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# Investigating the product spectrum of an anaerobic biorefinery and optimisation of process parameters

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**2021**

https://hdl.handle.net/10539/32955

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# ABSTRACT

This study investigated the various products that can be generated from the anaerobic digestion of fruit and vegetable waste, and the downstream treatment of the FVW digestate using hydrothermal carbonisation. The aim of the study was to explore the concept of biorefineries, i.e. multiple product generation, for anaerobic digestion processes. Additionally, the study examined the potential of anaerobic biorefineries as alternative, environmentally friendly, waste management methods for treating organic waste such as fruit and vegetable waste. In Experiment 1 (Chapter 3), the study investigated the production of biohydrogen and volatile fatty acids using FVW as feedstock, via anaerobic digestion, in a process known as dark fermentation. To enhance biohydrogen production, the study applied seed inoculum pre-treatment including heat, alkali, acid, and heat-alkali. Acid pre-treatment resulted in the highest hydrogen yield (142, 74 Nml/g VS), and hydrogen content (54%). Heat pre-treatment, on the other hand, generated the lowest hydrogen yield (0, 90 Nml/g VS). The hydrogen yields of the pre-treatments tested were substantially different ($p<0.001$). Valeric acid was the main VFA produced under all pre-treatments as well as the control. Butyric, propionic, and acetic acid were observed in small amounts only in the control, heat, and alkaline pre- treatments.

Experiment 2 (Chapter 4), focused on methane and volatile fatty acids production. Firstly, the study investigated how three factors, namely, pH, co-digestion and ultrasonification affect methane and VFA production. The effect of initial pH was investigated at pH (4, 6, 8, 10, 12), while for ultrasonic pre-treatment, specific energy from 2 500 up to 17 500 (kJ /kg TS) was applied. Fruit and vegetable waste to pig manure co-digestion ratios of (100/0; 0/100; 75/25; 50; 50; 25/75) were studied. Secondly, Response Surface Methodology, utilising Central Composite Design was applied to find the optimal conditions and interactive effects of the three studied process parameters. The maximum methane yield (497 Nml/g VS) was obtained at pH8 (control) and the minimum yield at pH 4 (11 Nml/g VS). Specific energy of 17 500kJ/kg TS resulted in the maximum methane yield (312 Nml/g VS). A FVW/pig manure (PM) co-digestion ratio of 75/25 gave the max methane yield (434 Nml/g VS). The maximum yield predicted via RSM model was 692.82 mL/g VS at the optimal conditions of pH 8 and the co-digestion ratio of 60 % fruit and vegetable waste: 40 % pig manure. The pH was found to be the only factor to significantly affect methane yield.

Experiment 3 (Chapter 5), investigated the production of hydro-char via hydrothermal carbonization of Fruit and Vegetable Waste (FVW) digestate. The Hydrothermal carbonization

(HTC) experiments were carried at temperatures of 180 $^{o}$C and 200 $^{0}$C for 2 hours in a 50ml stainless steel batch reactor, which was externally heated. The proximate composition, elemental composition, heating values, and thermal stability of the HTC solids were characterised. The study results show that there was an improvement in the Higher Heating Value (HHV) of the hydro-chars compared to the digestate. The highest energy yield (85, 26 %) and HHT (10, 75 MJ/kg) was obtained from the digestate treated at 200 $^{0}$C for 2 hours.