An evaluation of leach beds coupled to methanogenic reactors for energy production from maize (Zea mays)

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1 THESIS ABSTRACT

The potential for using the crop maize (Zea mays) for the production of biogas in simple anaerobic leach beds was evaluated. The results showed that leach beds coupled to high-rate methanogenic reactors performed better than other systems on a specific methane yield per gram of substrate added basis while their performance on a volumetric gas yield basis was poorer.

Initial experiments using a single stage digester showed rapid acidification due to the low buffering capacity of the system. To overcome this problem, leach beds were used as part of a two-phase system in which the intermediate metabolic products were flushed out and used as substrate for a second stage methanogenic reactor.

Initial experiments simulated the effect of a hydraulic flush in the leach bed using clean water as the flush liquid. Methane potential of the leachate was estimated based on the cumulative soluble chemical oxygen demand (SCOD) production. Under this operation mode, the effect of substrate to inoculum ratio, fresh substrate load (FSL), hydraulic retention time (HRT) and buffer and trace element addition was tested. The performance of the leach bed was found to be poor compared to conventional digesters where the methane yield is \(\sim 0.35 \text{ l CH}_4 \text{ g}^{-1} \text{ VS}_{\text{added}}\) and volatile solids (VS) destruction is \(\sim 85\%\); this was thought to be due to the low pH in the reactor. Increasing the FSL improved methane yield but the maximum obtained was \(0.12 \text{ l CH}_4 \text{ g}^{-1} \text{ VS}\). Decreasing the HRT allowed the leach bed to operate at a slightly higher pH. In this case, a volatile solids destruction of \(\sim 50\%\) and a methane yield of \(0.17 \text{ l CH}_4 \text{ g}^{-1} \text{ VS}\) was achieved using an HRT of 2.6 days. The addition of buffer (NaHCO$_3$) to maintain pH \(\sim 6.5\) increased VS destruction to 89% and methane yield to \(0.37 \text{ l CH}_4 \text{ g}^{-1} \text{ VS}\) at an HRT of 1.5 days. This performance was similar at a HRT of 28 days despite the high VFA concentrations. Acid production increased with the addition of buffer as 75-97% of SCOD was converted to this form. Buffering was also shown to increase the number of culturable anaerobic cellulolytic microorganisms. VS degradation and methane potential were further enhanced by the addition 0.5 mg l$^{-1}$ of cobalt to the buffered flush medium giving an apparent VS destruction of 115% and a methane yield of 0.46 l CH$_4$ g$^{-1}$ VS$_{\text{added}}$, which indicated that a proportion of the inoculum was also degraded.

Cumulative VFA production per gTS added throughout the feed cycles in the 14-day cycle leach bed reactor

In the final part of the research the leach beds were coupled to methanogenic reactors and trials were conducted using different feed cycle durations, in which all the digestate and leachate from the preceding run was used as inoculum, and only the sol-
ids destroyed were replaced with fresh feed material. The effect of the methanogenic reactor was multi-fold as it not only stripped out intermediate compounds, according to its primary design function, but also played an important role in stabilising pH, maintaining nutrients and retaining the microbial population in the system. The leach bed operated with a 7-day feed cycle showed higher substrate degradation and was able to receive a higher OLR of 2.4 gTS l\(^{-1}\) reactor d\(^{-1}\) than the 14-day feed cycle at 1.7 gTS l\(^{-1}\) reactor d\(^{-1}\) and the 28-day feed cycle at 1.3 gTS l\(^{-1}\) reactor d\(^{-1}\). This provided a higher volumetric methane yield the shorter the feed cycle, 0.839 l\(\text{CH}_4\) l\(^{-1}\) d\(^{-1}\), 0.618 l\(\text{CH}_4\) l\(^{-1}\) d\(^{-1}\) and 0.482 l\(\text{CH}_4\) l\(^{-1}\) d\(^{-1}\) in the 7-day, 14-day and 28-day feed cycle, respectively.

However, the specific methane yield obtained from the system was slightly higher in the 14-day and 28-day cycles at 0.434 l\(\text{CH}_4\) g\(^{-1}\) VS\(_\text{added}\) while in the 7-day cycle it was 0.418 l\(\text{CH}_4\) g\(^{-1}\) VS\(_\text{added}\). The retention of the digestate and leachate over successive cycles for a period of ~160 days appeared, however, to cause an accumulation of suspended solids (SS) and total and soluble COD in the leachate. This was especially the case in the higher loaded 7-day feed cycle reactor and was probably the cause of the lower methane production. Initially the methanogenic reactors were responsible for removal most methane production but with progressive cycles the leach beds themselves became methanogenic and eventually accounted for more than 50% of the methane generated in the system. The methanogenic and cellulolytic bacteria were shown to be present in the leachate from both reactors and suggested a synergy between them in exchange of microbial consortia.

2 ADDITIONAL INFORMATION

2.1 Supervisory team

Prof Charles Banks, Dr Sonia Heaven

2.2 Funding

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3 PUBLICATIONS


