BioDEN: What did we achieve in 2022?

The purchase of artificial fertilisers accounts for an average of 6% of the share of input costs for EU farmers. For arable crop farmers, this contribution is as high as 12%. High and volatile fertiliser prices are more than ever a major challenge. The spiking gas price led to a 149% price increase for fertilisers in September 2022 compared to the previous year. As a result, farmers have been delaying and reducing their purchases of these products[1].

The main innovation goal of the BioDEN project is to realise an extensive valorisation of the nitrogen- and phosphorus-rich digestate originating from anaerobic digestion into existing and new bio-based fertilisers. In this manner BioDEN creates an opportunity to realise a closed nutrient cycle and offers a possible escape from the high artificial fertiliser prices. More specifically, techniques such as (vacuum)stripping of ammonia in combination with acid scrubbing, and phosphorus leaching are tested in both lab- and industrial settings.

The BioDEN project kicked off early January 2022 and spans two year. It is a collaboration between Biogas-E, KU Leuven, UGent, Marmara University, VCM and Ostim Enerjik. This article provides an overview of the achievements of the first project year, together with an outlook on the upcoming research.

Post-digestion of stripped digestate results in a significantly higher biogas production

Experimental set-up bench-digester ©KU Leuven

In this project, KU Leuven takes the lead in investigating the most optimal combination of anaerobic digestion and nitrogen recovery from digestate. The elevated temperature and pH applied during the stripping process changes the structure of the organic matter, thereby increasing the bioavailability of the more recalcitrant components and releasing dissolved organic matter. In addition, the risk of ammonia inhibition is reduced when stripped digestate, depleted of nitrogen, is introduced into a digester.

Lab scale experiments clearly showed that recirculation of the stripped digestate resulted in only a limited boost in biogas yield. A better yield could be obtained when the stripped digestate was digested in a post-digester. After lab-scale investigation of ammonia stripping conditions, one

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[1] European commission. (2022, 9 November). Food security: the Commission addresses the availability and affordability of fertilisers in the EU and globally. *European Commission*. https://ec.europa.eu/commission/presscorner/detail/en/IP_22_6564

condition is proposed for evaluating (mesophilic) post-digestion.

In a second phase, experiments were conducted at bench scale, using digesters with an active volume of 45 litres. The results confirmed that by combining ammonia stripping and post-digestion of the manure digestate from the main digester, significant additional biogas production can be achieved. These experiments were carried out using dairy manure as a substrate and will be repeated using organic waste as a substrate.

Stripping-scrubbing recovers N from digestate as ammonium citrate

Digestate (dairy manure as substrate) was stripped at 70°C and pH 8. Air was dosed at a flow rate of 8 litres/min (constant G/L of 1000) to purge the formed ammonia (NH_3) (due to high pH and high temperature) from the digestate. This NH_3 was collected in the alternative acid (i.e. citric acid) to form ammonium citrate. An additional benefit of ammonium citrate is a potentially improved uptake of phosphorus by the plant. This will be further investigated by UGent in pot tests.

During the stripping process, 89% of nitrogen was removed from the digestate and 87% organic matter was released.

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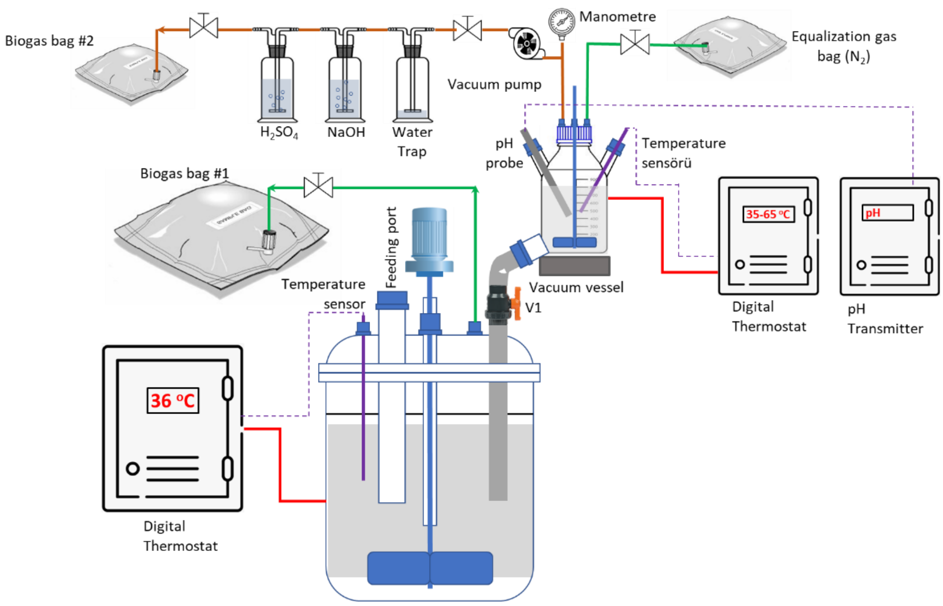
Vacuum stripping increases methane yield

