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Comparison of process stability in methane generation from palm oil mill effluent using dairy manure as inoculum

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HIGHLIGHTS

- This study investigated methane production from dairy manure as inoculum.
- Addition of dairy manure improved both the start-up time and rate of biogas production.
- Biogas production was achieved at ambient temperature.

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ABSTRACT

The potential of methane production in a continuously stirred tank reactor (CSTR) was investigated using dairy manure as inoculum at pH 6.8 and 37 °C temperature in this study. Two identical anaerobic bioreactors namely $CSTR_1$ and $CSTR_2$ filled with palm oil mill effluent (POME) as a carbon source were used. $CSTR_1$ was not added with the inoculum, while $CSTR_2$ was added with dairy manure as inoculum. Both the reactors were allowed to run for 5 days (d) in batch condition at hydraulic retention time (HRT) 10 d. The $CSTR_2$produced 0.85 L/d gas yield and 59% methane content compared to 0.39 L/d gas yield and 20% produced in $CSTR_1$, respectively. A better chemical oxygen demand (COD) reduction percentage of 48% was found in $CSTR_2$ compared to $CSTR_1$ with 33%. The investigation showed that dairy manure as inoculum has a marked influence on the start-up period and the biogas production rate.

1. Introduction

The increase in world's energy demand and depletion of energy reserve, strive biofuels as a favourable choice over fossil fuels due to their biodegradability, renewability and carbon neutrality (Krishnan et al., 2017a; Mishra et al., 2017). Methane production has a higher potential in the Asian countries due to the availability of agricultural and industrial waste water (Wang et al., 2014). The Methane production through anaerobic digestion is a promising strategy which got significant advantages over other forms of bioenergy production. It is because the anaerobic digestion is highly efficient in the organic removal while simultaneously generating renewable energy (Mamimin et al., 2015; Panpong et al., 2014). The by-products produced during the anaerobic treatment can also be used as further such as bio-fertilizers (El-Mashad and Zhang, 2010).

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Abbreviations: CSTR, Continuously stirred tank reactor; Dm, Dairy manure; HRT, hydraulic retention time; COD, Chemical Oxygen Demand; TS, Total Solids; VS, Volatile Solids; NH_3-N, Ammonia Nitrogen; CH_4, Methane

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Table 1
Chemical characteristics of raw POME.

Parameter[a]	Concentration (mg L^{-1})
pH	5.1± 0.2
Biochemical oxygen demand (BOD)	3,500 ± 500
Chemical oxygen demand (COD)	56,500 ± 300
Total carbohydrate	16,400 ± 200
Total nitrogen	960 ± 100
NH_4^+–N	810 ± 100
Total phosphorus	110 ± 1
Phosphorous	22± 1
Oil	109,000 ± 20
Total solids (TS)	32,000 ± 300
Volatile solids (VS)	26,000 ± 400
Volatile Suspended solids (VSS)	8,300 ± 200
Ash	4,500 ± 200

[a] All in mg L^{-1} except pH.

Table 2
Chemical characteristics of raw dairy manure.

Parameters	Concentration (mg L^{-1})
Total solids	186.8 ± 25
volatile solids	40 ± 0.5
COD	28,585 ± 500
NH3-N	610 ± 35
moisture	41.2 ± 1.5%
pH	7.2

[a] All in mg L^{-1} except pH and moisture.

Generally, the biogas constitutes 55%–60% methane (CH_4), 30%–35% carbon dioxide (CO_2), 5%–7% ammonia (NH_4) and a trace amount of H_2S (Zhu et al., 2015). Methane is a colourless, flammable, and high energy content natural gas with the calorific value ranges between 6 and 6.5 KWh m^{-3} (Sompong et al., 2012). Methane can be produced using wide range of organic wastes and also at various temperature such as psychrophilic (below 25 °C) (Cheng et al., 2013; Sims et al., 2010), mesophilic (30 °C and 37 °C), thermophilic (55 °C and 60 °C), and extremophiles temperature (above 65 °C) (Wang et al., 2009; Krishnan et al., 2017a; Gungor-Demirci and Demirer, 2004).

In Malaysia, the palm oil mill effluent represents a constant environmental problem causing the high magnitude of hazards on the global environment (Krishnan et al., 2017b). Usually, the POME is acidic with high dissolved solids and difficult to degrade easily. Also, the huge amount of dairy manure produced nowadays by the feedlot farming is causing a major environmental damage (Forster-Carneiro et al., 2008). However, anaerobic digestion is carried out by microbial consortia and mainly depends on various factors like pH, temperature, HRT, and C/N ratio and it is a relatively slow process. Co-digestion is an important method to enhance biogas production. However, it is found that dairy manure is an outstanding co-substrate in anaerobic digestion because it contains eminent buffering capacity, rich in anaerobic bacteria and a wide range of essential nutrients for optimal microbial growth (Liu et al., 2013). Therefore, its supplementation as an additive with POME during anaerobic digestion is beneficial because it provides the energy source while concurrently resolving the pollution risk that is associated with dairy manure (Hniman et al., 2011). Previously, many researchers reported anaerobic co-digestion of POME using various substrates (Poh and Chong, 2009; Nasir et al., 2012). But the treatment of POME for methane generation using diary manure as inoculum (co-substrate) is very limited. In the present study, the potential of dairy manure as inoculum for the production of methane from POME with regulated pH and temperature was investigated. This experimental finding helps in wastewater management.

2. Materials and methods

2.1. Substrate preparations

Raw POME was collected from the final discharge point of Felda Palm Oil Industry, Lepar Hilir, Gambang, Malaysia and used as the substrate for methane production. The POME was stored at 4 °C in a 30 L container to prevent acidification and biodegradation prior use. The chemical characteristic of the POME used in this study is shown in Table 1. Fresh dairy manure was collected from Makmur Dairy Farm, Pahang, Malaysia and Bukit Tingi, Bentong, Malaysia. The dairy manure was scraped from the deposit directly and the samples were packed in polyethene bags and stored at 4 °C until use. The screening procedure removed sand, fibres, and straw from the raw POME and dairy manure. The chemical characteristic of the dairy manure used as inoculum in this study is shown in Table 2.