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Pretreatment of oil palm empty fruit bunch (OPEFB) by *N*-methylmorpholine-*N*-oxide (NMMO) for biogas production: Structural changes and digestion improvement

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HIGHLIGHTS

- Oil palm empty fruit bunch was pretreated by NMMO.
- The pretreatment was performed at 90, 120 °C for 1, 3, 5 h using NMMO 73%, 79%, and 85%.
- The pretreatment increased the amorphous phase of OPEFB's cellulose up to 78%.
- Methane yield was improved up to 98.3% compared to the theoretical yield.

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ABSTRACT

Pretreatment of OPEFB (oil palm empty fruit bunch) by NMMO (*N*-methylmorpholine-*N*-oxide) on its subsequent digestions was investigated. The pretreatments were carried out at 90 and 120 °C for 1, 3, and 5 h in three different modes of dissolution (by 85% NMMO solution), ballooning (79% NMMO solution), and swelling (73% NMMO solution). The total solid recovery after the pretreatment was 89–94%. The pretreatment process did not have a major impact on the composition of OPEFB, other than a reduction of ash from 5.4% up to 1.3%. The best improvement in biogas production was achieved by a dissolution mode pretreatment of OPEFB, using conditions of 85% NMMO, 3 h, and 120 °C. It resulted in 0.408 Nm^3/kg VS methane yield and 0.032 Nm^3 CH_4/kg VS/day initial methane production rate, which correspond in improving by 48% and 167% compared to the untreated OPEFB, respectively.

1. Introduction

Biogas is a promising alternative energy source that can be used for different applications in heating, cooking, electricity production, vehicle fuels. 1 m^3 of biogas is approximately equivalent to 0.65 l fuel oil (ECO2L, 2011), depending on its methane content. Biogas production from various waste substrates is performed by different groups of anaerobic bacteria in a series of biochemical reactions including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. The ultimate products are methane and carbon dioxide, and a solid residue "digestate", which is a nutrient-rich product used as fertilizer (Seppälä et al., 2009). Biogas can be produced from a variety of available carbon sources such as manure, wastewater sludge, crops residuals, biological fractions of municipal wastes and lignocellulosic materials.

Oil palm empty fruit bunch (OPEFB) is a solid lignocellulosic waste generated as a byproduct of the palm oil industry. Annual world production of OPEFB in 2011 was approximately 14.5 million tons (dry base), where half of this amount was produced in Indonesia (USDA, 2012; DOA, 2006). OPEFB was previously considered as feedstock for production of a variety value-added products, such as citric acid (Bari et al., 2009), xylose (Zhang et al., 2012), activated carbon (Alam et al., 2009), butanol (Noomtim and Cheirsilp, 2011), hydrogen (Ismail et al., 2012), bio-oil (Abdullah and Gerhauser, 2008), ethanol (Jung et al., 2011), and biogas (Nieves et al., 2011).

In addition to cellulose, hemicellulose, and lignin, OPEFB is rich in inorganic elements such as silica and metal ions e.g. copper, calcium, manganese, iron and sodium (Law et al., 2007). The cell walls of OPEFB fibers are much thicker than hardwoods e.g. aspen, and as

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