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Improved biogas production from whole stillage by co-digestion with cattle manure

Maria Westerholm [a], Mikael Hansson [b], Anna Schnürer [a,*]

[a] Department of Microbiology, Swedish University of Agricultural Sciences, Uppsala BioCenter, P.O. Box 7025, SE-750 07 Uppsala, Sweden
[b] Swedish Institute of Agricultural and Environmental Engineering, P.O. Box 7033, SE-750 07 Uppsala, Sweden

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ABSTRACT

Whole stillage, as sole substrate or co-digested with cattle manure, was evaluated as substrate for biogas production in five mesophilic laboratory-scale biogas reactors, operating semi-continuously for 640 days. The process performance was monitored by chemical parameters and by quantitative analysis of the methanogenic and acetogenic population. With whole stillage as sole substrate the process showed clear signs of instability after 120 days of operation. However, co-digestion with manure clearly improved biogas productivity and process stability and indicated increased methane yield compared with theoretical values. The methane yield at an organic loading rate (OLR) at 2.8 g VS/(L × day) and a hydraulic retention time (HRT) of 45 days with a substrate mixture 85% whole stillage and 15% manure (based on volatile solids [VS]) was 0.31 N L CH_4/g VS. Surprisingly, the abundance of the methanogenic and acetogenic populations remained relatively stable throughout the whole operation and was not influenced by process performance.

1. Introduction

Intensifying demands to mitigate anthropogenic greenhouse gas emissions and to supply sustainable energy have led to increasing attention for biofuel production in recent years. Today, ethanol is one of the major biofuels obtained from agriculture in Europe, but biogas is also produced in increasing amounts (EurObserv'ER, 2010). Biogas production is considered to have comparably higher potential benefit with regard to resource and energy efficiency (Börjesson and Mattiasson, 2007), whereas ethanol can be blended with petrol and thereby has the advantage of being more easily integrated into the existing petroleum fuel system. Thus, with the aim of reaching the EU goal of replacing 20% of the fossil fuels used for transportation with fuels from renewable sources by 2020 (EC, 2001), it seems likely that the production of both biogas and bioethanol will expand in the future. In this regard, combining the processes through biogas production from the by-products of ethanol fermentation has recently gained increased interest. Several studies have illustrated that combining these processes improves both the economic and ecological outcome of biomass utilisation (Börjesson and Mattiasson, 2007; Dererie et al., 2011; Kreuger et al., 2011).

The residue from ethanol fermentation is called whole stillage and is today mainly used for animal feed. Before being used as feed, the stillage is processed through centrifugation, evaporation and drying in order to increase shelf-life and reduce the transportation costs. This processing is very energy-intensive and accounts for about 30–45% of the total energy demand at the bioethanol plant (Eskicioglu et al., 2011; Ziganshin et al., 2011). Whole stillage contains high levels of proteins, and is therefore an energy-rich material with high potential as substrate for biogas production. Furthermore, if unprocessed whole stillage were used for anaerobic degradation, the total energy requirement at the ethanol plant would be significantly decreased. Whole stillage, or processed fractions of whole stillage, has been demonstrated in batch assay and laboratory-scale anaerobic reactor experiments to possess a considerable biogas potential (Dererie et al., 2011; Eskicioglu et al., 2011; Gao et al., 2007; Ziganshin et al., 2011). It is currently being used for biogas production in several large-scale biogas plants in Sweden (Mariana Fridfjell, Swedish Biogas, Linköping, Sweden, personal communication 2011).

Different feedstocks and different fermentation and processing technologies are used for ethanol production at present (Sánchez and Cardona, 2008). The physical, chemical and biological properties of the stillage produced at different ethanol plants thereby vary, which consequently influences the methane yield and performance of the anaerobic digestion process. Factors that need to be considered during usage of distiller's waste as substrate for biogas production include: (i) low C/N ratio (<15), as the high protein content of distiller's waste poses a risk of process disturbance due to ammonia inhibition (Chen et al., 2008; Weiland, 2010); (ii) high levels of sulphate, as sulphuric acid is often added for pH control and pre-treatment during ethanol fermentation. Sulphate in distiller's waste can activate sulphate-reducing bacteria, which compete with methanogens for substrate, resulting in gas production

* Corresponding author. Tel.: +46 18 671000; fax: +46 18 673393.
E-mail address: Anna.Schnurer@slu.se (A. Schnürer).

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