IEA Bioenergy

Value of batch tests for biogas potential analysis

Method comparison and challenges of substrate and efficiency evaluation of biogas plants

Summary Series

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Executive Summary

The key parameter for the evaluation of substrates to be used in anaerobic digestion plants is the biogas potential. It states the maximum amount of biogas that can be obtained from a given amount of substrate and therefore represents the benchmark for any technical application for biogas production. The biogas yield describes the amount of gas retrieved under technical conditions at a given biogas facility.

The biogas potential of a specific substrate defines the maximum amount of biogas that can be produced during anaerobic digestion, but it includes a certain amount of substrate utilised for microbial growth and maintenance, which consequently lowers the amount of degradable substrate available for biogas production. There are several methods of substrate characterisation available which are used to determine, or correlate to, biogas potential. Most common are total solids and volatile solids determination, chemical composition analysis, chemical oxygen demand, total organic carbon and nutrient composition. For a direct determination of the biogas potential via a chemical analysis, these methods all lack the precise direct determination of the degradable fraction of the substrate and the amount of substrate used for microbial growth. Therefore, they use calculation methods based on empirical correlation or coefficients to estimate the biogas potential.

Discontinuous batch tests (or continuous tests) are biological test systems, which allow for the direct assessment of factors not considered by the chemical test analysis but add the uncertainty of a biological test. Several standards and guidelines are available for performing anaerobic digestion by means of batch experiments. The experiments give a biogas yield which can be used for estimation of the biogas potential and provide additional information on degradation kinetics.

One of the major factors influencing the results of a batch test is the inoculum used. Source and sampling of the inoculum, pre-treatment and storage and in particular the adaption to the substrate of choice have a significant impact on results. However, there is no measure yet to judge the adaption of an inoculum to an available substrate other than a monitored adaption process. Substrate sampling and pretreatment are also important factors, which influence the results. Sampling needs to deliver a representative sample. Pre-treatment of the sample should be minimised in order to compare with real world applications in the biogas facility.

Major factors, which influence the results of the test are: the test equipment; the reference system used; the blank test; and the inoculum to substrate ratio. The impact of the test equipment has not been analysed extensively. For the reference system, the blank and the inoculum to substrate ratio, standard conditions should be met. The criteria used to signify termination of the test is also an important factor. The evaluation must include for standardisation

of the gas volume at standard temperature and pressure, include for subtraction of water vapour and allow for gas production from inoculum. Most analyses give the gas produced over a period of time assuming only a negligible amount of gas would have been produced in case of longer retention times. A more precise evaluation of the test results includes model-based estimations of the biogas potential assuming an infinite retention time. Inter-laboratory tests help to identify variability in results within several laboratories and reduce errors in test execution.

Recommendations

The purpose of the test, whether to inform plant design or plant performance analysis or pretreatment technology evaluation, must be known in advance of the test. Different purposes require different approaches and additional supporting measurements. For a successful test series, it is essential that the aim of the study is defined; this leads to the development of a sampling procedure and test scenario and allows for an evaluation of uncertainties and interpretation of results. The representability of the sample analysed is crucial to the veracity of the output of the test. The adaptation of the inoculum to the substrate must be considered. The evaluation of the results – besides the validity of the test according to the standard protocols – should include a model-based estimation of the biogas potential at infinite retention time. When interpreting the results, the uncertainty and inherent variability should be considered and highlighted. In order to ensure the quality of lab-scale experiments for determination of biogas potential a regular participation in inter-laboratory tests is recommended. For those who employ labs to undertake biogas potential tests it is recommended to check if the lab is participating in such tests and is deemed to be a reputable laboratory for such tests.

Conclusion and outlook

The batch test is an established test system for the determination of the biogas potential of organic materials. Interlaboratory tests and investigations analysing the impact of inoculum have revealed a significant variability in the results of the test. Other methods for the determination of the biogas potential based on chemical analysis show a significant lower variability in the results, but limited correlation with batch tests. Which test result is more accurate and free of bias remains unknown since there is no absolute value or method to be compared with.

A limited literature screening showed coefficients of variation of 1– 20 % (in some cases >30 %) are possible when comparing different inocula. This translates into a similar variation possible in case non-adapted inocula are in use. The only measure for adaption available is the execution of an adaption process which increases the effort of the test considerably. Inter-laboratory reproducibility of batch tests is in the range of 8 – 26 % when looking at the results of three national inter-laboratory tests. Therefore, any result should be interpreted carefully under consideration of available literature data, calculations based on chemical or physical substrate analysis and the known intra-laboratory variability of the lab analysing the sample.

A further reduction in the variability seems to be possible when examining the impact of the test procedures and the inoculum. A standard method for the transfer of batch test to continuous test or full-scale systems is as yet not available.

Revisions of the available protocols and identification and elimination of causes for the variability is needed. If the variability of the batch test can be reduced, the development of biochemical analysis combined with regression analysis might become more precise and result in a higher accuracy. A further series of inter-laboratory tests (including for continuous processes and chemical analysis such as nutrient assessment) and the publication of these results are necessary for further improvement of applied test procedures and more precise results.

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