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Comparison of solid-state to liquid anaerobic digestion of lignocellulosic feedstocks for biogas production

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HIGHLIGHTS

- ▶ Solid state anaerobic digestion (SS-AD) of eight types of lignocellulosic biomass.
- ▶ Liquid anaerobic digestion (L-AD) of eight biomass feedstocks was compared with SS-AD.
- ▶ No significant difference in methane yield between SS-AD and L-AD.
- ▶ Volumetric biogas productivity of SS-AD was 2- to 7-fold greater than that with L-AD.
- ▶ Methane yields from crop residues were higher than those from woody biomass.

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ABSTRACT

Lignocellulosic biomass feedstocks (switchgrass, corn stover, wheat straw, yard waste, leaves, waste paper, maple, and pine) were evaluated for methane production under liquid anaerobic digestion (L-AD) and solid-state anaerobic digestion (SS-AD). No significant difference in methane yield between L-AD and SS-AD, except for waste paper and pine, were found. However, the volumetric productivity was 2- to 7-fold greater in the SS-AD system compared with the L-AD system, except for paper. Methane yields from corn stover, wheat straw, and switchgrass were 2–5 times higher than those from yard waste, maple, and pine biomass. Waste paper had a methane yield of only 15 L/kg VS caused by souring during SS-AD due to organic overloading. Pine also had very low biogas yield of 17 L/kg VS, indicating the need for pretreatment prior to SS-AD. The findings of this study can guide future studies to improve the efficiency and stability of SS-AD of lignocellulosic biomass.

1. Introduction

Anaerobic digestion (AD) is a naturally occurring phenomenon in which organic matter is decomposed by an assortment of microbes in an oxygen-free environment to produce biogas, composed primarily of methane (CH_4) and carbon dioxide (CO_2) (Frigon and Guiot, 2010). Although the initial applications of AD were for stabilization and treatment of waste sludge, AD can also be a source of renewable energy (Yu and Schanbacher, 2010). AD not only provides an alternative source of energy but is also an alternative route to divert organic wastes and reduce greenhouse gas emissions from landfills (Mata-Alvarez et al., 2000; Frigon and Guiot, 2010).

The presence of lignin, the crystallinity of cellulose, and limited surface availability reduce the biodegradability of lignocellulosic biomass, making the hydrolysis step one of the bottlenecks that limit the production of methane (Frigon and Guiot, 2010). The methanogenic bacteria involved in AD have a low growth rate and are sensitive to inhibitors such as low pH caused by excessive concentrations of volatile fatty acids (VFAs). Thus, maintaining a balance of the four phases (hydrolysis, acidogenesis, acetogenesis and methanogenesis) of the AD process is essential. The effect of composition of lignocellulosic biomass on methane yield has already been studied extensively; however, most of these studies were limited to liquid AD (L-AD) which operates at a total solids (TS) content of 15% or less even though solid-state AD (SS-AD), which is generally operated at a TS content of 15% or higher (Guendouz et al., 2010), would be ideal for feedstocks such as agricultural and municipal solids wastes due to their availability and low moisture content (Yu and Schanbacher, 2010). SS-AD has many advantages over L-AD including a smaller reactor volume for the same solids loading; fewer moving parts; lower energy input for heating and mixing; easier to handle end product; and a greater acceptance of inputs containing glass, plastics, and grit (Li et al., 2011). Problems in L-AD, such as floating and stratification of fats, fibers, and plastics, are not present in SS-AD (Chanakya et al., 1999).

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