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Feasibility of anaerobic co-digestion of pig waste and paper sludge

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HIGHLIGHTS

- ▶ Benefits of co-digestion of pig waste and paper sludge demonstrated by BMP assays.
- ▶ Hydrolysis constants for co-digestion 2–20 times higher than baseline wastes.
- ▶ Semi-continuous digester shows higher performance for co-digestion than pig waste.

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ABSTRACT

Pig waste (PW) and paper sludge (PS) possess complementary properties that can be combined for successful anaerobic digestion. Biochemical methane potential (BMP) tests revealed that a PW:PS 3:1 (v/v) ratio had the highest normalized CH_4–COD removal (54%), while PS had the lowest value (11%) and PW had 44%. Batch BMP tests revealed a significant decrease in lag times for methane production in the order of PW:PS 1:3 (14 days) < PW:PS 1:1 (17 days) < PW:PS 3:1 (20 days) < PW (23 days). Hydrolysis constants (k_{hyd}) were higher for all PW:PS combinations than for either of the individual waste streams: 0.004 d^{-1} (PS) < 0.02 d^{-1} (PW) < 0.024 d^{-1} (PW:PS 3:1) < 0.03 d^{-1} (PW:PS 1:1) < 0.05 d^{-1} (PW:PS 1:3). Semi-continuous reactors performing co-digestion of PW and PS at a 2:1 ratio showed 1.5 times higher methane production than baseline PW-only reactors, confirming the BMP results.

1. Introduction

The carbon in organic wastes has high-energy electrons that can be transformed into useful forms of energy for society. Anaerobic digestion, a mature technology for capturing these electrons as methane gas (CH_4), is widely used worldwide. In the USA, for example, over 1500 anaerobic digesters are currently in operation: approximately 135 treating livestock/agricultural wastes, 850 for municipal solid waste removal, and 544 in wastewater treatment plants (Alternative and Advanced Fuels – Biogas, 2009). While the current application of anaerobic digestion is significant, much more anaerobic digestion is possible for animal waste and pulp and paper waste, which represent the two largest fractions of waste biomass generated in the USA; waste biomass amounts are summarized in Table 1.

Pig waste (PW) represents a significant fraction of animal wastes, the largest waste stream in Table 1. Likewise, paper sludge (PS), which is mainly residues from various stages of paper mill operation, is the largest pulp and paper waste. While containing a large potential for energy recovery, both of these large waste streams pose unique challenges when subjected to anaerobic digestion.

Due to the high protein content in the diet of young pigs, PW has a very high organic-nitrogen (N) content that is converted to total ammonia during hydrolysis and fermentation. Inhibition of methanogenesis due to high concentrations of total ammonia is a well-established fact (Van Velsen, 1979; Cheung et al., 2002; Sossa et al., 2004; Sawayama et al., 2004; Kayhanian, 1993; Poggi Veraldo et al., 1997; Koster and Lettinga, 1984; Hansen et al., 1998). The major inhibition is caused by unionized ammonia (NH_3) at a concentration of 150 mg N/L or higher, but the ammonium ion NH_4^+ also exhibits toxicity at very high concentrations, 5 g N/L or above (Braun et al., 1981). Overcoming inhibition has a high payback, because 30–40% of the total COD in PW is soluble and immediately bioavailable (Jindal et al., 2006), a value much higher than in stabilized biomass, such as waste activated sludge (Jindal et al., 2006). In addition, the high N content of pig waste gives it a high alkalinity, because the organic N is hydrolyzed to NH_3, a moderately strong base ($pK_b = 3.7$, Snoeyink and Jenkins, 1980): 1 mol of bicarbonate alkalinity is released for every mole of ammonia released, and this corresponds to 3.6 mg as $CaCO_3$ per mg N. Alkalinity is essential for stable pH control.

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