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Biological pre-treated oil palm mesocarp fibre with cattle manure for biogas production by anaerobic digestion during acclimatization phase

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ABSTRACT

Oil Palm mesocarp fibre (OPMF), is a byproduct from palm oil production industries, the waste was utilized as a substrate for biogas production. The main barrier in using this type of biomass is its complexity in biodegradation. OPMF was biological pretreated using oyster mushroom for breaking the complex structure so as to expose the lignin to microbial activities and improve the efficiency of anaerobic digestion, and it was subjected to anaerobic digestion with cattle manure (CM) and seeded with Palm oil mill effluent (POME). The biological pretreatment decrease the hemicellulose, cellulose and lignin to 10.91%, 8.96% and 10.63% respectively, lower than the initial lignocellulose content. Laboratory experiment was carried out in a single stage 10 L bioreactor. The reactors were named R1, R2, R3, and R4 at different mixture conditions with organic loading of 1.62 and 2.11 g VS_{added} L^{-1} d^{-1} at HRT of 10 days. R1 produced highest cumulative biogas of 29.16% which was higher than R2, 39.8% higher than R3, and 64.13% higher than R4. This result indicates that R1 which is a mixture of pretreated OPMF with CM seeded with POME produced the best result during the anaerobic digestion process. Thus, anaerobic digestion of pretreated OPMF with CM inoculated with POME shows a better potential for biogas production. Is a good source of biogas production and waste reduction in the palm oil mill industry.

1. Introduction

With the rapid world increased in population, dependence on the fossil fuel as a source of energy is increasing and the global economy would equally be affected. Thus, there is need to utilize all alternative sources of energy which can be more sustainable. Agricultural production can be a source of renewable energy, since it produces large residue during production of various products. Agricultural plants residues are produced in large quantity annually worldwide but are not fully utilized.

The palm oil sector in Malaysia generates large amount of biomass, since the country is one of the highest producer of Palm oil in the world. About 77.24 million tons per year of biomass from the oil palm mills comprising of 44.48 million tons of palm oil fronds, 6.93 million tons of empty fruit bunches, 13.97 million tons of trunk, 7.29 million tons of fiber and 4.21 million tons of shell, and this is expected to increase by 2020 (Ng et al., 2011). The present system contributes to Green House Gases due to the present system of generating energy in the palm oil mills. During anaerobic digestion process, there are four different stages of reaction: namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Yuzir et al., 2012).

Lignocellulosic biomass is a food alternative source to fossil fuel (Suhardi et al., 2013). Mesocarp fibre has a potential to produce biogas. As a lignocellulose material there is need to develop a more sustainable way of achieving it. Ward et al. (2008) suggested that for any lignocellulosic materials to be used as a substrate for production of biogas, there is need for pre-treatment of the lignocellulose substrate in order to partially remove the hemicellulose, cellulose and lignin which aid in exposing the material to microbial degradation and any substrate that contains some form of ruminant manure with high level of organism which is capable of hydrolyzing

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lingo cellulose materials can be used as a co-substrate. Although anaerobic digestion method has been studied by many researchers on different types of substrates (Nishio and Nakashimada, 2007), there is limited report on anaerobic digestion of oil palm mesocarp fibre with cattle manure. Therefore, there is need to utilize the substrate in a cleaner system which is biogas production. Anaerobic digestion is more suitable than other systems of composting (Liu et al., 2009). Conducting pre-treatment needs on the oil palm mesocap fibre can expose the hemicellulose and cellulose to microorganism for degradation. There are different methods of pretreatment which includes physical, physiochemical, chemical and biological (Chynoweth et al., 2001; Zeng et al., 2007; Taherzadeh and Karimi, 2008; Yu et al., 2010; Sills and Gossett, 2011; Chang et al., 2012). da Silva et al. (2014) reported that cattle manure (CM) is a good source of renewable energy.

From the several literature studied, the best promising form of pretreatment is the biological pretreatment, and the best microorganism for biological pretreatment are white rot fungi. And among the whit rot fungi is the oyster mushroom which produces ligninlytic enzymes and mineralizes lignin into CO_2 and H_2O in pure culture. According to Zadrezil and Grabbe (1983) *pleurotus* spp. is an edible mushroom grown on lignocellulosic agricultural waste for human consumption; various strains of this fungus utilize woody materials and straws efficiently by degrading their lignocellulosic ingredients.

The objective of this paper is to determine the potential of biogas production from biological pretreated oil palm mesocarp fibre with cattle manure using wet anaerobic digestion system.

