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Effect of goethite on anaerobic co-digestion process of corn straw and algae biomass

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1 Introduction

Recently the demand for fossil fuel has grown significantly with the rapid development of the Chinese economy. Renewable energy was developed to replace traditional fossil fuels, which would decrease the greenhouse gas emissions and reduce air pollution caused by fossil fuel combustion (Shen et al., 2010). Micro-algae are well-suited biomass resources because of their relatively high lipid, starch, and protein contents, as well as the lack of lignin. According to their carbon and nitrogen compositions, the co-digestion of algal and lignocellulosic biomass is an effective way to improve the conversion efficiency and methane yield in anaerobic digesters (Zhong et al., 2012).

Recently, it has been demonstrated that iron oxides could accelerate the anaerobic conversion of organic biomass, such as aquatic plant, and algal biomass (Ma et al., 2015). However, it is still not clear whether the methane production yield and substrate degradation efficiency could be further enhanced in the anaerobic co-digestion process with the addition of iron oxide. So, in the current study effect of goethite on the anaerobic co-digestion of lignocellulosic and algal biomass feedstocks was investigated.

2 Materials and Methods

Corn straw was collected from a private farm located at Feidong (Hefei, China). Algal biomass was taken from Chao Lake and stored at −20°C. Digester sludge was taken from the industrial wastewater treatment plant of the Anhui Golden Seed Winery Co., Ltd. (Fuyang, Anhui). The sludge was passed through a 40-mm sieve, and the filtrate was used as the inoculum.

Goethite was bought from a Zhenxin refinery chemical company (Zhenxin, China). Six batch tests were performed with 7.0 L anaerobic fermenter with a working volume of 3.5 L. The initial substrate concentration was fixed at 20 g VS L^{-1} and the inoculum sludge was 2.0 g VS L^{-1}. Firstly, three anaerobic fermenters were operated following the addition of corn straw, algal biomass, or a mixed substrate (14.2 and 5.8 g VS L^{-1} of corn straw and algal biomass, respectively). Secondly, goethite (1.12 g L^{-1} based on the iron content) was added to three other batches.

Soluble fractions of the reactor samples were obtained after centrifugation at 14000 rpm for 10 min at 4°C. The supernatant liquid was filtered with a 0.45 μm membrane and was used to measure carbohydrate and protein. Methane was determined by using a gas chromatography (GC-2010, Shimadzu Co., Ltd., Kyoto, Japan).

3 Results and Discussion

Methane yield in the reactor with only algae biomass was 142±12 mL g-1 VS and that in the reactor with corn straw was only 49±10 mL g-1 VS. The experimental result showed a yield of 253±22 mL g-1 VS in the reactor with mixture of algae biomass and corn straw, which was around 3 times of their production when digested alone based on the VS ratios. Such synergistic effect was attributed to the balanced nutrient levels as previously reported (Zhong et al., 2012). The low methane yield in the reactor with corn straw was attributed to the low pH, which inhibited the activity of methanogenic microorganisms. This might be attributed to the low buffering capacity in the corn straw-dosed reactor. It has been reported that in pH-controlled reactors, the addition of goethite increased the methane production yield from an aquatic curly leaf plant that was mainly composed of lignocellulose (Ma et al., 2015).

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Table 1 Effect of goethite on the reactor performance and liquid characteristic

	Algae	Algae + Goethite	Corn straw	Corn straw +Goethite	Co-digestion	Co-digestion + Goethite
Methane yield (mL/g VS)	142±12	163±16	49±10	55±18	253±22	289±21
VS reduction (%)	45.6±0.7	49.2±0.6	35.2±0.6	37.6±1.3	51.6±0.4	56.1±1.2
pH	7.68±0.08	7.82±0.12	6.54±0.13	6.72±0.07	7.06±0.06	7.15±0.11
Carbohydrate (mg/L)	375.7±25.6	338.3±33.4	238.4±25.9	178.5±20.7	410.5±34.1	307.9±24.5
Protein (mg/L)	974.3±35.1	710.2±22.8	15.2±3.5	13.6±4.7	680.3±48.9	570.1±56.1

When goethite was dosed into the co-digestion reactors, methane production increased to 866±39 mL, while the co-digestion reactors only produced 758±25 mL. The maximum methane yield in the goethite dosed co-digestion reactor was 289±21 mL g^{-1} VS, but it was only 253±22 mL g-1 VS in the co-digestion reactor (Table 1). Benefits from the external addition of goethite could be listed as follows. Firstly, release of Fe^{2+} could serve as an essential trace element for anaerobic microorganisms regarding to its function as an energy carrier for methanogenic microorganism and as a constituent of many enzymes, and decrease the system re-dox potential (Zhang et al., 2012). Secondly, goethite could promote the methane production from lignocellulosic biomass by enhancing the cellulolytic enzyme activity (Ma et al., 2015). Thirdly, goethite influenced the bacterial and methanogenic community significantly and further enhanced the syntrophic effects between acidogenic and methanogenic microorganisms (Yue et al., 2015).

The relatively low concentrations of carbohydrate and protein in the goethite-dosed reactors also demonstrated the higher hydrolysis efficiency (Table 1). Normally the doubling growth times of acetoclastic methanogens are much longer than those of fermentative and acidogenic microorganism under mesophilic conditions. This would result in the accumulation of acetate and inhibit the activities of acetoclastic methanogens and syntrophic fatty acid oxidizing bacteria (Karakashev et al., 2006). It has been proposed that co-digestion of dairy manure and corn straw improves the abundance of *Bacteroidetes* and *Clostridia* in the microbial community (Yue et al., 2013). Goethite addition would also improve the abundance of fatty acid oxidizing bacteria and promote methane production in the previous report (Tan et al., 2013). Thus, further research is needed to investigate these effects on the microbial community, as well as their underlying mechanism.

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