Biogas production by anaerobic co-digestion of cattle slurry and cheese whey

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Abstract
Biogas yield of mixtures of cattle slurry and cheese whey, rates of production of methane, removal efficiencies of chemical oxygen demand (COD) and biological oxygen demand (BOD) were investigated at 35 °C. Stable biogas production of 621 l/kg volatile solids at a hydraulic retention time of 42 days in a mixture containing 50% slurry and whey was obtained. The concentration of methane in the biogas was around 55%. Maximum removal efficiencies for COD and BOD5 were 82% and 90%, respectively. A maximum biogas production increase of 79% with respect to the start-up phase was achieved. The result of this study show that co-digestion of a high volume of whey (up to 65% in volume) is possible without the use of chemicals for pH correction, but also that this kind of mix has a similar energetic potential for anaerobic digestion as energy crops such as maize.

1. Introduction

Anaerobic digestion is a technology for wastewater treatment, but also for energy production (electricity and heat) (Tchobanoulous et al., 2006). Biogas production from agricultural biomass is of growing importance as it offers considerable environmental benefits and is an additional source of income for farmers (Amon et al., 2007).

Currently the most-used feedstock for the anaerobic digester are crops. Maize is the dominating crop for biogas production and more than 40 tons of maize per hectare can be produced in Europe with a biogas yield of up to 350 l-CH4/kg-VS (after ensilage) at a low cost of 20–40 € per ton. Beside crops, other agro-wastes can be of interest for anaerobic co-digestion with livestock effluents in the form of manures (generally semi solid with a high straw content) or slurry (only cattle excrement that is generally liquid) because of their high energy potential (Angelidaki and Ellegaard, 2003).

Anaerobic co-digestion of livestock effluents and agricultural waste is widely applied in Europe (Weiland, 2010; Murto et al., 2004). Cheese whey is a by-product of cheese production rich in proteins and lactose with a high organic matter content (up to 70,000 mg/l chemical oxygen demand COD), very high biodegradability (approximately 99%), and relatively high alkalinity (about 2500 mg/l CaCO3) (Mawson, 1994; Erguder et al., 2001). Several studies found that treatment of raw whey was a concern due to the tendency for rapid acidification (Kalyuzhnyi et al., 1997). Other problems associated with direct anaerobic treatment of whey include instability of the reactor, difficulty to obtain granulation, and reduced sludge settling due to the tendency to produce an excess of viscous expolymorphic materials, probably of bacterial origin (Malaspina et al., 1995). Low biogas productivity and methane yields have been associated with the low pH of whey (Ghaly, 1996; Lo and Liao, 1989; Yan et al., 1990). Gelenegis et al. (2007), Comino et al. (2009), and Kavacik and Topaloglu (2010) examined the co-digestion of whey with different types of manure and concluded that whey was quantitatively degraded to biogas but not in an efficient way. In the present study, the feasibility of co-digestion of raw cheese whey and cattle slurry was investigated in a dairy farm anaerobic digestion treatment plant. Anaerobic digestion was initiated without the use of inoculums and tests with untreated substrates at different ratios were conducted. A digestate methane yield test was also carried out and economic aspects of the technology were analyzed.

2. Methods

2.1. Experimental device

The anaerobic reactor (Fig. 1) had a total volume of 128 L. The reactor was heated with 15 m of electrical resistance and insulated to maintain a constant temperature of 35 °C ± 0.5. The system can be divided into control panel, feeding system, digester and agitation system and gasometer.

The control panel was located in a closed box and included the electric system controls required for the functioning of the digester.