Research article

Assessment of Biogas Production Potential from Commercial Pig Farms in Cambodia

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Abstract Commercial pig farms in Cambodia are increasing, representing 30% of the overall pig production in 2018. To run the farms, huge quantity of water is used on daily basis, and its large proportion ends up being wastewater that can cause air and water pollution, fly-related illnesses, and methane emissions. In response, anaerobic digestion (AD) is applied to convert waste into energy. Covered lagoons are an anaerobic biodigester that has long been used for commercial biogas plants in Cambodia due to acceptable investment cost and favorable climatic conditions for biogas production. However, lack of local technical data and technical assessment is a barrier to wider implementation of biogas systems in the country. Therefore, the study was conducted to explore the characteristics of commercial pig farms and wastewater use; to analyze the quality of biogas compositions from different covered lagoons; and to estimate biogas production, electricity generation, and CO_2 reduction equivalent from the collected data. The study was started from January to October 2020, selecting 9 farms with evaporative cooling systems for in-depth interviews, along with direct observations, biogas analysis, and power analysis. The findings indicate that all the studied farms were fattening farms operated under purchase contract with private companies. Pig production varied from 2,800 to 7,200 head per cycle, with two cycles per year. Moreover, daily wastewater was 0.033 m^3 d^{-1} $head^{-1}$, with dry matter (DM) accounting for 0.9%. Annual biogas production and electricity generation were 32.7 m^3 y^{-1} $head^{-1}$ and 42.5 kWh y^{-1} $head^{-1}$, respectively. Biogas quality was 59.5% CH_4, 31.5% CO_2, 1.3% O_2, and 2,256 ppm H_2S. With biogas systems, individual farms could reduce CO_2 emission by 0.676 tCO_2eq y^{-1} $head^{-1}$, which is economically and environmentally beneficial. However, a business model should be taken into account for successful implementation.

Keywords CO_2 reduction, covered lagoon, methane emission, pig manure

INTRODUCTION

Pork is considered an important protein source for daily Cambodian diets. In this country, an average person eats 17.6 kg of meat per year, of which 9.29 kg is pork. Likewise, annual domestic demands for meat in 2018 was estimated at 285 thousand tons, and pork alone accounted for 52.8%. This high demand led to a 126% increase in local pig production between 2014 and 2017, from 2.44 million to approximately 3.18 million heads. A tendency toward large-scale production has emerged, as commercial pig farms rose by 30% in 2018 (MAFF, 2019). Commercial pig farms in Cambodia are farms with more than 100 fattening pigs, or more than 50 sows. There are around 500 farms in operation across 10 provinces, with 30-40% concentrated in Kampong Speu Province (NBP, 2019). Commercial pig farms in Cambodia are operated similarly with Thailand because they use evaporative cooling systems to maintain optimal temperatures inside the barns from 25 to 27 ^{0}C (Thanapongtharm, 2018). Such operation is vital for pig growth and disease prevention. For secure market and prices, farms turn to contract farming with private companies, such as C.P. Cambodia Co., Ltd., that provide both technical and financial support. Farm operation differs by pig type. In Cambodia, pig farms are classified into breeding farm and fattening farm. Among them, fattening farms are more popular. Fattening farms have three categories: small-sized (100 - 1,000 heads), medium-sized (1,001 - 5,000 heads), and large-sized (>5,000 heads) (MAFF, 2018).

Pig farms normally use large amounts of water for pig drinking, pig bathing, and barn cleaning. Daily water use rates vary by production type and pig weight. It is reported that average daily required water rates for breeding farms, fattening farming, and nursery farms are 92, 48, and 32 L d^{-1} $head^{-1}$, respectively. However, a large proportion (50-70%) ends up being wastewater (Nokyoo, 2016). Improper treatment of wastewater is associated with odor, flies, water pollution, and greenhouse gas emission. Some key elements used as pollutant indicators include chemical oxygen demand (COD), biological oxygen demand (BOD), total Kjedahl nitrogen (TKN), and total suspended solid (TSS). A study by Tokhun (2010) indicates that untreated wastewater from large-scale pig farms in Thailand

contains 4,889 mg L^{-1} COD, 3,555 mg L^{-1} BOD, 481 mg L^{-1} TKN, and 2,317 mg L^{-1} TSS. These parameters are too high to be directly discharged into natural lakes. In the Cambodian wastewater standards for public water areas and sewers, COD, BOD, TSS, and nitrate (NO_3) must be no more than 100, 80, 80, and 20 mg L^{-1}, respectively (Council of Ministers, 1999). Thus, sound waste management is strongly required, as it is important for the sustainable operation of pig farms. One of the most effective wastewater treatment methods is the adoption of anaerobic digestion (AD). AD is known as a process under which organic matters, mainly in the form of fine particles, are fermented with the absence of air. The process consists of four stages: hydrolysis, acidogenesis, acetogenesis , and methanogenesis, with biogas produced as a final product and convertible into energy (Deublein and Steinhauser, 2011). Biogas is a gas mixture that contains 50-70% methane (CH_4), 30-40% carbon dioxide (CO_2), and other trace elements (EESI, 2017). CH_4 contained in biogas is the only source of energy such as heat and electricity. Nevertheless, it is harmful to the environment, if released into the atmosphere, because it is 28 times more powerful than CO_2 in terms of global temperature potential (GTP) for 100 years (IPCC, 2014). In contrast, converting biogas into electricity or upgrading it into bio-methane can reduce its harmfulness.

To promote manure management, the National Biodigester Program (NBP) was established in Cambodia in 2006 to turn cow manure into biogas for cooking and lighting. The program has built nearly 30 thousand biodigesters for smallholder farmers nationwide. In recent years, attention has been turned to large-scale biogas systems, which are covered lagoons. Covered lagoons are an AD technology, commonly used in commercial pig farms in Cambodia. It is reported that there are 44 covered lagoons in operation across the country (NBP, 2019). This number is still considered low in comparison to the potential pig farms and other biogas resources. This is due to lack of necessary documents and knowledge, or biogas skills. Therefore, in-depth studies on commercial pig farms are deemed vital for solving problems with wastewater and for economic profitability through energy generation.

OBJECTIVE

The objectives of this study were (1) to explore the characteristics of commercial pig farms and wastewater use; (2) to analyze the quality of biogas from covered lagoons; and (3) to estimate methane production, electricity production, and CO_2 reduction equivalent.

METHODOLOGY

The selection criteria for pig farms were farms that had thousands of pigs, used evaporative cooling systems, and were interested in setting up biogas systems. However, the scope of this research was based on a one-year study period only, from January to October 2020. To represent diverse pig farm characteristics, 9 commercial farms were selected from 6 different provinces: 5 from Kampong Speu and 1 each from Kampong Chhnang, Kampong Cham, Kampong Thom, Siem Reap, and Kratie. More farms were selected from Kampong Speu, as this province had the greatest farm number in the country. The study procedure was arranged by face-to-face interviews with farm owners on the site, direct observation, biogas analysis, and power analysis.

Materials

Biogas quality is an important indicator to determine generator efficiency. A 5000 gas analyser, supplied by Geotech, UK, was used to analyze biogas quality based on the percentage of CH_4, CO_2, O_2, and H_2S in ppm with the maximum of 5,000 ppm.

Peak load is considered a vital indicator to determine the generator size for the farm. A Hioki