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Methane production from cattle manure supplemented with crude glycerin from the biodiesel industry in CSTR and IBR

L. Castrillón *, Y. Fernández-Nava, P. Ormaechea, E. Marañón

Chemical Engineering and Environmental Technology Department, University Technology Institute of Asturias (IUTA), University of Oviedo, Campus of Gijón, 33203 Gijón, Spain

HIGHLIGHTS

- Biogas production of cattle manure was optimised by adding glycerin as co-substrate.
- Better results using induced bed reactor versus continuously stirred tank reactor.
- Optimum organic loading rate was 6.4 kg COD/m^3 day in inducted bed reactor.
- Ninety percent COD removal and 0.59 m^3 CH_4/kg VS (56.5 m^3/t waste) were achieved.

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ABSTRACT

The aim of the present research work was to optimise biogas production from cattle manure by adding crude glycerin from the biodiesel industry. For this purpose, 6% v/v crude glycerin (the optimum amount according to previous research) was added to ground manure and the mixture was sonicated to enhance biodegradability prior to anaerobic co-digestion at 55 °C. Two different reactors were used: continuously stirred (CSTR) and induced bed (IBR). The methanol and pure glycerin contents of the crude glycerin used in this study were 5.6% and 49.4% (w/w), respectively. The best results when operating in CSTR were obtained for an organic loading rate (OLR) of 5.4 kg COD/m^3 day, obtaining 53.2 m^3 biogas/t wet waste and 80.7% COD removal. When operating in IBR, the best results were obtained for an OLR of 6.44 kg COD/m^3 day, obtaining 89.6% COD removal and a biogas production of 56.5 m^3/t wet waste.

1. Introduction

In view of its high greenhouse gas emission saving potential, the use of agricultural material such as manure, slurry and other animal and organic wastes for biogas production has significant environmental advantages in terms of heat and power production and its use as a biofuel. As a result of their decentralised nature and region-based investment structure, biogas plants can contribute significantly to sustainable development in rural areas in addition to providing farmers with new income opportunities (Directive 2009/28/EC). However, the low biogas yield of animal manure sometimes does not warrant the capital costs of farm-scale plants (Cavinato et al., 2010). The high water content, together with the high fraction of fibres in cattle manure, is the reason for the low methane yields obtained when manure is anaerobically digested, typically ranging from 10 to 20 m^3 CH_4 per tonne of manure treated (Angelidaki and Ellegaard, 2003). The authors of the present study obtained specific methane yields of 0.15–0.19 m^3 CH_4/kg volatile solids (VS) in the anaerobic treatment of dairy cattle manure and 69.7% chemical oxygen demand (COD) removal efficiencies (Marañón et al., 2001; Castrillón et al., 2002). These values are similar to those found by Amon et al. (2007), who reported a yield of 0.17 m^3 CH_4/kg VS.

In spite of low methane yields, manure is an excellent "carrier" substrate to enable anaerobic digestion of concentrated waste (which would be difficult to treat separately) for a number of reasons: its high water content, high buffering capacity and wide variety of nutrients, which are necessary for optimal bacterial growth (Angelidaki and Ellegaard, 2003).

Pre-treatments (chemical, thermal, ultrasound, enzymatic) can be applied to enhance biogas production and/or the manure can be co-digested with other wastes to achieve synergetic effects that make the anaerobic digestion process profitable. One possible co-substrate is glycerin from the production of biodiesel. The biodiesel industry generates millions of tonnes of crude glycerin waste each year, the production of which exceeds the present commercial demand for purified glycerin (Siles et al., 2009). Furthermore, the

* Corresponding author. Tel.: +34 985182382; fax: +34 985182337.
E-mail address: cleonor@uniovi.es (L. Castrillón).

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