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Assessment of the resource associated with biomethane from food waste

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HIGHLIGHTS

- The biomethane potential (BMP) assessment is dependent on the inoculum.
- BMP results improve with active inoculum, which is acclimatised to the substrate.
- BMP of food waste was found to be between 467 and 529 LCH_4/kg volatile solids added.
- The resource of food biomethane is assessed at 2.8% of energy in transport.
- This assessment is predicated on source segregation of food waste.

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ABSTRACT

This paper assesses the resource of biomethane produced from food waste at a state level in the EU. The resource is dependent on the quantity of food waste available for anaerobic digestion and the specific methane yield from food waste. The specific method of undertaking biomethane potential (BMP) tests was shown to be crucial. BMP tests were carried out at different scales (5 L and 0.5 L) with different sources of inoculum, for both wet and dried substrate samples. The upper bound BMP results for source segregated canteen food waste gave specific methane yields of between 467 and 529 L CH_4 per kg volatile solids added. The higher results were associated with acclimatised inoculum and wet samples of food waste. The potential renewable resource of biomethane from food waste is shown to be equivalent to 2.8% of energy in transport in Ireland; this is significant as it surpasses the resource associated with electrifying 10% of the private car fleet in Ireland, which is currently the preferred option for renewable energy in transport in the country. However for this resource to be realised within the EU, source segregation of food waste must be effected. According to the Animal By-Products Regulations, digestate from source segregated food waste may be applied to agricultural land post anaerobic digestion. Digestate from food waste derived from a mixed waste source may not be applied to agricultural land. Thus biomethane from food waste is predicated on source segregation of food waste.

1. Introduction

1.1. Landfilling of biodegradable municipal waste

Effective management and treatment of biodegradable waste is a topic of increasing importance for municipalities across the globe. The organic fraction of municipal solid waste (OFMSW) which is dominated by food waste is problematic as it is putrescible; it contaminates recyclable material in combined waste collection systems and releases methane to the atmosphere when deposited in landfill sites. Methane has a global warming potential (GWP) over a 100 year time horizon of 23 times that of carbon dioxide [1] and is a significant contributor to climate change. The Landfill Directive 1999 [2] has set significant targets for reducing biodegradable waste going to landfill, while the Waste Framework Directive 2008 [3] has introduced more demanding waste recycling and energy recovery targets. Many EU countries have introduced landfill levies. Some countries including Germany have placed an outright ban on dumping untreated OFMSW.

1.2. Quantities of food waste generated

This paper uses Ireland, an EU state with a population 4.6 million [4] to exemplify the bioresource analysis. Approximately three

Abbreviations: ABP, Animal By-Product Regulations; AD, anaerobic digestion; BMP, biomethane potential test; BMW, biodegradable municipal waste; CSTR, continuously stirred tank reactor; DS, dry solids; FW, food waste; FW-wt, food waste wet weight; MBT, mechanical biological treatment; MSW, municipal solid waste; OFMSW, organic fraction of municipal solid waste; SMP, specific methane production; RES-T, renewable energy supply-transport; SSFW, source segregated food waste; UCC, University College Cork; VS, volatile solids.

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million tonnes of municipal solid waste (MSW) is generated annually (652 kg/person/annum), two thirds of which is considered to be biodegradable [5]. Food waste makes up about 25% of domestic household waste and 42% of commercial waste [6]. It is estimated that approximately 820,000 t/annum (178 kg/person/annum) of food waste is generated in Ireland. Ireland landfilled 860,000 t of biodegradable municipal waste (BMW) in 2010. The Landfill Directive [2] permits landfill of a maximum of 420,000 t/annum of BMW by 2016 (based on 35% of 1995 quantities). Alternative waste treatment methods are required for approximately 530,000 t/annum of BMW by 2016 (Table 1). The Waste Management (Food Waste) Regulations 2009 [7] has mandated source segregation of food waste from commercial premises in designated organic waste bins (brown bins). The catering sector alone produces over 100,000 t/annum of food waste [8].