2. Materials and methods

2.1. Substrate preparations

The oil palm mesocarp fibre (OPMF) was collected from Tai Tak Palm Oil Mill, Kota Tinggi, Johor State, Malaysia. The substrate was dried and the impurities were removed manually, it was then milled my electric ball miller to reduce the particle size. Fresh cattle manure was sourced from Mujer Javanese Farm, Seri Bunian in Pontian, Malaysia. And palm oil mill effluent (POME) was collected from Felda Besar Oil Mill; Kulai, Malaysia was used as inoculum. All the prepared substrate was store at 4 °C room until use. The use of cattle manure was to increase the rate microbial activities during the digestion period and POME was used as inoculum which increased the start-up time of the reaction.

2.2. Biological pre-treatment

Biological pretreatment was conducted on the POMF to reduce its lignocellulose content. Thus, oyster mushroom was cultivated on the POMF as reported by Saidu et al. (2011), before the cultivation the lignocellulose content; hemicellulose, cellulose and lignin were determined according to Arora and Sharma (2009) method and the same method was used after biodegradation had taken place to determine the percentage reductions.

2.3. Analytical determination

Parameters such as biogas production, total solid (TS), volatile solids (VS), chemical oxygen demand (COD), ammonia-nitrogen (NH_3—N) and carbon—nitrogen C/N) ratio were measured according to Standard Methods for the Examination of Water and Wastewater (APHA) (2005). The biogas volume was determined by water displacement method and analyzed by using BW Gas Alert Micro Percentage analyzer to determine the methane content in percentage from the biogas produced. Both the temperature and pH were monitored by using HI 8424 Hanna instruments electrode/probe.

2.4. Experimental set-up

The experiment was carried out in a single stage laboratory scale reactor. The complete mix anaerobic reactor is made from stainless steel of 10 L capacity consisting of a top plate supporting a mixer, a mixer motor and equipped with sampling ports. The four reactors were run concurrently. Sludge was sampled from an outlet port located at the bottom side of the reactor. Prior to daily feeds, an equivalent volume of the sludge was sampled for analytical analysis. The schematic configuration of the anaerobic biogas reactor is given in Fig. 1. The general characteristics of the oil palm mesocarp fibre, cattle manure and palm oil mill effluent are given in Table 1.The experiment was carried out at both batch and semi-continuous digestion process under uncontrolled daily ambient temperature and uncontrolled pH. The reactors were named R1 (pre-treated OPMF + CM + POME); 3.5 L each of both treated POMF and CM seeded with 1 L of POME, R2 (untreated OPMF + CM + POME); 3.5 L each of both pre-treated OPMF and CM seeded with 1 L of POME, R3 (pre-treated OPMF), and R4 (untreated OPMF) as substrate mixtures at different mixture conditions with organic loading of 1.62 and 2.11 g VS added L^{-1} day. Organic loading rate of 1.0 and 2.11 kg VS L^{-1} d^{-1} were achieved.

2.5. Statistical analysis

The results obtained were statistically analyzed using analysis of variance (ANOVA), and tests of significance carried out by Duncan's multiple range test at $P \leq 0.05$ (Steel and Torrie, 1980).

3. Results and discussion

3.1. Effect of pretreatment on OPMF

Table 1 shows the characteristics of the substrate used in this study. The lignocellulose composition of OPMF was determined before and after cultivation of oyster mushroom and analyzed for hemicellulose, cellulose and lignin, the results were presented in Fig. 2. The spectrum of mesocarp fiber pretreatment with *Pleurotus* spp. revealed a Proportional decreased in the lignocellulose contents. Fig. 2 shows the initial lignocellulose content of the mesocarp

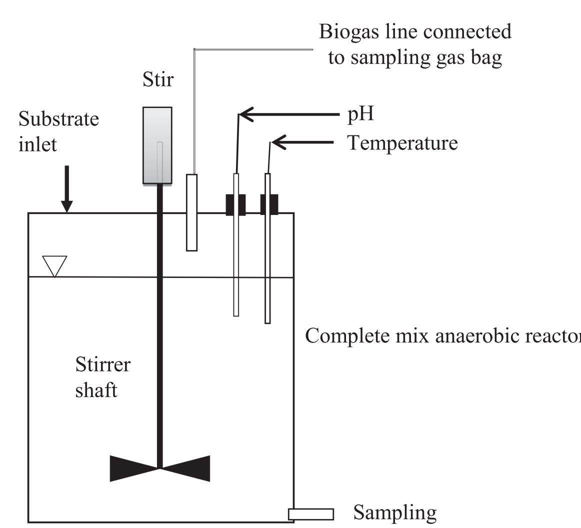

Fig. 1. The schematic configuration of the anaerobic biogas reactor.