benefits, compared to digesting a single substrate. However, combining two or more different types of feed stocks requires careful selection to improve the efficiency of anaerobic digestion (Álvarez et al., 2010). The main resource is represented by animal manure and slurries from cattle and pig production units as well as from poultry, fish, etc. And agricultural substrate suitable for anaerobic digestion is represented by energy crops, of which most common are grain crops, grass crops and maize. Grass crops are among the most promising energy crops for biogas production (Seppälä et al., 2013).

Grassland biomass is suitable in numerous ways for producing energy. Using grassland biomass for producing energy especially biogas production currently is the most common. There are so many types of grasses that are popularly grown in Thailand. Grass is converted to silage to be used as feedstock for anaerobic digestion (Seppälä et al., 2013). Furthermore, grass silage, due to its high digestible organic matter content, is also an excellent feedstock for anaerobic digestion. Elephant grass (*Pennisetum purpureum*) is one of the most promising grasses available for ruminant production in tropical and subtropical areas because of its high potential dry matter yield (Yang et al., 2013). Consequently, the main objective of this research was to produce large amount of biogas yield from pig farms and co-digesting with grass and to deliver the transport directly.

2. Methods

2.1. Grass silage preparation and reactor design

Pig manure and pig form waste water was obtained from a pig farm "the sacred pig farm and Sons Farms Ltd" in Chiang Mai, Mae Taeng district, Thailand. The farm has 35,000 pigs; those pigs were produce fresh active substrate of about 10–12 tons per day mixed with the effluent a day and the farm size is about 300 m^3. Elephant grass was collected from the agriculture form which was cultivated around Mae Taeng district, Thailand. The Elephant grass silage (grass silage) was used about 20–23 tons per day which was grown at 45 days period. The grass silage particle size was 1.0 mm.

In this study performed with continuously stirred tank reactors (CSTRs) and triplicate production units (i.e. CSTR1, CSTR2, and CSTR3) were used; each unit having a working capacity of 1700 m^3 per tank and a volume control for consistent feed. The CSTRs were placed on a three-position stirrer hotplate system.

2.2. Substrates preparation and experiment procedure

The continuous experiment fed with sewage sludge and shredded grass was stably operated for 31 days (data was not shown). As the main objective of this work was the anaerobic treatment of pig manure and wastes (due to the relatively high volume generated in the region), with elephant grass silage of co-digestion experiments using CSTRs. The experiments were carried out at mesophilic (40 °C) temperature. The prepared pig farms substrates (10–12 tons per day) and grass silage (20–23 tons per day) was pumped through a grinder and then to the equalization tank. The tank capacity was 150 m^3. The equalization tank was preheated with preheating unit up to fixed fermentation temperature. The thermal capacity was 600 kWh. This set up was connected with two anaerobic bacteria cultivation tanks (capacity is 20 m^3) and anaerobic bacteria storage / dosing tank (2×0.2 m^3). The bio substrate feed was provided 32,500 kg/24 h, as liquid 325 m^3/24 h to the fermenters. Fermenters were run 24 h continuously; cascade continuous temperatures of the fermentation tank were fixed and constant throttling feed regularly. In addition, the installations of tank agitator, agitator control system of PLC (Programmable Logic Controller) were connected with fermentation tank. Subsequently, the gas production process was monitored and followed the gas quality improvements. The process of gas quality improvement was performed by using molecular sieve, activated carbon for removal of moisture and membrane for hydrogen sulfide (H_2S) and carbon dioxide (CO_2) removal, respectively. Gas quality improvement was tested and evaluated the system performance and quality improvements after that compressed gas cylinders. It so called compressed biomethane gas (CBG) product. The CBG was delivered to the right and a gas pump supplier for cars in Thailand.

2.3. Analytical methods

The pH determination procedure was adopted from Weiland (2010). Biogas composition in laboratory test (CH_4, CO_2, H_2, H_2S, and O_2) was measured using an automated gas analyzer according to Brettschneider et al. (2004). Biogas composition was analyzed according to ASTM-D1945-03 (2010), Standard test method for analysis of natural gas by gas chromatography (GC) and to Standard UNE-EN ISO-6976-2005, Natural Gas-Calculation of calorific values, density, relative density and Wobbe index from composition (UNE-EN ISO-6976, 1995).

3. Results and discussion

3.1. Biogas production

Anaerobic co-digestion of pig subtracts and grass silage on the digestion process was studied in three CSTRs units with the same substrate. The efficiency of gas production in biogas digesters depends on temperature, pH, and suitable co-digesting bio substrates and reactor design (Vindis et al., 2009). Biogas fermenters were maintained at constant rates of temperature and pH; were continuously monitored and stable operation of the process was continued. Temperature markedly affects the biogas yield during anaerobic digestion of manure by affecting the thermodynamics of acetogenic reactions and methanogenic reactions. Most of fermenters are operated at mesophilic temperatures with optima between 38 and 42 °C (Weiland, 2010). Deublein and Steinhauser (2008) demonstrated that small variation in temperature of digester affects the biological activity of anaerobic bacteria thus reducing the rate of gas production. Most of methanogenic microorganisms are mesophilic and very sensitive to thermal temperature. Constant temperature is important for preventing negative effects on biogas production (Weiland, 2010). Consequently, the available literatures suggestions, chosen optima temperature was 40 °C in this study.

Co-digestion of pig manure with energy crop residues can increase the biogas yield by maintaining an optimal pH for methanogens. Hence, pH is necessary to be in desired range because it directly affects the growth of microbes. Biomethanation formation takes place within a reasonably narrow pH range, from 6.8 to 7.5. At such level, methane content in the biogas could theoretically be up to 72–82% at pH 7.2–7.4 (Rittmann and McCarty, 2001); therefore in this selected optimum pH was 7.3 for this research.

Anaerobic digestion of animal slurry, agricultural feedstock for biogas production is commonly practiced in continuously stirred tank reactor (CSTR). Also known as a completely stirred tank reactor, the complete mixed system is most commonly a circular tank with a mechanical agitator. The mixing prevents settling and maintains contact between bacteria and the manure/prepared