

Biogas for agriculture

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The production of biogas as a fuel obtained from the fermentation of organic wastes has undoubted benefits for the environment. These benefits include both reduced methane emissions from livestock enterprises and the production of green energy which can be fed into the national electricity grid. The heat generated from biogas production can also be used locally for heating livestock buildings or hot water. Biogas is about 70% methane and 30% CO₂. The actual methane producers are microbes known as 'methanogens'. These belong to some of the oldest groups of organisms on the planet, known as the Archaea. They are common in wetlands, where they are responsible for producing marsh gas, and are also commonly found in the gut of ruminants such as cattle, and in their faeces.

In terms of biochemistry, there are four stages to the production of biogas by the anaerobic digestion of degradable organic materials. The early stages of breakdown require an acidic environment, whereas in the later stages, when the methane is actually produced, a neutral pH environment is advantageous. To facilitate this procedure in practice, therefore, in the UK we prefer a two-stage system to accommodate more efficient microbial activity that produces higher amounts of biogas. On the continent, however, a single-stage tank is used which simplifies the production process and reduces the initial capital costs of purchase.

Biogas feedstock

Livestock manure slurry is the main source of feedstock for biogas production, having a dry matter content of about 5-15% w/w, but potentially a wide range of organic wastes can be used as starter materials, ranging from fats and greases to vegetable wastes. Some potential sources, such as food and abattoir wastes, would need to be heat-treated before use as a biogas feedstock as a biosecurity measure, however, in order to prevent any contained pathogens escaping to reinfect farm livestock via grazing or other crop sources. Organic wastes imported onto the farm are also a good source of nutrients for spreading on the land and can significantly reduce artificial fertiliser use, both saving money and reducing the requirement for fossil fuels.

In Europe, biomass in the form of maize has been used to supplement the feedstocks to produce larger quantities of biogas. The high nitrogen content of livestock manure when used alone does not provide enough carbon for efficient biogas production. This optimisation of biogas production is something IGER North Wyke is focusing on in a new EU AGRO-BIOGAS contract funded under Framework 6.

Current research

Even while premiums for the production of green electricity remain available in the UK, there is still some debate as to whether biogas production is

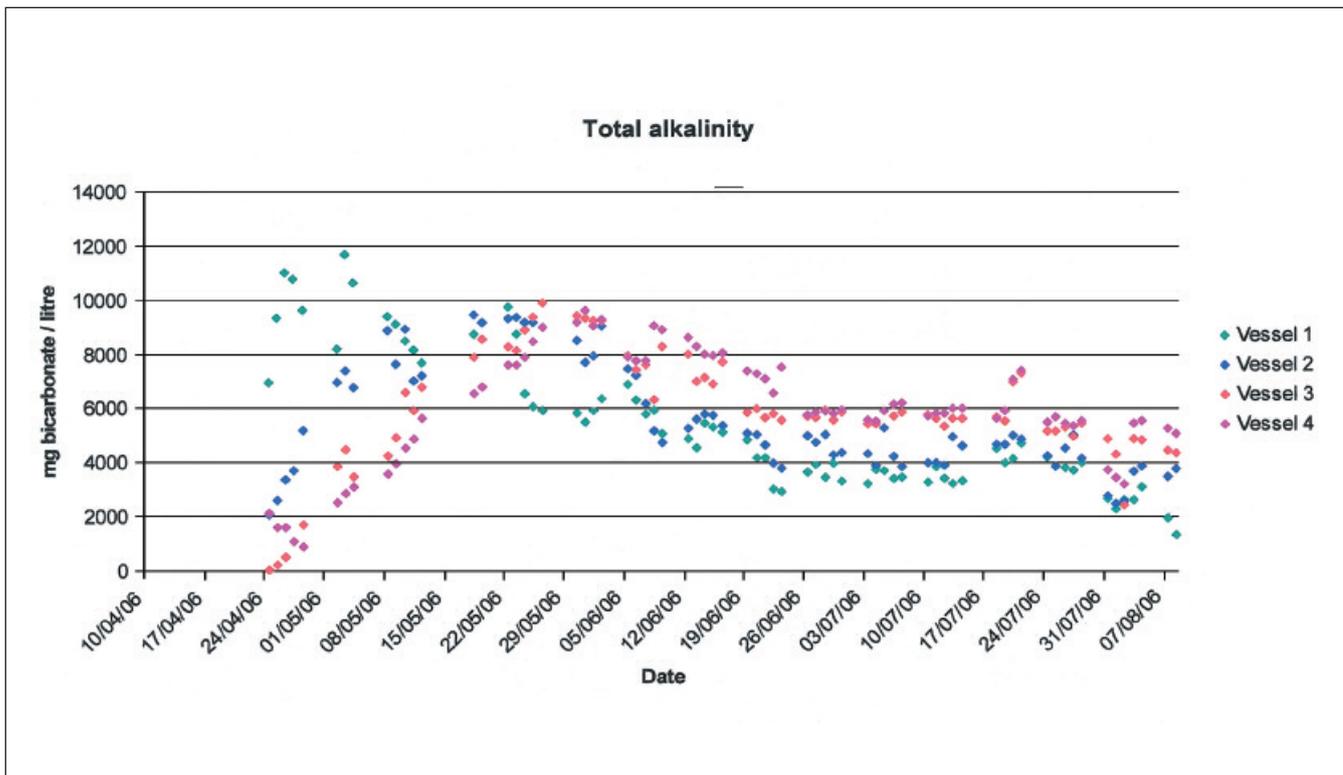


Fig. 1. Level of increasing alkalinity as the digestate travels from vessel 1 to vessel 4 as the system achieves fermentation stability after an inoculation of organisms from a biogas digester.

currently economical. A biogas plant can also be considered difficult to operate due to the complexity of the processes involved.

