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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 environments, 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 an overlooked mechanism deserves a physiological, meta-omics, and quantum simulation 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 the microbial structure and epigenomics modification (i.e., 6mA and 4mC), corresponding to micro-aeration conditions for methane yield with cellulosic biomass 2) its regulation using quantum information theory via quantum computing platform and 3) to evaluate its techno-economic impact on waste-to-energy biogas industry and ruminant animals in the 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 and quantum simulation (WP2). To evaluate its techno-economic impact on energy-crop digestion and the livestock and dairy industry (Obj3), the 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 Onesmus Mwabonje. Dr Lee is a Senior Lecturer in Quantum microbiology and Anaerobic Biotechnology. Dr Mwabonje is a Research Fellow in Sustainable Development, specialising in environmental impact, techno-economic and sustainability assessment.

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