Bioresource Technology 118 (2012) 445–454

Contents lists available at SciVerse ScienceDirect

Bioresource Technology

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

Stable operation during pilot-scale anaerobic digestion of nutrient-supplemented maize/sugar beet silage

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HIGHLIGHTS

- High performance in crop mono-anaerobic digestion was achieved in pilot-scale.
- Methane yields were comparable to lab-scale maximum expected yields.
- Macro-and micronutrients enabled digestion at short hydraulic retention time.
- Contrary to previous reports, no viscosity problems were encountered.
- The effluent compiled with Swedish certification standards for bio-fertilizers.

ARTICLE INFO

Article history:
Received 20 March 2012
Received in revised form 15 May 2012
Accepted 19 May 2012
Available online 26 May 2012

Keywords:
Bio-fertilizer
Biogas
Energy crops
Macronutrients
Micronutrients

ABSTRACT

Biogas production from maize/sugar beet silage was studied under mesophilic conditions in a continuous stirred tank reactor pilot-scale process. While energy crop mono-digestion is often performed with very long hydraulic retention times (HRTs), the present study demonstrated an efficient process operating with a 50-day HRT and a corrected total solids (TS_{corr}) based organic loading rate of 3.4 kg/m^3 d. The good performance was attributed to supplementation with both macro- and micronutrients and was evidenced by good methane yields (318 m^3/ton TS_{corr}), which were comparable to laboratory maximum expected yields, plus low total volatile fatty acid concentrations (<0.8 g/L). A viscoplastic and thixotropic digester fluid behaviour was observed, and the viscosity problems common in crop mono-digestion were not seen in this study. The effluent also complied with Swedish certification standards for bio-fertilizer for farmland application. Nutrient addition thus rendered a stable biogas process, while the effluent was a good quality bio-fertilizer.

1. Introduction

The use of energy crops as feedstock for biogas production is increasing. An estimated 7% of the farmland in Germany was used for this purpose in 2011 (FNR, 2012). The characteristics of crops, such as poor nutrient concentration, have led to problems such as low methane yields, acidification and process instability in crop mono-digestion, leading to application of low organic loading rates (OLRs) and long hydraulic retention times (HRTs) (Lebuhn et al., 2008; Weiland, 2010). A deficiency of micronutrients such as iron (Fe), cobalt (Co), nickel (Ni), tungsten (W) or molybdenum (Mo), has been shown to cause problems in the microbial degradation chain, while supplementation has been shown to improve the performance of anaerobic digestion of crop silage (Hinken et al., 2008; Pobeheim et al., 2010; Takashima et al., 2011). These micronutrients are cofactors of enzymes or coenzymes involved in the biosynthesis of methane and the growth of anaerobic bacteria. Macronutrients such as nitrogen (N), sulphur (S) and phosphorus (P) also play a vital role in the growth and metabolism of anaerobic bacteria; acting as buffering agents/balancing carbon (C):N ratio (N) or as integral part of enzymes involved in methane production (S and P) (Pobeheim et al., 2010; Procházka et al., 2012; Takashima et al., 2011). Thus, adequate amounts of both macro- and micronutrients, as for example in manure (Bruni et al., 2010), are crucial for the overall performance of the biogas process. The requirements for a better nutrient balance are often fulfilled by co-digesting energy crops with manure (Cavinato et al., 2010). However, there is regional scarcity of manure (Lebuhn et al., 2008). In a large number of crop-based biogas plants monitored in a German study (FNR, 2010), presented data showed that continuously stirred tank reactors (CSTRs) operating with more than 50% manure together with the energy crops (13 plants) were operated at an average HRT of 46 ± 9 days, while plants operating with no or less than 30%

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http://dx.doi.org/10.1016/j.biortech.2012.05.096