ANAEROBIC CODIGESTION OF HOG AND POULTRY WASTE

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Abstract. This study assessed the feasibility of the anaerobic codigestion of hog and poultry waste. Anaerobic batch tests were performed using hog and poultry wastes in various proportions. Treatments that received both wastes produced higher yields of biogas, up to 200±30 mL/g volatile solids (VS) destroyed, and methane, up to 130±20 mL/g VS destroyed, compared to either waste alone. The apparent complementation of the two wastes may reflect the absence of an added inoculum during the test.

Keywords: agricultural waste, animal waste, anaerobic digestion, methanogenesis, waste treatment.

INTRODUCTION

The massive waste loads generated by large confined animal operations have made animal waste treatment a critical issue. Proper treatment is required to avert the adverse effects of these wastes on water quality, public health, and air quality. Many states, including Georgia, have halted or drastically curtailed the establishment of new hog feedlots. As Georgia already generates a large volume of poultry waste, this study investigated the treatment of a combined stream of hog and poultry waste through anaerobic digestion.

Anaerobic digestion results in the conversion of organic matter into methane and carbon dioxide via a series of interrelated microbial metabolisms. Digestion of manure (Hill, 1982), a complex substrate containing dissolved and particulate organic matter, initially proceeds through the hydrolysis and solubilization of complex high molecular weight organic compounds into smaller compounds, which are in turn fermented by acidogenic bacteria into volatile fatty acids (VFAs). Acidogenesis principally yields acetate, propionate, and butyrate, the latter two degraded further by propionate- and butyrate-utilizing acetogens into acetate, hydrogen, and carbon dioxide. Acetate is then converted into methane and carbon dioxide by aceticlastic methanogens, while hydrogenotrophic methanogens convert carbon dioxide and hydrogen into methane. The resulting gas mixture, mostly methane and carbon dioxide, with smaller amounts of hydrogen, hydrogen sulfide, and ammonia, is referred to as biogas.

Given the complex interactions between the various constituent populations of the microbial consortium, a number of factors can upset the anaerobic digestion process. Excessive VFA accumulation can reduce the pH to a level that inhibits methanogenesis, while high hydrogen levels can inhibit propionate- and butyrate-degrading acetogens (Angelidaki *et al.*, 1993). Manure also contains compounds, i.e., proteins and urea, which upon degradation release ammonia, a potent inhibitor of aceticlastic methanogens (Poggi-Varaldo *et al.*, 1991). Ammonia toxicity has been observed in the digestion of cattle manure, which has ~2.5 g/L ammonia nitrogen (NH_3-N) (Angelidaki and Ahring, 1994), and is an even greater problem in hog and poultry manure, which contain >4 g/L NH_3-N (Angelidaki and Ahring, 1993). Toxic effects are attributed to free ammonia and not to the protonated ionic species (Hansen *et al.*, 1998).

Preliminary studies were undertaken to assess the feasibility of anaerobic codigestion of hog and poultry manure and to identify potential process constraints.

METHODS

Experimental

Flushings from hog operations were collected at the drainage sump of a hog house at the UGA Swine Research Facility, South Milledge Ave., Athens, GA. Layer manure was collected at the UGA Poultry Research Facility, South Milledge Ave., Athens, GA, and diluted with tap water to the approximate concentration obtained after washdown. The wastes were poured through a coarse (~0.25 in) plastic mesh to remove gross solids and transferred to 125 mL serum bottles. Six treatments, containing 100 (H100), 80 (H80), 60 (H60), 40 (H40), 20 (H20), or 0 (H0) mL of hog waste, plus sufficient poultry waste to make 100 mL, were prepared in five replicates. The bottles were sealed using aluminum crimp closures with gray butyl

rubber septa, and incubated at 35±2 °C for up to 113 d. Biogas production was measured daily by water displacement. Headspace methane concentration was monitored in one series of bottles, while a second series was regularly sampled for ammonia analysis and pH measurement. Periodically, bottles from each treatment were sacrificed for solids and soluble chemical oxygen demand (SCOD) analysis.