New research at IGER funded by Defra and the EU Framework 6 Programme will address these two issues by improving the biogas production process. By doing so, we will not only be able to enhance the green electricity output, but also reduce capital costs through introducing more efficient and faster processes which will require less space. One of the major concerns for biogas production so far has been the lack of automatic and safe process controls at each stage of the procedure. By introducing appropriate and robust sensors to monitor the correct amounts of feedstock and nutrients for the biogas-

producing microbes, together with the most efficient environmental conditions (e.g., alkalinity) for the organisms to break down the organic materials, the final chemical reactions that produce methane from acetic acid, or from hydrogen and CO_2 , can be made much more efficient. Such process control will not be easy, however, because there is a lag time of about 10-20 days between the feedstock going in and the final biogas output, and hence there is an element of prediction required for best control throughout each stage. Modern modelling and statistical techniques can be used to overcome these problems, however, and we have initiated a new collaboration with Exeter University's Mathematics, Computing and Engineering Department which has a wide range of process control expertise to help achieve this.

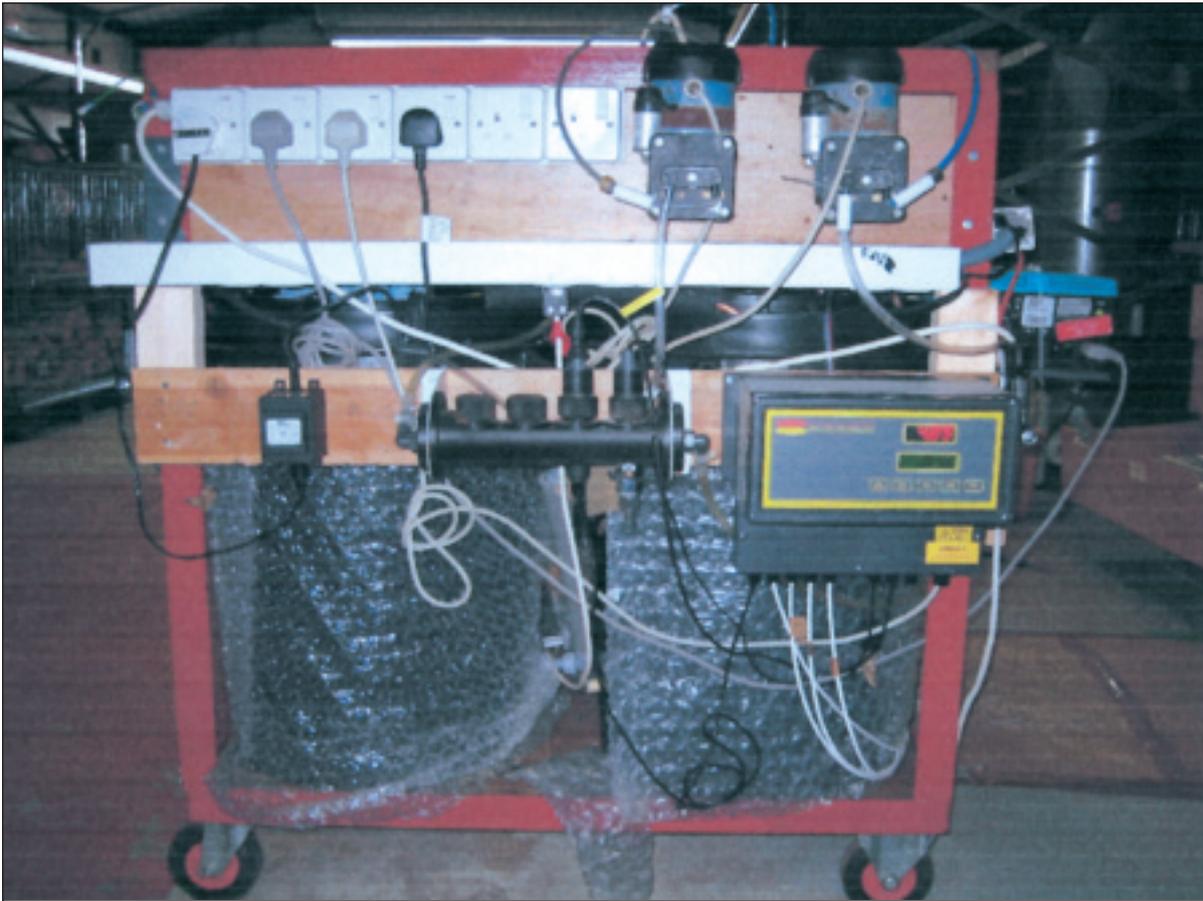


Fig. 2. Old four-stage biogas experimental rig showing the sensor manifold, data processor and biogas recirculating pumps.

