Food waste served three ways: butyric, lactic or caproic acid

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HIGHLIGHTS:

- Operating strategy influenced microbial community development, and the predominant metabolic product in food waste fermentation
- Chain elongation was stimulated at higher retention times
- Lactic acid was the dominant product at higher organic loads

BACKGROUND: Effective food waste (FW) management must provide cost-efficient resource and energy recovery to enable a sustainable circular bio-economy[1]. Of particular interest is fermentation with anaerobic mixed microbial cultures (MMC) to generate products, such as biogas, lactic acid, ethanol, H_2, or carboxylic acids (CA) ranging from volatile fatty acids (VFA), to medium chain carboxylic acids (6-8 carbon atoms, MCCA) via chain elongation. Various factors dictate fermentation outcome and MMC composition, e.g. the organic loading rate (OLR) and retention times[2, 3].

To improve chain elongation yields in FW fermentation, various reactor configurations, e.g. two-stage or leach bed, and supplementation of chemicals have been considered[4, 5]. However, studies have shown MCCA production from FW is possible in a single-stage stirred tank reactor (STR)[6]. The current study aimed to improve our understanding of how operation of a single-stage STR steers product outcome and the microbial community. The effects of OLR and hydraulic retention time (HRT) were assessed separately by operating three sets of duplicate semi-continuous STR over three HRT. We compared operation at a baseline HRT of 8.5 days and OLR of 12 gCOD L^{-1} d^{-1} (LH/LO) to operation at a higher HRT of 10.5 days (HH/LO) and a higher OLR of 20 gCOD L^{-1} d^{-1} (LH/HO). FW was collected from a full-scale industrial anaerobic digestion (AD) plant (GENeco, UK) and seeding cultures from in-house acidogenic fermentation reactors.

RESULTS & DISCUSSION: In previous experiments, we found that the collected FW from the AD plant varies slightly in composition, is high in biodegradable total COD (130 to 163 gCOD L^{-1}) and already contains ethanol (5 to 13 g L^{-1}) and lactic acid (around 20 g L^{-1}). The three sets of

operating conditions resulted in three different fermentation outcomes and MMC enrichments (Figure 1).

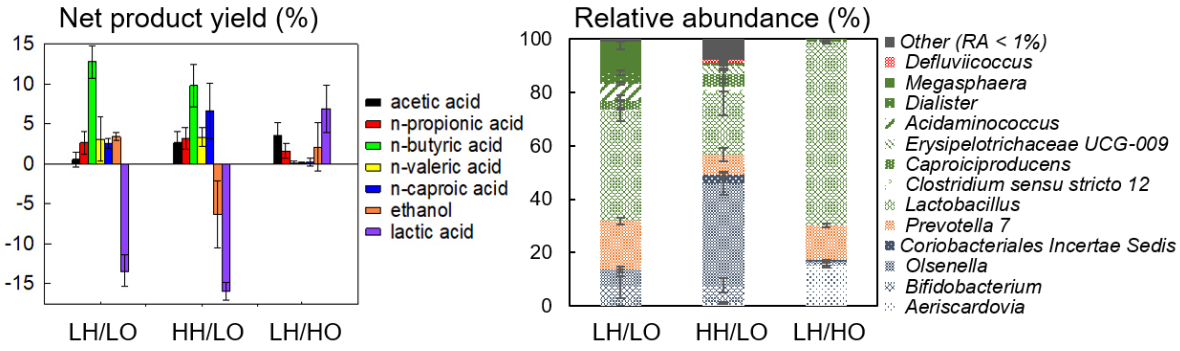

Figure 1: Average net yields of liquid fermentation outputs (left) and MMC composition at the genus level (right, colour per phylum) for varying operating conditions (i.e. combinations of HRT and OLR).

At lower OLR, lactic acid was net consumed and the total CA yields were similar, yet product distribution differed. In the LH/LO reactors, 55 ± 14% of the CA was butyric acid, and the fermentation was enriched in lactic acid bacteria and VFA-producers typical of primary acidogenic fermentation. At longer HRT in the HH/LO system, over three times more caproic acid was obtained (up to 6.2 g L^{-1}). The semi-continuous fermentation cycle showed consecutive fermentation stages of acidogenic fermentation and chain elongation in HH/LO, in line with earlier reports on chain elongation in FW[6]. The net consumption of both ethanol and lactic acid, and the presence of genera related to ethanol- and lactate-based chain elongation, e.g. *Caproiciproducens*, *Clostridium sensu stricto 12* and *Olsenella* spp., indicate chain elongation could occur with either or both electron donor. Thus, operating at longer HRT stimulated chain elongation. The residual butyric acid and ethanol concentrations in the effluent of HH/LO suggest the process could be further optimised.

When operating at higher OLR (LH/HO) minimal CAs were detected and predominantly lactic acid accumulated (32 ± 5 gCOD L^{-1}). More than twice the amount of NaOH was required to correct pH compared to operations at lower OLR. This was reflected in a MMC enriched in lactic acid producing and acid-resistant *Lactobacillus* and *Aeriscardovia* spp.

CONCLUSION: Food waste, with high biodegradable COD content, can serve as a feedstock for a range of platform chemicals. This can be achieved in a simple STR setup by manipulation of the operating conditions. Operating at a high OLR resulted in an organic overload, characterised by acidogenic lactic acid accumulation, where an acid-resistant community thrived. At lower OLR, an increased residence time allowed the community to evolve to perform chain elongation via secondary fermentation after acidogenesis. These results improve our understanding of the underlying metabolic pathways in food waste fermentation, and demonstrate the potential of adapting current single-stage food waste AD systems to produce other bio-chemicals by modifying HRT and OLR.

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