Hydrolysis and Acidogenesis of Farm Dairy Effluent for Biogas Production at Ambient Temperatures

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Abstract

Anaerobic ponds are an established technology for treating farm dairy effluent in New Zealand. These ponds produce a significant amount of methane but because of their large size, they are rarely covered for methane capture. The removal of solids prior to entering the ponds would allow for shorter retention times resulting in smaller ponds that could be covered. However, removal of solids entails loss of organic material and thus methane production. It was proposed that improved hydrolysis of solid content prior to solids separation could increase the organic content of the liquid fraction. No literature was found describing two-stage (acidogenic/hydrolytic and methanogenic) systems which achieve hydrolysis combined with solids separation of manure slurries. Hence, the aim of the present study is to examine the feasibility of such a system.

Five parameters were examined to determine favourable conditions for hydrolysis of solids and acidogenesis in farm dairy effluent. These were: 1) mixing, 2) hydraulic retention time (HRT), 3) liquid to solid ratio (dilution), 4) addition of rumen contents, and 5) reactor configuration.

Continuous mixing of cow manure sludge inhibited net volatile fatty acid (VFA) production, likely due to oxygenation. By comparison, a once-daily brief stirring regime resulted in production of 785 mgVFA/Lsludge compared with 185 mg/L from a continuously stirred reactor. Mixing had little effect on soluble COD yield.

HRTs ranging between 1 and 10 days resulted in greater hydrolysis yields (0.25 to 0.33 $gCOD/gVS_{added}$) compared with 0.15 $gCOD/gVS_{added}$ for a 15-day HRT. It was hypothesised that the attachment of hydrolytic bacteria to solids prevented washout at shorter HRTs. In contrast, longer HRTs favoured VFA production. This may have been due to the planktonic nature of acidogenic bacteria, making them more vulnerable to washout at shorter HRTs.

The effects of solid:liquid ratio on hydrolysis and acidogenesis were examined with sludge:water ratios ranging from 1:1 to 1:0.25. The addition of larger volumes of

water resulted in improved acidogenesis with the 1:1 sludge:water mixture producing a liquor with 245% more VFA mass (635 mg) than reactors with a 1:0.25 sludge:water mixture (184 mg).

Addition of rumen contents was shown to have little or no effect on either acidogenesis or hydrolysis. This may have been due to a masking effect of an increased organic load through the addition of undigested grass in the rumen.

A mix, settle and decant (MSD) system and an unmixed flow-through leachbed separator system were trialled and compared as hydrolytic/acidogenic reactors. The MSD system produced $0.033gVFA/gTS_{added}$ and $0.315gCOD/gTS_{added}$ compared with $0.015gVFA/gTS_{added}$ and $0.155gCOD/gTS_{added}$ in the unmixed leachbed separator. It was hypothesised that improved mixing and longer solid-liquid contact times in the MSD system provided greater surface contact and transfer of organics to the liquid phase thereby enhancing hydrolysis.

A two-stage (acidogenic/hydrolytic and methanogenic) system was tested at bench scale. A partially mixed leachbed separator was fed with manure slurry. This retained solids while leaching out a treated feed high in organic content to be fed into a variety of methanogenic systems. The leachbed separator produced a treated feed with a VFA concentration of 562 mg/L, 120% higher than the influent slurry (255 mg/L). Soluble COD increased 60% from 1,085 mg/L in the slurry to 1,740 mg/L in the treated feed.

20-day HRT and 10-day HRT unmixed unheated methanogenic reactors, both fed with treated feed from the leachbed separator, had lower specific methane yields (0.14 and 0.11 LCH_4/gVS respectively) than a 50-day HRT reactor fed with untreated slurry (0.17 LCH_4/gVS). However, both the 20-day HRT reactor and the 10-day reactor had higher volumetric methane yields (0.033 and 0.057 LCH_4/Lreactor/day respectively) than the 50-day HRT reactor fed with slurry (0.024 LCH_4/Lreactor/day). Gas production was shown to rise as the VFA levels in the treated feed rose. Fermentation in the leachbed followed by separation was shown to improve average gas production by up to 57% compared to separation alone.

Field-scale trials of a leachbed separator system followed by a 20-day HRT methanogenic reactor were undertaken. VFA concentrations increased from 100 mg/l in the influent to 1,260 mg/l in the treated feed, while the soluble COD increased from 2,766 mg/L to 5,542 mg/L. The methanogenic reactor produced 0.08 m^3 CH_4/ $m^3_{reactor}$/day, four times higher than that which would be expected from a covered pond of the same size. This was hypothesised to be due to the increased biodigestability of the feed to the tank digester as well the increased organic loading rate.

This study indicates that the use of a leachbed separator would be an effective low-tech strategy for reducing the HRT of farm anaerobic ponds, and reducing the size of covers required for biogas energy recovery.

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