Conversion of digestate from anaerobic digestion of food waste into fertilizers

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1. Background

Anaerobic digestion (AD) has been evaluated as one of the most cost-efficient and environmentally friendly biotechnologies for renewable energy production, in the form of heat and power, organic waste management, and recovery of valuable nutrient rich digestate [1]. The latter has the potential to be used as fertilizer for agricultural utilization, landscaping, and soil amelioration since it contains essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) [2]. Digestate is produced from anaerobic degradation of organic wastes, mainly derived from food waste, crops and sewage sludge from wastewater treatment processes. However, the use of digestate has become a crucial challenge due to the limitation of cost and quality for the production of fertilizers as well as the application location. This study examined the optimization of an anaerobic digestion waste-to-energy system for food waste management and conversion of digestate to fertilizers. Following which, how the use of digestate for the cultivation of vegetables was investigated in comparison with chemical fertilizers. The objectives of this study are: 1. to optimize the operational parameters of a distributed anaerobic digestion waste-to-energy system for food waste management. 2. to study the efficiency of various fertilizers extracted from digestate and chemical fertilizers by cultivating green vegetables and comparing the major indexes for the growth of vegetables.

2. Materials and methods

2.1. Operation of an anaerobic digestion waste-to-energy system for food waste management

Briefly, an integrated anaerobic digestion eco-system for food waste will be set up. The main unit is anaerobic digester that consists a blender, a digester body, a temperature control system, an auto-pH testing system, and a controllable stirring system. After being seeded, the anaerobic digester is operated under a semi-continuous mode at room temperature with a proper mixing speed. Food waste is obtained from a canteen of the National University of Singapore, which mainly consisted of rice, noodles, meat, vegetables, and condiments. After removing any bones and non-biodegradable waste like plastic bags, food waste is homogenized in a blender and then pumped into the anaerobic digester for biogas generation. The seed sludge was collected from a large-scale anaerobic digester at Ulu Pandan Water Reclamation Plant in Singapore. Digestate will be collected from the anaerobic digester every day. Waste heat from IC engine will be used to heat up the liquid fraction for evaporation. Three different digestates i.e. untreated digestate, heat treated digestate and chemical fertilizers are compared for cultivation of vegetables.

2.2 Chemical analysis

The pH is recorded using a pH analyzer. Total solid and volatile solid are determined based on the weighing method after being dried at 103-105 C and burnt to ash at 550 C. C, N, S, P and H elemental analyses were determined using the vario MICRO cube (Elementar, HANAU, Germany). Metals elemental analyses were conducted using an inductively coupled plasma (ICP) – optical emission spectrometer (Perkin Elmer Optima 5300V, USA). Total nitrogen, ammonia, and COD were determined using HACH color meter (DR900, USA) according to the manufacturer's instructions. The CH_4 production was determined using a gas chromatograph (Clarus 580 Arnel, PerkinElmer, USA) equipped with a thermal conductivity detector.

3. Results and conclusion

1) Anaerobic digestion performance for methane production from food waste –Fig. 1 illustrates the increase in biogas and methane yield with increasing OLR. A higher OLR translates to a larger amount of VS (i.e.

biodegradable organic substances) fed to the reactor leading to greater biogas volumes per unit weight of food waste fed. Over the 36-day period, biogas yield increased from 0.56 to 1.1 L/gVS day and methane yield increased from 0.31 to 0.6 L/gVS day.

2) Table 1 shows the characteristics of digestate. The original digestate from this 1000L anaerobic digester, heat treated digestate and chemical fertilizer are used for cultivation of vegetables. The results showed that the interaction between heat treatment and digestate concentration (in 250 mL of digestate and water mixture) is significant (p=0.0380), so the trend-lines for the different types of digestate are different (high=121C, low=60C, untreated=untreated). The treatment with the highest yield (40%, untreated) was also compared with the control treatment (chemical fertilizer, 15N:15P:15K, 1.2 g per application) using t-test. The yield of the best performing digestate (0.64197+-0.09072741) is not significantly different from the control (0.58634+-0.05022737). It means that the performance of digestate is almost same to the use of chemical fertilizer.

Table 1 Characteristics of digestate

Parameters	Solid digestate
Elemental analysis (wt%)	
Carbon	44.3 ± 5.7
Hydrogen	6.6 ± 1
Nitrogen	8.9 ± 0.5
Sulfur	0.87 ± 0.1
Phosphorus	1.82 ± 0.1
Metals (wt%)	
Ca	2.0 ± 0.9
K	0.87 ± 0.3
Mg	0.13 ± 0.02
Na	4.0 ± 0.7
Zn	0.04 ± 0.006
Fe	0.57± 0.04
Mo	<0.01
Hg	ND

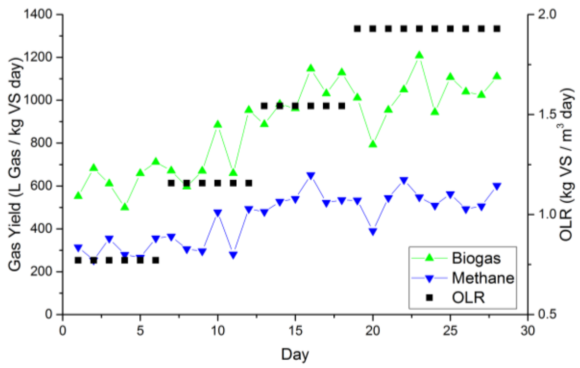

Fig. 1. Specific methane production and (B)

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