Anaerobic Fermentation Workshop

Summary of Workshop Output

Joint EBNet / BBNet workshop on the Role of Anaerobic Fermentation in the Circular Bio-economy

Hosted by the Environmental Biotechnology Network and the Biomass Biorefinery Network

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Workshop participants

Luca Alibardi, Cranfield University
Yadira Bajon-Fernandez, Cranfield University
Gabriel Capson Tojo, INRA Narbonne, France
Zeynep Cetecioglu, KTH, Sweden
Des Devlin, Dwr Cymru Welsh Water
Richard Dinsdale, University of South Wales
Ozge Eyice-Broadbent, University of Birmingham
Lindsey Gove, Anglian Water
Adrian Higson, NNFCC
Marie Kirby, Harper Adams University
Sigrid Kusch, Ulm University of Applied Sciences, Germany
Lily Lee, Imperial College University
Piet Lens, IHE Delft, Netherlands
Jaime Massanet-Nicolau, University of South Wales
Deborah Rathbone, University of York
Alba Serna-Maza, VORN Bioenergy, Spain
Tom Taylor, Yorkshire Water
Helen Theaker, Alps EcoSciences
Pete Vale, Severn Trent
Raffaella Villa, De Montfort University
Yue Zhang, University of Southampton

Also contributing

Paul Lavender, HaskoningDHV UK Ltd,
a company of Royal HaskoningDHV
Thomas Dietrich, Tecnalia, Spain

Supported by

Lucy Booth, BBNet
Louise Byfield, EBNet
Chloe Langley, BBSRC

Contact:

Dr Yue Zhang, University of Southampton, Y.Zhang@ssoton.ac.uk

Dr Lucai Alibadi, Cranfield University, L.Alibadi@cranfield.ac.uk

Environmental Biotechnology Network ebnet@ebnet.ac.uk

Biomass Biorefinery Network bbnet-manager@york.ac.uk

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Introduction

Anaerobic fermentation covers a range of biological processes. This workshop focused mainly on mixed-culture anaerobic fermentation (AF) of complex organic wastes and residues using robust microbial communities, without pre-sterilisation. Unlike precision fermentation which targets high-value products, or anaerobic digestion (AD) which focuses on energy recovery, AF offers a complementary pathway for valorising heterogeneous, putrescible organic wastes. Its strength lies in the metabolic flexibility of mixed microbial consortia capable of converting diverse substrates into volatile fatty acids (VFAs), a promising platform for biorefinery development. AF also offers opportunities for nutrient recovery, enabling additional value streams from essential plant nutrients embedded in biomass.

This approach can be considered a ‘dirty biorefinery’, where mixed organic waste streams are processed without stringent sterilisation requirements, leveraging microbial robustness. However, this operational flexibility introduces complexity in process control, microbial ecology, and integration with downstream extraction and conversion processes. These factors collectively influence efficiency, scalability, and economic viability.

The workshop explored AF’s current development, challenges, and opportunities within national and international decarbonisation frameworks. Our collective aim is to accelerate AF-based systems for value recovery from diverse waste streams, especially wastewater biosolids, municipal organic waste especially food waste, and agro-industrial residues/wastes, while addressing research gaps, engineering challenges, and policy needs.

Case Study 1: Wastewater Biosolids

Opportunities for Resource Recovery: Wastewater biosolids management faces increasing regulatory pressure due to emerging contaminants and net-zero carbon targets. Traditionally processed via AD for biogas, biosolids now require alternative valorisation strategies. AF offers a pathway to convert biosolids into VFAs, which can support internal wastewater treatment functions such as biological nutrient removal, or serve as feedstock for bioplastics and other bio-based chemicals.

Integration Challenges and Innovation Pathways: AF must complement existing treatment infrastructure rather than operate as a standalone process. Selective VFA recovery prior to methane production affects downstream processes, including thermal valorisation routes like pyrolysis or gasification. Successful integration demands careful balancing of energy recovery, cost-effectiveness, and environmental sustainability.

Scaling and Market Development: Transitioning AF from lab-scale to full-scale implementation requires structured pilot trials within operational wastewater treatment plants. Market development for VFAs is critical, alongside regulatory clarity on product classification and contaminant thresholds. Engaging policymakers early will help create a stable framework for adoption. Future innovation pathways include coupling AF with bioplastic production, and exploring syngas fermentation for enhanced flexibility.

Case Study 2: Municipal Organic Wastes (OFMSW)

Characteristics and Opportunities: The organic fraction of municipal solid waste (OFMSW) is highly biodegradable, rich in fermentable compounds, and increasingly available due to regulatory targets for source segregation. AF can process OFMSW rapidly, producing hydrogen-rich gaseous biofuel and fermentation liquids containing VFAs and nutrients. These outputs create opportunities for chemical recovery and integration with AD in two-stage configurations.

Integration with Existing Assets: Combining AF and AD enhances process stability, increases organic loading rates, and diversifies resource recovery streams. Short-term benefits include improved methane yields and ammonia recovery, while long-term opportunities involve VFA extraction for solventogenesis and innovative gas conversion systems.

Challenges and Next Steps: Key challenges include achieving cost-effective extraction and purification of VFAs and ammonia and developing robust markets. Research priorities include microbial adaptation to high ammonia concentrations and techno-economic analysis to validate AF's competitiveness against conventional chemical processes. Stakeholder engagement and regulatory alignment will be essential to drive implementation.

Case Study 3: Agro-industrial Materials

Feedstock Categorisation and Market Alignment: Agro-industrial residues vary widely in composition and strength, from low-value animal slurries to high-grade food processing wastes. In terms of potential application, categorising feedstocks is critical for process optimisation and product-market alignment. For example, VFAs from abattoir waste can feed bioplastic production, while energy recovery remains a priority for certain industrial effluents.

Stakeholder Engagement and Policy Development: To overcome technical and commercial barriers, the workshop proposed establishing an Anaerobic Fermentation Alliance. This alliance would develop research tools, foster industry collaboration, and support lobbying for policy frameworks that incentivise AF adoption. Feasibility studies with industrial partners will be key to demonstrating economic viability and scaling deployment.

Summary and Way Forward

The AF Working Group is committed to advancing research and innovation that transforms waste into value, delivering measurable environmental, societal, and economic benefits. By enabling AF integration into existing infrastructure and promoting business opportunities, we can also accelerate the transition from energy-driven AD plants to product-driven biorefineries. This evolution will not only enhance profitability but also position AF as a powerful enabling technology in the circular bio-economy.

Recommended Actions

- Develop and publish white papers and technical briefs to raise awareness and share best practices across academia, industry, and policy circles.

- Establish a dedicated AF network or alliance to foster stakeholder engagement, knowledge exchange, and coordinated lobbying for supportive policy frameworks.

- Pursue targeted research funding opportunities through UKRI, Horizon Europe, and other innovation schemes to support pilot-scale trials, techno-economic assessments, and life-cycle analyses.

- Engage with regulators and industry partners early to clarify standards, address safety concerns, and accelerate market development for VFAs and other AF-derived products.

- Organise workshops and webinars to build capacity, strengthen partnerships, and identify pathways for scaling AF technologies within existing infrastructure.

By taking these steps, we can move beyond theoretical discussions toward practical implementation, ensuring AF becomes a key enabler of sustainable resource recovery and circular economy goals.