1.3. The requirement for source segregation of food waste

It has been widely acknowledged in many EU states and in other developed countries that in order to maximise diversion of food waste from landfill, effective source separation is required [9]. This may be effected through use of a three bin collection system which incorporates a specific bin for food waste. Department of Agriculture Regulations in EU countries only allow compost or liquid fertiliser (digestate) from food waste which is source segregated (as opposed to co-mingled food waste with other waste from a materials recovery facility) to be used in agricultural applications [10,11]. Food waste accounts for the majority of the organic fraction of municipal solid waste (OFMSW). If not source segregated food waste may be separated from mixed waste through mechanical biological treatment (MBT). Mechanically derived OFMSW has been shown to have very stable anaerobic digestion characteristics with a carbon to nitrogen ratio of about 25:1 which is in the recommended range for stable digestion (20–30:1). However mechanically derived OFMSW contains higher concentrations of potentially toxic elements and lower nutrient content than source segregated food waste (SSFW) [12]. It is important to note that digestate from MBT derived OFMSW may not be applied to agricultural land due to potential for contamination of the food chain [10].

1.4. Significance of BMP assays in assessing biomethane potential from food waste

The biochemical methane potential (BMP) test is a widely used method to assess the maximum upper range of methane production from an organic substrate. There have been many papers published on the BMP yield of various organic substrates used for biogas production. However, despite a mass of data having been gathered, comparison of biomethane potential data in literature can prove difficult as different methods and protocols have been followed. Parameters such as substrate preparation, inoculum to substrate ratio, liquid and headspace volumes, pH of substrate and inoculum, headspace pressure and the gas flow measurement system employed can all differ from one test to another [13,14]. To assess the BMP of SSFW samples, both large and small scale BMP tests were carried out. Nizami and co-workers [14] showed that micro BMP assays using dried substrate samples gave lower BMP yields than larger BMP assays using wet weight samples. They also stressed the importance of acclimatising the inoculum to the substrate.

Table 1
Biodegradable municipal waste (BMW) disposed to Landfill in Ireland.

Target year	Allowable (kt)	Actual (kt)	Requiring stabilisation (kt)
2010	900	860[a]	–
2013	600	882[b]	282
2016	420	950[b]	530

kt kilotonne.
[a] Reported BMW sent to landfill in 2010 [5,6].
[b] Estimated BMW quantities based on economic growth rate of 2.5% from 2012 onwards.

1.5. Sustainability and applications of OFMSW biomethane

Anaerobic digestion (AD) is an economical and environmentally effective waste treatment solution with the added benefit of energy recovery in the form of biogas (ca. 60% methane) [15]. The EU Renewable Energy Directive 2009 [16] indicates that biomethane from OFMSW has a nominal green house gas saving of 80% of the displaced fossil fuel when used as a compressed gaseous biofuel. This saving is well in advance of other first generation liquid biofuels [17]. Although AD technology is widely available, research in the field is still ongoing due to the complexity of the biochemical process, the wide variety of substrates which can be utilised and reported problems in applications of certain substrates. These include low C:N ratios (associated with SSFW and other biowaste streams) leading to increased levels of NH_3–N which can result in reduced biogas yields [18,19]; Problems associated with the long term mono-digestion of food waste have been linked to a lack of essential trace elements (such as molybdenum and cobalt) which can lead to the failure of the AD process [20]. However considering the poor energy balance associated with many first generation liquid biofuels (such as rape seed biodiesel) and increasing public concern towards biofuels displacing food production, the concept of utilising biomethane from biowaste as a biofuel is very attractive [15–17].

1.6. Objectives of the paper

The principal objective of this paper is to assess the biomethane resource from food waste, using Ireland as a case study. In undertaking this task, the importance of the scientific methodology for conducting biomethane potential assays was realised. This paper will highlight the variance in BMP yields for food waste, taken from the same sample, depending on the BMP methodology employed. In addition, this paper seeks to highlight the impact which EU waste management policy and its implementation has on the quantity of food waste which could be utilised to generate biomethane.

2. . Materials and methods

2.1. Preparation of food waste

As food waste is a heterogeneous substrate that can change depending on the season and region it is difficult to model for lab scale experimental work. The food waste which was used in the experiments was collected from the main university campus canteen in University College Cork (UCC), Ireland. The canteen serves approximately 1000 students per day and produces approximately 2500 kg of food waste per week during the academic year (September–June). The canteen food waste consisted of mixed cooked and uncooked food such as pasta, rice, meat, fruit and vegetable peelings. It has been previously shown that source segregated food waste gives higher methane yields than co-mingled MSW [12,20]. SSFW from the university canteen was chosen as the substrate to be used in the BMP tests. It was decided to take a large bulk quantity of food waste in an effort to get a representative sample. Approximately 200 kg of SSFW was collected from the main campus restaurant. The SSFW was manually screened for non