Challenges in biogas production: Increasing methane yields from residual biomass and moving towards standardisation of research methods

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Organic wastes can be degraded by a complex community of microorganisms as the result of their incubation in the absence of oxygen. The process called anaerobic digestion occurs in a closed tank (digester). It stabilises the wastes and generates biogas and digestate. Biogas contains methane which can be used for energy production and digestate can be used as a fertiliser. Anaerobic digestion is a sustainable process which can contribute to limit climate change as it combines waste treatment, nutrient recycling and green energy production. However, in order for this technique to be more widely used, production of biogas from available wastes (residual biomass) needs to be maximised and more research is required to develop treatments and investigate substrate suitable for anaerobic digestion. The present work investigates strategies to improve the utilisation of two residual biomasses: pig manure and waste water sludge. Further it proposes a new laboratory method as well as software tools to facilitate research in biogas production.

Pig manure is a globally available organic waste, which has to be managed to reduce gaseous emissions and contamination of water streams. It contains organic matter in excreta that has been transformed by pigs and straw (from litter) and is therefore difficult to convert into methane. The present work showed that the methane production from pig manure could be improved by separating a solid fraction of the digestate and recycling it back to the digester. Wastewater sludge is composed of organic matter that has settled during the first part of its treatment, and of cells from microorganisms that have been transforming organic matter and contaminants in the wastewater. The cells from microorganisms are protected by a membrane and external substances that constitute a barrier to the production of methane. Anaerobic digestion of sludge aims to reduce the amount of organic matter contained is the sludge and to produced methane and to reduce the costs the process could be improved. This thesis investigated the use of a complementary biological treatment (using aeration) to improve the methane production and reduce the organic matter content of the sludge. It showed that the combination of aeration treatment and anaerobic digestion, could improve the removal of organic matter but that the improvement in methane production was highly dependent on the sequence of the aerobic and anaerobic treatments.

In order to know how much methane can be obtained from a waste, laboratory assays are necessary. Some of them are done by incubating small amount of waste into closed bottles, and measuring the volume of gas produced. If leakage occurs out of the measurement periods and is not quantified, tests should be started over which is time-consuming and expensive. This thesis presents a new approach for measuring biogas production in laboratory assays based on the reduction in the bottle mass when gas is vented out of the bottle. The method, which only requires a scale and a control reactor filled with water, can be used alone or in parallel with other traditional methods to detect inadvertent leakage. Analysing biogas data requires multiple steps and can be tedious. Reporting of calculations methods is rarely detailed making research results difficult to compare and reproduce. This thesis presents two software tools to analyse biogas data and predict methane production: the package “biogas” using the open source programming language R, and a web application “OBA” which does not require any programming skills. These tools could potentially improve sharing and reproducibility of biogas research and provide a mean to spread the expertise gained from research in biogas to a broader audience.