2022_16_Civil Eng_Lee: Investigating epigenetics regulation and the techno-economics of micro-aeration microbiome for manipulating methane formation to support the Net Zero Carbon Transition

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Motivation: Climate change, energy security, and environmental threats urge us to consider a mutual strategy for sustainable future. Considering climate change in greenhouse gas (GHG) reduction, the global warming potential (GWP) and 100-year GWP of CH₄ is 28 and 36 times that of CO₂, respectively. CH₄ serves as an energy source that, if enhanced in production and utilisation and reduced production from ruminant animals and the environment, can offset fossil fuel usage and reduce its emission. One of the overlooked mechanisms is epigenomics modification for manipulating microbial CH₄ formation under micro-aeration conditions. For example, cows’ rumination uses co-grinding and enzymatic degradation in the mouth induced by micro-aeration, increasing their ruminate activities. Our preliminary mimicking results showed that micro-aeration increased lignocellulosic decomposition and methane yield over three times. Such a methane yield is associated with microbial epigenetic modifications (DNA methylation on N6-adenine and N4-cytosine- 6mA and 4mC) in gene expression and regulation. Some studies also reported high methane yield in micro-oxygen marine environments. Such overlooked mechanism deserves a physiological and meta-omics study and further evaluation of its potential techno-economic impact. This work is within the remit of the 2019 revision of the UK Climate Change Act, committing the UK to a Net-Zero by 2050 and the UK’s National Energy and Climate Plan (NECP) for the development of renewable energy and GHG reduction.

Aim: The overarching aim of the project is 1) to understand microbial structure and epigenomics modification (i.e., 6mA and 4mC), corresponding to micro-aeration conditions for methane yield with cellulosic biomass and 2) to evaluate its techno-econom impact in waste-to-energy biogas industry and ruminant animals in dairy product industry.

Objectives (Obj) and work packages (WP): to investigate microbial micro-aeration physiology (Obj1); a micro-aerated cellulosic-fed digester will be operated and investigated (WP1). To understand micro-aeration microbial epigenomics regulation (Obj2), sludge samples will be analysed with hybrid long- and short-read 16S rRNA gene, meta-genomics, and -transcriptomics techniques (WP2). To evaluate its techno-economic impact on energy-crop digestion and the livestock and dairy industry (Obj3), carbon mass balance of microbial cellulosic biomass transformation and its respective life-cycle assessment will be performed.

The project will be supervised by Dr Po-Heng (Henry) Lee and Dr Jeremy Woods. Dr Lee is a Senior Lecturer in Anaerobic Biotechnology and Microbiomes and his team developed anaerobic digestion reactors and genomics techniques. Dr Woods is a Reader in Sustainable Development, specialised in environmental impact, techno-economic and sustainability assessment applied to policymaking and industry standards. Their complementary expertise is related to the project proposed.

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