Alkalinity can be determined indirectly from sensor data using these models. Work at IGER has identified that alkalinity at the methanogenesis stage of biogas production is important because the relevant microbes are highly sensitive to their environment, with reproduction rates which can slow to about 2.5 days. Current research has also demonstrated that when the fermentation becomes unstable, the alkalinity can be increased by reducing the waste loading rate or by adding alkali.

Our microbial-orientated research observes the synergies between organisms and how they can best digest the waste together. To achieve this, we monitor both the Archaea organisms themselves and

the extracellular polymeric substances that bind them together to allow them to improve the fermentation rate.

To improve our understanding, we are building a 2m³ biogas plant at North Wyke to determine the optimum mixing and loading rates of different amounts of organic waste types, process temperatures and the speed and frequency of the stirring process. The stirring process has proved important because the organisms need a regular supply of nutrients which the mixing helps to provide; however, over-mixing causes the “methanogen” organisms to be detached from their colonies and washed out of the digester. The study of

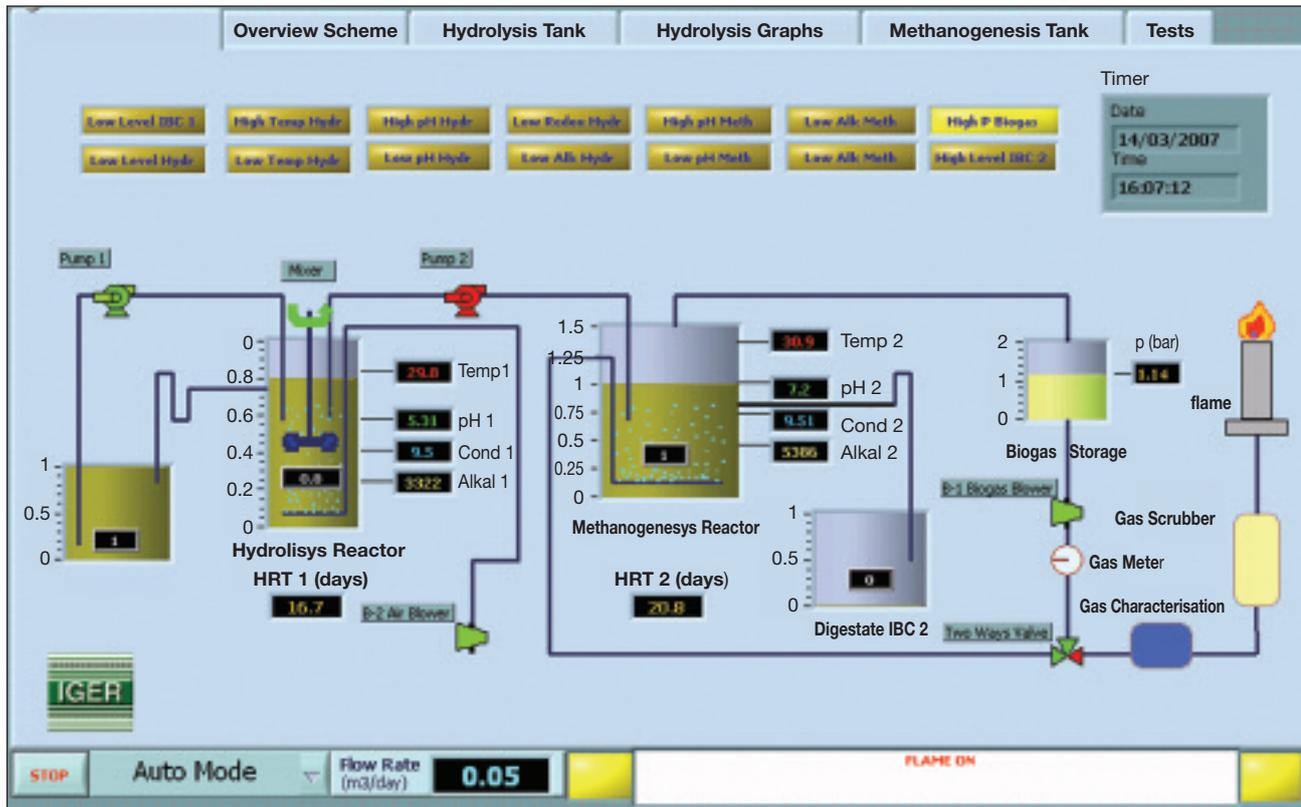


Fig. 3. Schematic of the process control interface for the new pilot plant showing status and sensor responses.

mixing, known as the hydrodynamics of the digester, is also a valuable means of fault finding.

The implications of our research for biogas production and the effects of the current economic climate on the financial viability of the process will be investigated in collaboration with Exeter University's Rural Studies Department. This

collaboration will look both at farm-scale digesters and at more centralised larger-scale digesters that can more easily accept wastes, from a greater range of sources.

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