Analytical

Methane concentration was measured using a 5890 Series II Plus gas chromatograph (Hewlett-Packard, Palo Alto, CA) equipped with a thermal conductivity detector and a Hayesep A 120/140 40'x 1/8" x 0.085" stainless steel column (Alltech, Deerfield, IL), with helium as carrier gas. Total ammonia nitrogen (NH_3-N) was quantified based on the phenate method, *Standard Methods* (1992) Part 4500-NH_3D, using a TRAACS 2000 analyzer (Braun + Luebbe, Norderstedt, Germany). Equivalent free NH_3-N concentrations were calculated based on temperature, pH, and equilibrium data (Hansen *et al.*, 1998). SCOD was quantified by the colororimetric dichromate closed reflux method, *Standard Methods* (1992) Part 5220D, using Hach (Loveland, CO) COD digestion vials. Samples for ammonia and SCOD analysis were acidified to pH ~2 with *o*-phosphoric acid, centrifuged at 12,000 rpm for 10 min, and the supernatant decanted. SCOD samples were then purged with nitrogen for 2 min. Total (TS), volatile (VS), total suspended (TSS), and volatile suspended (VSS) solids were determined according to *Standard Methods* (1992) Part 2540. The pH was estimated using pH paper (Micro Essential Laboratory, Brooklyn, NY).

RESULTS

Destruction of Organic Matter

VS (Figure 1a) and VSS (Figure 1b) decreased in all treatments. VS destruction (Figure 2a) was comparable in all treatments except H100, where it was lower. SCOD (Figure 1c) initially increased as particulate organic matter was hydrolyzed and solubilized, but subsequently decreased in all treatments except H0 as the dissolved organic compounds were degraded.

Biogas and Methane Yields

H100 exhibited the lowest initial gas production (Figure 1d), but eventually attained 380±2 mL after 99 d. In contrast, gas production in H0 leveled off after ~10 d and totaled 260±10 mL after 99 d. Treatments combining the two wastes produced higher gas volumes, up to 1,020±9 mL after 113 d (H40). Biogas yield (Figure 2b) was highest for H80, 200±30 mL/g VS destroyed. Methane production from H0 was extremely low (Figure 1e), 14±1 mL after 99 d, while H100 produced 220±1 mL in the same period. Treatments that received both wastes produced the most methane, up to 700±6 mL after 113 d (H40). Methane yield was highest for H80, at 130±20 mL/g VS destroyed.

pH and Ammonia

The pH (Figure 1f), initially 5.0 for the hog waste and 6.0 for the poultry waste, dropped over the first 15-20 d to as low as 4.5, but eventually stabilized at 6.0 in H0 and at 7.0-7.5 in the remaining treatments. Total NH_3-N (Figure 2c) varied little over time, and ranged from 340±10 mg in H100 to 1,660±80 mg/L in H0. Calculated free NH3-N ranged from 3.2±0.2 mg/L in H0 to 24.4±0.9 mg/L in H20.

DISCUSSION

The anaerobic digestibility of hog manure, despite its high NH_3-N content, is well documented. Stable digester operation is possible provided the microbial consortium is sufficiently acclimated (Angelidaki and Ahring, 1993). Although inhibition was observed at 1.1 g/L free NH_3-N, digestion continued even at 6 g/L free NH_3-N, albeit at a greatly reduced methane yield (Hansen *et al.*, 1998). With poultry manure, up to 2.6 g/L total NH_3-N had no effect on biogas or methane production, but reductions of 50-60% in biogas production and 80-90% in methane production were observed with 2.6-7.9 g/L total NH_3-N (Krylova *et al.*, 1997). The free NH_3-N concentrations calculated in this study were far below those reported to inhibit digestion, due partly to the acid to neutral pH of the test bottles. Moreover, the wastes had undergone dilution, which reduces the volumetric ammonia loading and promotes stable digester operation (Webb and Hawkes, 1985; Pechan *et al.*, 1987).

