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Improving Soluble Chemical Oxygen Demand Yields for Anaerobic Digester Feedstock using Leaching

A thesis presented in partial fulfilment of the requirements for the degree of

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By

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Abstract

Waste biomass is often a liability to many municipalities. Technologies exist that can turn this biomass into energy which can then be sold. Anaerobic digestion is one of the important technologies that utilises this biomass to turn it into biogas. One of the factors that affects the rate that biogas can be produced is the speed that suitable organic compounds can be delivered to methanogenic microorganisms. These organic compounds such as sugars and amino acids are released from plant material at different rates depending on their availability. A portion of the compounds are readily soluble in water and are immediately available, some of the compounds are locked up inside the plant cells and some of the compounds such as cellulose are not soluble and need to be hydrolysed into sugars before they can be converted into methane. Hydrolysis is usually the rate limiting step in anaerobic digestion. Leaching of green waste was investigated as a form of pre-treatment to externalise the initial stages in anaerobic digestion that makes soluble organic compounds available for the consecutive methanogenic stages of anaerobic digestion. The added benefit of leaching is it removes the complexity of solids handling from inside anaerobic digester. Many various forms of leaching technologies that are coupled to anaerobic digesters have been trialled with grass and silage, little research was found on leaching green waste and few trials had used the simplified unheated flooded tank system as tested here. Pilot and laboratory leaching trials were conducted on shredded green waste as well as grass clippings to establish the efficiency of leaching by measuring the COD yields in the leachate. Additionally, rumen contents from cattle rumen were added to grass clippings in order to investigate if the leaching efficiency from the grass could be improved. Leaching was tested at a pilot scale in an open to the air reactor tank in ambient temperature in a temperate climate. Hydraulic retention times ranging from 4 hours to 7 days were tested to establish the most effective leaching strategy. The laboratory trials were conducted with the temperature controlled at 25°C to simulate ambient environmental conditions in a temperate climate. The effect of storing feedstock was tested to see how changes in handling times affected the process. Gas production from the leachate was tested using 2 L CSTR (Continuously Stirred Tank

Reactor) anaerobic digesters to confirm the usability of the leachate as a feedstock in an anaerobic digester.

Pilot scale trials of shredded green waste and grass clippings gave maximum COD concentrations of 5.4 ± 0.5 and 47 ± 4 g COD / L of leachate respectively. Pilot trials of shredded green waste and grass leachate reached a maximum total COD yields of 53 ± 2 and 410 ± 20 kg COD / tonne VS respectively. Laboratory scale trials of shredded green waste and grass clippings gave maximum COD concentrations of 7.0 ± 0.1 and 49 ± 2 g COD / L of leachate respectively. Laboratory trials of shredded green waste and grass leachate reached a maximum total COD yields of 132 ± 8 and 410 ± 20 kg COD / tonne VS respectively. Laboratory trials are indicative of how pilot trials will behave and differences are likely to be due to an increased bulk density in solids in pilot trials.

Shredded green waste and grass leachate gave maximum 3.7 and 7.8 g BOD / L respectively. Nutrients in the leachate were tested: nitrogen levels in shredded green waste and grass leachate reached maximum levels of 51 and 460 mg / L respectively; DRP (Dissolved Reactive Phosphorus) levels in the shredded green waste and grass leachate reached maximum levels of 6 and 85 mg / L respectively. The leaching tanks produced gas while leaching was taking place; a sample of this gas was captured and the levels of CH₄, CO₂ and H₂ were measured as 0%, 25.5% and 5.0% respectively. Gas production from anaerobic digestion of shredded green waste and grass in a CSTR at 35°C produced 0.23 ± 0.01 and 0.534 ± 0.005 m³ biogas / kg COD respectively.

Use of grass that is fresh gives much higher yields of dissolved organic compounds in the leachate than when the grass is stored in covered area for 30 days. Leaching grass with an HRT (Hydraulic Retention Time) of 1 day gave optimal results in terms of concentration and yields of dissolved organic compounds in the leachate compared to leaching trials with an HRT of 4 hours or 7 days. Green waste gave much lower concentration and yields of COD than grass and an HRT of 7 days was the most suitable for gaining the best concentration and yield of dissolved organic compounds compared to a 4 hour or 1 day HRT.

The overall mass transfer of organic compounds when leaching freshly shredded green waste is most likely limited by a combination of hydrolysis and the rate that soluble compounds are released from within plant cells as the cell membranes degrade. In trials of fresh and stored grass and stored shredded green waste, shortening the HRT increases the total yield of dissolved organic compounds leached into the leachate; however, this is at the expense of increased concentrations of dissolved organic compounds within the leachate. The lower leachate concentrations with the shorter HRTs means that the leachate is less suitable to use as a feedstock for an anaerobic digester.

Anaerobic digestion of grass leachate produced much more biogas / kg COD than anaerobic digestion of shredded green waste leachate, this may be a result of an inhibiting compounds such as tannins, additionally to this the material that the shredded green waste is composed of will have higher levels of lignocellulose materials that are not readily soluble. The leachate was found not to degrade when stored at 25°C in an open top container, this maybe a result of low pH inhibiting degrading micro-organisms, this has significant benefit as the leaching process can be separated from the anaerobic digestion process without degrading the quality of the leachate while it is being stored.

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