The setup, shown in the figure below, was used by Marmara University to perform batch vacuum-stripping experiments. The experiments were conducted with raw digestate acquired from a full-scale biogas digester fed with more than 70% chicken manure. Different durations (30 and 120 minutes), temperatures (35-50-70 °C) and pH (8-9.5-10.5) were tested. Disintegration efficiency was assessed by dissolved and total chemical oxygen demand (COD), volatile dissolved solids and UV254 analysis. Additionally, Total Ammonia Nitrogen (TAN) removal was also determined. Both dissolved COD and TAN removal increased with increasing temperature. Increasing pH results in increased TAN removal and a greater share of dissolved COD.

Set-up batch vacuum experiments, watch the experiment in action © Marmara University

Next, BMP tests were performed with the vacuum stripped digestate (vacuum treatment at different temperatures (50 and 70°C) and pH (8-9.5-10.5)). From the BMP tests, it can be inferred that the digestate subjected to vacuum treatment at 70°C, without pH adjustment resulted in the highest methane yield. In this set, the TAN was only 16% lower than in the control, but approximately 50% more methane was produced. This indicates an increase in the methane potential of the digestate due to disintegration during vacuum treatment. It is concluded that the excess of NaOH used for pH adjustments, up to a pH 10.5, in the vacuum experiments inhibits methane production due to the high sodium concentration (± 2,900 mg/l).

Following the BMP tests, the effect of vacuum treatment on methane production was investigated in daily-fed, completely stirred anaerobic reactors. For this purpose, two 6-litre lab-scale mesophilic reactors were started up and under operation for more than 300 days. The study is ongoing and it is estimated that the first results will be available within three months.



Laboratory scale daily-fed anaerobic reactor integrated with vacuum stripping © Marmara University

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P-leaching with waste and organic acids

Ghent University, specifically the Re-Source Lab, deals with phosphorus recovery from the solid fraction of digestate by acid leaching and reprecipitation of P as either struvite, Ca phosphate or Mg phosphate. To achieve this, both conventional (sulphuric acid, citric acid) and alternative (recovered scrubbing liquids from stripping-scrubbing tests done by KU Leuven, waste acids obtained from Solvakem) leaching agents are used. Large chemical consumption (e.g., H2SO4 as P-leaching agent) is unavoidable in this process and poses adverse cost and safety implications. The use of (recycled) organic acids, e.g., citric acid, is more interesting in this respect as they are less hazardous and more sustainable than their inorganic counterparts.

So far, P-leaching tests have been conducted using sulphuric acid and citric acid at different L/S ratios of the leaching step (0.5:1-5:1) in a broad pH-screening (pH 3-6) to obtain P-release curves. The P-rich leachates were characterised and then used to reprecipitate P. The experimentally determined optimal conditions will be applied in P-leaching tests using alternative acid streams in the next step.

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On the agenda

Soon, KU Leuven will start large-scale experiments, linking a stripping-scrubbing installation to two full-scale digesters. Subsequently, the collected data will be applied by VCM and Biogas-E to carry out an economic, technological and ecological study of the different recovery options.

This month, Marmara University started a lab-scale trial using Fe-modified biochar as phosphate adsorbents. Two different biochar modification methods are being investigated. In addition, the recovery of phosphorus from the liquid fraction of the digestate in the form of struvite is being tested in a pilot-scale crystalliser. Various test conditions will be investigated and optimised.

Furthermore, this year, Ghent University will start plant-trials and soil incubation experiments together with a thorough characterisation of the products' quality, including novel N-based fertilisers (e.g. ammonium sulphate, ammonium citrate and ammonium bicarbonate), P-based fertilisers (e.g. calcium phosphate, struvite, P-adsorbed biochar), together with nutrient-deficit but C-rich biosolids that can be applied as soil improver.

Would you like more information about the BioDEN project in general or would you like to follow the project more closely? Contact: info@biogas-e.be

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