The observed methane yields were below values typically reported for high-rate digester configurations, 300-660 mL/g VS for swine manure (Masse *et al.*, 1997) and 115-390 mL/g VS for dairy manure (Safley and Westerman, 1992, 1994). The pH was in the range considered optimum for methanogenesis in all treatments except H0. The lower pH, high SCOD concentration, and low methane production in H0

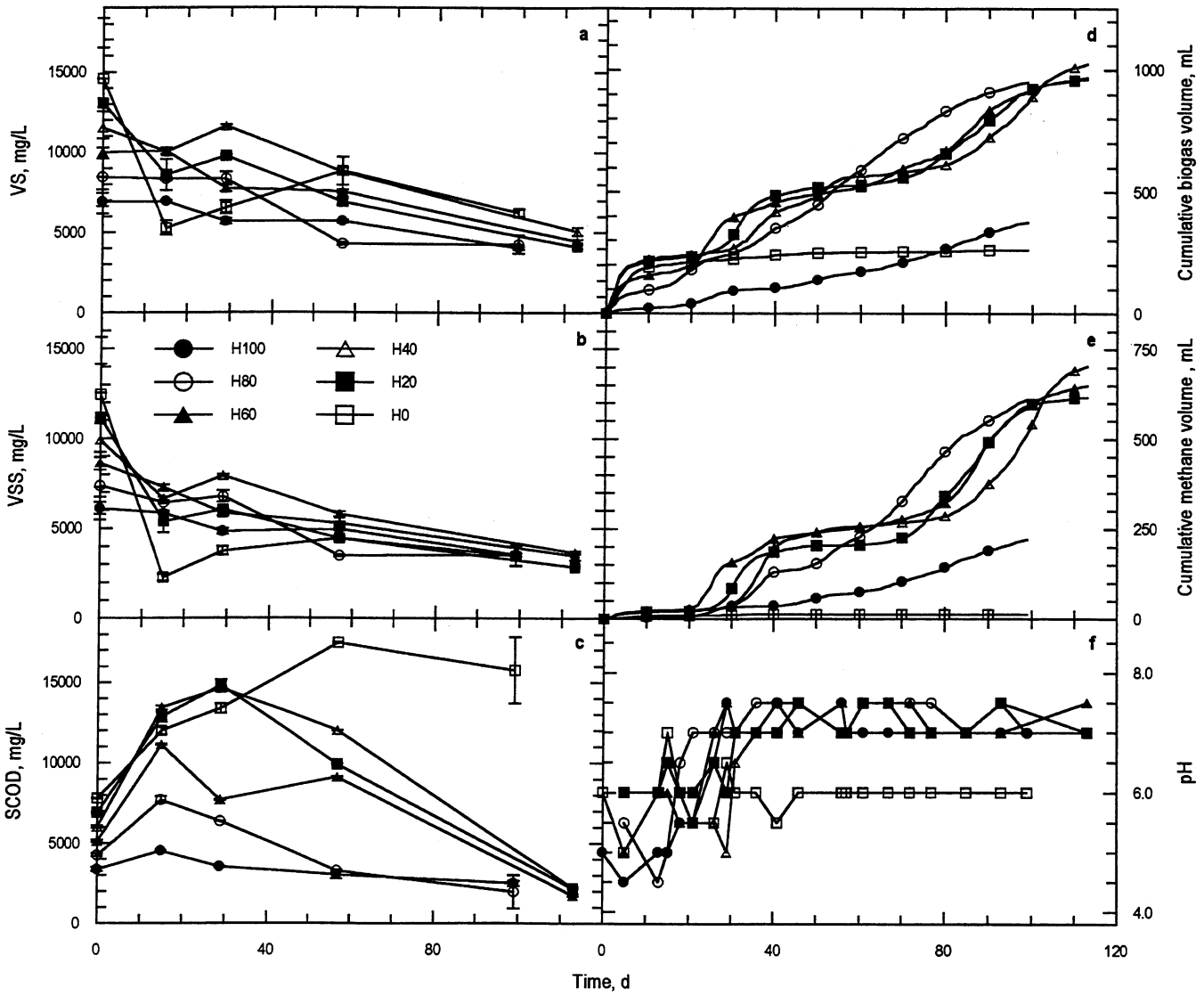

Figure 1. Variation of (a) VS concentration, (b) VSS concentration, (c) SCOD concentration, (d) cumulative bioga volume, (e) cumulative methane volume, and (f) pH during the batch test.

suggest that VFAs accumulated and inhibited methanogenic activity in that treatment.

