



Biogas production from wheat straw in batch and UASB reactors: The roles of pretreatment and seaweed hydrolysate as a co-substrate

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HIGHLIGHTS

- ▶ Wheat straw for biogas production.
- ▶ Acid catalysed steam pretreatment and enzyme hydrolysis improved methane yields.
- ▶ High methane production rate of straw hydrolysate in UASB reactor.
- ▶ Seaweed hydrolysate supplemented nutrients and buffer for straw hydrolysate.

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ABSTRACT

This research evaluated biogas production in batch and UASB reactors from pilot-scale acid catalysed steam pretreated and enzymatic hydrolysed wheat straw. The results showed that the pretreatment was efficient and, a sugar yield of 95% was obtained. The pretreatment improved the methane yield ($0.28 \text{ m}^3/\text{kg VS}_{\text{added}}$) by 57% compared to untreated straw. Treatment of the straw hydrolysate with nutrient supplementation in a UASB reactor resulted in a high methane production rate, $2.70 \text{ m}^3/\text{m}^3 \cdot \text{d}$ at a sustainable OLR of $10.4 \text{ kg COD}/\text{m}^3 \cdot \text{d}$ and with a COD reduction of 94%. Alternatively, co-digestion of the straw and seaweed hydrolysates in a UASB reactor also maintained a stable anaerobic process and can thus reduce the cost of nutrients addition. We have shown that biogas production from wheat straw can be competitive by pretreatment, high methane production rate in UASB reactors and also by co-digestion with seaweed hydrolysate.

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1. Introduction

The objective of the European Commission on Renewable Energy Road Map is to increase the gross domestic energy consumption from renewable energy sources, which amounted to 12.4% in the EU in 2010 (EurObserv'ER, 2011), to 20% by 2020. Sweden, however, already produces about 30% of its total energy from renewable sources, due to its large renewable energy assets and an active engagement in energy policies (Swedish Energy Agency, 2011). Biogas currently contributes 0.4% (3 TWh/year) of energy consumed in Sweden, and this could be increased to 74 TWh/year by using natural waste and forest residues. The use of new biomass resources, improved process technology, and energy, agricultural, environmental and waste-handling policies that promote sustainable development (Lantz et al., 2007) are all important to maximise the use of the energy bound in biomass resources and to attain the goal that have been set.

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Biogas production can be increased by using abundant lignocellulose materials such as agricultural and forest residues (Zeng et al., 2007). However, the complex lignocellulose structure limits the accessibility of the sugars in cellulose and hemicellulose. This means that pretreatment is necessary to gain access to the sugars bound in lignocellulose, and several efficient pretreatment methods for lignocellulose material have been developed (Alvira et al., 2010). One example of such a method is steam pretreatment in the presence of dilute acid, which results to efficient lignocellulose hydrolysis and sterilisation. Building a steam pretreatment unit requires a huge initial investment, and the operation of such a plant consumes energy. Both of these factors are major drawbacks. However, process integration with other heat and power plants that produce waste heat, and the use of heat exchangers in the processing steps can substantially reduce the requirement for energy input (Ljunggren and Zacchi, 2010). Today, there are many operational demonstration ethanol plants that employ steam pretreatment and enzyme hydrolysis techniques for lignocellulose degradation (Gnansounou, 2010). The use of sulphuric acid during steam pretreatment in the presence of dilute acid is another