Bioresource Technology 114 (2012) 406–413

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Hydrolysis and acidification of grass silage in leaching bed reactors

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ARTICLE INFO

Article history:
Received 25 November 2011
Received in revised form 28 February 2012
Accepted 2 March 2012
Available online 10 March 2012

Keywords:
Acidification yield
Anaerobic digestion
Grass silage
Hydrolysis yield
Leaching bed reactor

ABSTRACT

Hydrolysis and acidification of grass silage (GS) was examined in leaching bed reactors (LBRs) under organic loading rates (OLRs) of 0.5, 0.8 and 1.0 kg volatile solids (VS)/m^3/day. The LBRs were run in duplicate over five consecutive batch tests (Batch tests 1–5) to examine the effects of pH, leachate dilution and addition of inoculum on the process of hydrolysis and acidification. The highest GS hydrolysis yields of 52–58%, acidification yields of 57–60% and VS removals of 62–66% were obtained in Batch test 4. Increasing OLRs affected the hydrolysis yield negatively. In Batch test 4, the reduction of lignocellulosic materials was up to 74.4% of hemicellulose, 30.1% of cellulose and 9.3% of lignin within 32 days. Cellulase activity can be used as an indicator for the hydrolysis process. Methane production from the LBRs only accounted for 10.0–13.8% of the biological methane potential of GS.

1. Introduction

Anaerobic digestion (AD) of organic matter produces methane-rich biogas. Methane can replace fossil fuels for heat and electrical power generation as well as a vehicle fuel. Ireland has a suitable climate for grass production and has 4.3 million ha of grassland in comparison with only 280,000 ha of arable land. Grass is often conserved as winter forage for ruminant livestock as grass silage (GS). It has high digestible organic matter and volatile solids (VS) contents, and can be used as a feedstock for AD (Nizami and Murphy, 2011). Anaerobic digestion of GS alone or with animal wastes is considered as a feasible way to generate sustainable energy and mitigate greenhouse gas emissions (Prochnow et al., 2009).

The conversion of GS to biogas via AD consists of three steps: hydrolysis, acidogenesis and methanogenesis, in which hydrolysis is the rate-limiting step (Shin-ya et al., 2001). Hydrolysis converts starch, lignocellulosic materials (cellulose, hemicellulose and lignin), fats and proteins, into small molecules like sugars, long-chain fatty acids and amino acids. These compounds are further broken down, with volatile fatty acids (VFAs) as major final products; this process is called acidification. Enhancement of hydrolysis will lead to faster anaerobic digestion. To maximize methane production, two-stage anaerobic digestion has been studied and adopted in practice (Lehtomäki et al., 2007). The two-stage AD process consists of two separate reactors or reactor zones where the individual fermentative or methanogenic stages are carried out. Fermentative micro-organisms, dominating in the first fermentation stage, hydrolyze and acidify biomass to hydrogen, carbon dioxide and volatile fatty acids, while methanogens, dominating in the second methanogenic stage, convert the gaseous products and VFAs produced in the first stage into methane and carbon dioxide. The separation of the two types of microorganisms in two individual reactors or reactor zones where different conditions are applied to optimize their activities increases the stability of the AD process and biogas yields.

Leaching bed reactors (LBRs) have been developed as the first-stage reactor to treat solid wastes and biomass such as energy crops (Nizami et al., 2010). LBRs are operated in a batch mode instead of a continuous feeding/withdrawing mode. The solid feedstock is added into LBRs at the start of a batch and liquid leachate is continuously circulated along the reactors upwards or downwards to enhance solubilisation and hydrolysis of solid biomass. The leachate in LBRs contains high concentrations of dissolved organic matter mainly in the forms of VFAs which can be further treated in reactors where acetogenesis and methanogenesis occur (Demirer and Chen, 2008). For example, LBRs can be integrated with upflow anaerobic sludge bed reactors (UASB) for biogas production. This integrated system can be more effective than conventional one-stage AD systems (Nizami et al., 2010). By using LBRs, problems associated with operation of direct anaerobic digestion of energy crops, like pumping, handling and mixing, can be avoided (Jagadabhi et al., 2010).

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0960-8524/$ - see front matter
http://dx.doi.org/10.1016/j.biortech.2012.03.008