The superior biogas and methane yields of treatments that combined hog and poultry waste clearly demonstrates that codigestion of these wastes is viable. The apparently complementary nature of the two wastes, however, may be an artifact of the absence of an added inoculum. The hog waste was collected from a drainage sump and may have harbored a significant quantity of methanogenic bacteria, while the poultry manure was collected from the ground after exposure to the air and may have had a low population of obligate anaerobes. At the same time, the hog waste had lower levels of solids, SCOD, and ammonia than the poultry waste. Hence, in the mixed waste treatments, the hog waste would have supplied methanogens, while the poultry waste would have provided substrate and nitrogen. This hypothesis is consistent with the VFA accumulation and low methanogenic activity observed in H0, and, along with the lack of continuous agitation, may also explain why the observed methane yields were lower than reported in the literature.

RECOMMENDATIONS

This study used batch experiments to confirm the feasibility of anaerobic codigestion of hog and poultry manure. Future work should use an inoculum that has been acclimated for manure digestion to reduce the

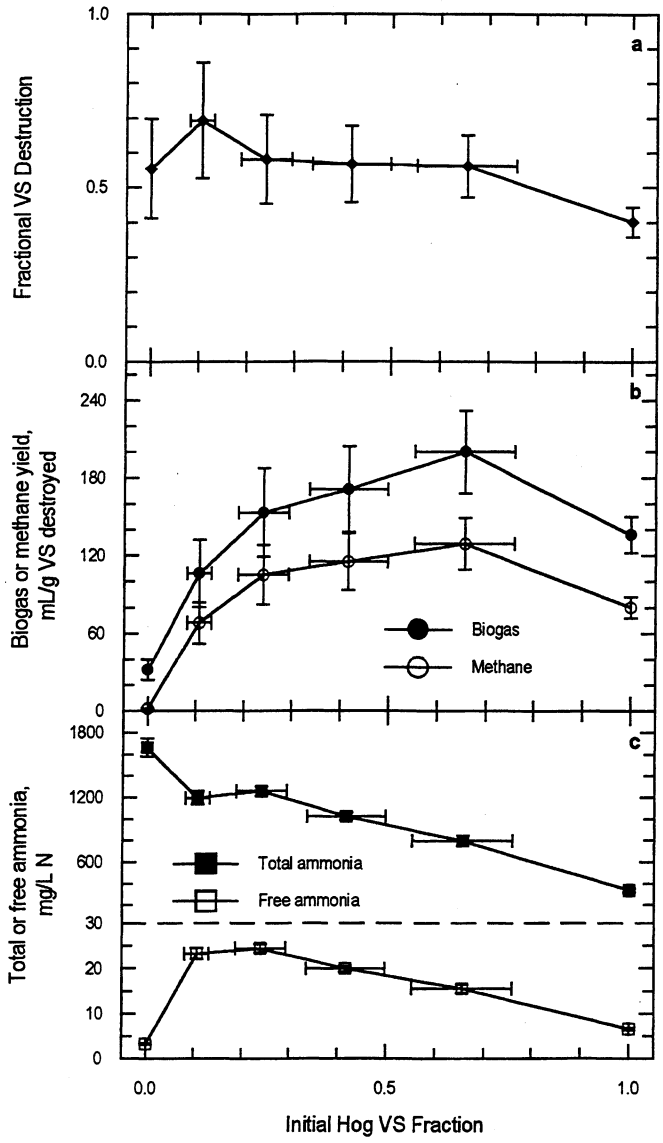

Figure 2. (a) VS destruction, (b) biogas and methane yield, and (c) total and free ammonia concentration at varying of initial hog waste VS fractions. The dashed horizontal line in (c) denotes a change in vertical scale.

duration of the tests, to minimize inhibition from ammonia and from certain substrate constituents, e.g. antibiotics incorporated in the animals' feed, and to attain the maximum biogas and methane potential from each waste. Stringent monitoring and control of critical process parameters, e.g., pH, alkalinity, VFA concentration, and ammonia concentration, should be undertaken so that process conditions can be optimized.

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