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RESEARCH ARTICLE

BIOENERGY GENERATION FROM ANIMAL MANURE AND FOOD WASTES

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European Union (EU) mandated national targets for reducing greenhouse gas (GHG) emissions and increasing the provision of renewable industry continue to drive demand for renewable energy technologies in Europe. On-farm biogas plants have been a key component of the renewable energy generation and energy security strategies of several EU countries for the past 25 years, in particular Germany and Denmark. They typically operate with a feedstock comprised primarily of manures (generated on-farm) supplemented with energy crops or agricultural by-products.

Anaerobic digestion converts organic matter to methane-rich biogas for energy recovery. Anaerobic co-digestion is the process of combining multiple substrates which undergo anaerobic digestion. It is undertaken in order to improve the performance of anaerobic digestion of specific substrates by altering the carbon to nitrogen (C/N) ratio, providing buffering capacity, supplying essential micronutrients and modifying total solids contents. Mono-digestion of animal manure is prone to inhibition caused by high ammonia concentrations. On the other hand, mono-digestion of easily biodegradable organic wastes, like food waste, is negatively affected by high volatile fatty acid (VFA) concentrations. Hence, co-digestion of food waste and animal manure provides a promising solution to address each of these issues through the interaction between the VFAs and ammonia.

The addition of energy crops or agricultural by-products is undertaken to increase methane yields, thereby increasing the economic viability of anaerobic digestion plants (Xie et al., 2011; Xie et al., 2012). However concerns regarding sustainable land use associated with energy crops have led to increased interest in alternative low cost co-substrates in the past decade. Organic wastes such as food waste, source segregated food waste (FW) and the organic fraction of municipal solid waste are increasingly used as co-substrates in on-farm biogas plants. On-farm plants may receive gate fees for digestion and subsequent disposal of these wastes. Additionally, high specific methane yields (SMYs) of these wastes make them attractive as co-substrates. Increased quantities of FW in digesters will result in a reduction in landfilling of organic waste, as part of meeting EU Landfill Directive targets.

Anaerobic co-digestion has the potential to mitigate GHG emissions by providing a means to generate renewable energy which can offset GHG emissions from the agricultural sector, and by providing nutrient-rich organic fertiliser (digestate). In particular, anaerobic co- digestion will be able to play a role in the Irish agricultural sector, which has set up ambitious plans to increase agricultural outputs by 2020: increasing the value of primary output of the agriculture, fisheries and forestry sector by 33% compared to the 2007-2009 average.

According to an in-house survey in Ireland, the total number of sows in 2012 was 147,899, with an estimated 3.1 million m^3 of pig manure (PM) generated per year. It is mainly disposed of by land spreading. 589,260 tonnes of biodegradable municipal waste (BMW) was generated in 2012, comprising primarily of food waste (FW), but almost all of it was treated by landfilling (589,000 tonnes) (McCoole et al., 2014). If all the PM and FW are treated by dry co-digestion, the biomethane volume produced would be 6.3×107 m3 per year, with the energy potential of 2.14×106 GJ per year, which is equal to 3.1% of the total natural gas consumption and 8.4% of the residential natural gas consumption in Ireland in 2013 (Howley et al., 2014). If the biomethane is utilized by combined heat and power (CHP) technology with the electricity and heat efficiencies of 30% and 50% (NNFCC, 2010), the electricity and heat produced would be 1.78×108 kWh and 2.97×108 kWh, respectively. The electricity produced equals 0.7% of the total electricity consumption and 2.1% of the residential electricity consumption in Ireland in 2013 (Howley et al., 2014).

Depending on the total solids (TS) content of the feedstock, anaerobic digestion can be classified as wet digestion (TS < 20%) or dry digestion (TS ≥ 20%). Our research shows that wet co-digetion (TS=4.8%) of PM and grass silage (assuming a typical Irish pig farm with 500 sows) was not cost effective due to the large reactor volume, high heating energy consumption, low biomethane production yields and high cost of post treatment of liquid digestate (Nolan et al., 2012). Dry anaerobic digestion is promising, and it can greatly decrease the cost of biomethane production by (i) reducing the digester volume significantly, (ii) requiring less energy for heating to maintain the digesters' temperature, (iii) increasing biomethane yields per unit mass, and (iv) avoiding the post treatment of liquid digestate.

Our research work in this area includes: (1) assessment of the effects of changing operating conditions (such as hydraulic retention time, organic loading rate, substrate mixing ratio etc.) on properties such as methane yield, digestate dewaterability and pathogen removal, which determine the cost of digestate disposal; (2) assessment of the feasibility of dry co-digestion;

(3) investigation of compositional changes in bacterial and archaeal communities in response to changes in the operating conditions by using high throughput DNA sequencing; and (4) digestate treatment if discharged to water bodies directly.

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