Bio-augmentation of microbial consortia to reduce start-up time of thermophilic AD processes and to break down plastics/ bio-plastics mixed in food waste

at Energy and Environmental Sustainability for Megacities (E2S2) Program

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Background

Thermophilic anaerobic digestion (AD) with a higher metabolic rate has been proposed as a possible solution to improve the overall process efficiency of AD. Other advantages of thermophilic AD include a larger degree of pathogen deactivation, increased destruction rates of organic solids and higher biogas production yields. However, several limitations of thermophilic AD have also been reported, such as slower start-up time, poorer stability, and lower endurance at high organic loading rate (OLR). These limitations could be overcome by inoculating the thermophilic bio-reactors with a microbial consortia that generates methane effectively at thermophilic conditions.

Research Questions

It is hypothesised that the bio-augmentation of thermophilic microorganisms can significantly reduce the time required to start up thermophilic digesters. One of the aims of this sub-topic is to determine a method to cultivate an optimised consortium of thermophilic microbes to aid in the start-up of thermophilic digesters.

The bio-augmentation of plastics-degrading microbes to the AD of food waste mixed with plastics is hypothesised to be able to break down plastics during the AD process. This not only solves the contamination problem faced by operators, but could also improve the efficiency of the AD process through the supply of more nutrients.

Methodologies

Optimisation of the consortium of bio-augmentation microbes would be carried out by enrichment of sludge collected from the pilot-scale bioreactor treating food waste (FW). Two different start-up strategies (step-wise vs. one-step start-up) to acclimatise mesophilic sludge to thermophilic consortia would also be compared. Preliminary results show that stable thermophilic AD was achieved within 10 days from a mesophilic digester treating food waste by adopting the one-step start-up strategy. After the increase of temperature, thermophilic methanogenic community was established, which was characterised by the colonisation of *Thermotogae*, *Methanosarcina*, *Methanomassiliicoccaceae* and *Methanoculleus*. Results from this study demonstrated that the one-step start-up strategy could allow the rapid establishment of the thermophilic anaerobic microbial community.

Data of the type and amount of plastics mixed in food waste would be collected from the two demonstration plants located within the campus of NUS, which were set up during Phase 1. The data collected will be used to design the laboratory experiments to investigate the threshold of AD systems to withstand contamination by these plastics as well as to understand how the leaching of plastic by-products (e.g., styrene) during the AD process affects the microbial consortia (acetogenic and methanogenic bacteria). Preliminary results show that methane production from the AD of FW was inhibited to different extents when different materials were present in FW. Polystyrene (PS) and polypropylene (PP) were found to reduce methane production from FW more than high density polyethylene (HDPE) and wooden chopsticks (WC). Pyrosequencing and Field Emission Scanning Electron Microscope (FESEM) results indicated that the reduction in methane production was more likely due to the interference of good contact necessary between microbes and FW for biodegradation, and that the biological processes of AD were not affected by the contamination of plastics.

Greater reductions in methane yields were also observed when the surface areas of the disposable materials were increased. The figures below show some results from the study.

Batch Study on Effects of Disposable Materials on Methane Production from Food Waste

Condition	Contents	Reduction in CH_4 yield as compared to A1/B1	
		Expt A	Expt B
A1/B1	POME Sludge + FW (Control)	-	-
A2/B2	POME Sludge + FW + HDPE Trash Bags	3%	7%
A3/B3	POME Sludge + FW + Polystyrene	10%	14%
A4/B4	POME Sludge + FW + Polypropylene	6%	11%
A5/B5	POME Sludge + FW + Wooden Chopsticks	2%	6%

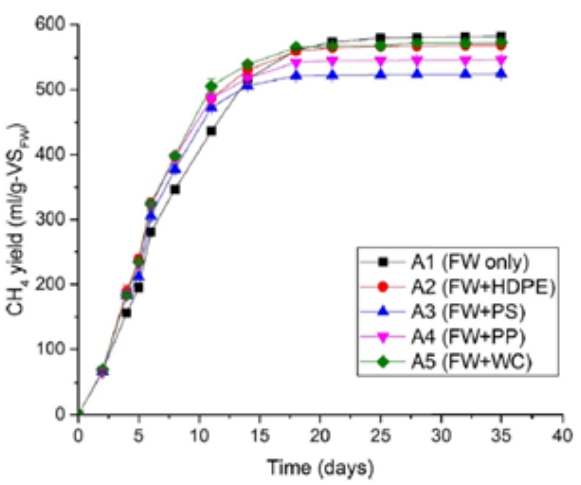

Figure 1: Methane yield of food waste contaminated with different disposable materials

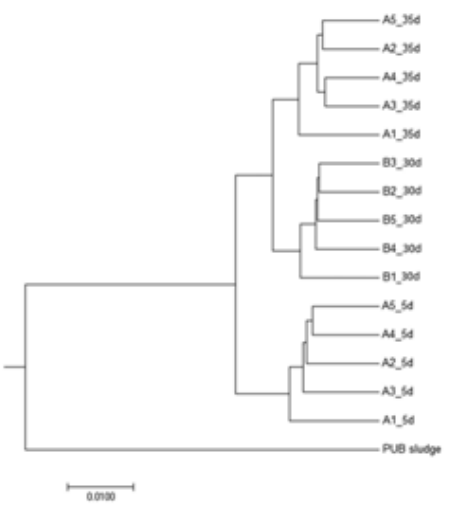

Figure 2: Dendrogram of metagenome constructed for microbial communities from sets 1 to 5 in experiments A and B

More details can be found from publication: Lim et al. (2018). Effects of disposable plastics and wooden chopsticks on the anaerobic digestion of food waste. Waste Management, 79, 607-614. Studying the effects of disposable materials on the AD of FW would provide plant operators with more information that could optimise the process of resource recovery from food waste.

After the successful selection and cultivation of a consortium of thermophilic/ plastics-degrading bacteria, the bio-augmentation of these microbes will be tested in the demonstration plants to study the effectiveness of bio-augmentation in enhancing the efficiency of AD of food waste.

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