VFA as a route to renewable transport fuel

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Introduction

Declining petroleum resources, increased demand by emerging economies, and political and environmental concerns about fossil fuels are driving the search for new sources of renewable fuels. Currently the only sustainable source of organic carbon is biomass, but biofuel production must target idle and marginal land and use of wastes and residues so that it does not contribute to rising food prices that adversely affect the poorest. In order to achieve such a vision, the FP7 collaborative research project SUPRABIO aims to deliver novel unit operations that can be integrated into economic biorefinery options for the sustainable production of biofuels. Under SUPRABIO Volatile fatty acids (VFA) are considered as a possible route for second-generation biofuels. In this paper we aim to provide a detailed description of this novel concept, how it may be implemented in practice and a review of the foreseeable challenges.

Fuel Manufacture

AD is a popular technology for biowaste management due to two major benefits: renewable biogas production and residue can be used as fertilisers. However, it comes at a high cost. AD technology has significant capital and operational cost requirements due to the slow process kinetics and the need to transport and handle large waste and digestate volumes. In terms of application, as a form of energy, biogas has a number of serious drawbacks. Firstly, raw biogas is considered to be a dirty fuel with a high level of H_2S that requires costly clean up before it could be used (for example in CHP engines for electricity generation). Second, the gas is not easily transportable and mostly has to be used at the point of production. Fugitive emissions due to leakage often account for 2-4% CH_4 loss which gives rise to a significant greenhouse gas contribution. (Gomez and Guest, 2004)

VFA on the other hand have none of the mentioned issues. Once VFA is generated from the fermentation process, it can be recovered and concentrated to facilitate transportation and storage. However, the issue of odour needs to be addressed .This also offers more flexibility for the downstream processing of the VFA intermediate. Table 2 shows a comparison of some key impacts between the two methods of energy production.

Table 2: Impact analysis of VFA route and biogas route

Impacts	**VFA route**	**biogas route**
Capital requirements	Low	High
Transport cost	Low	High
Value of product	High	Low
Carbon footprint	Low	High
Biofuel contribution	High	Low

The fact that VFA may be economically produced on relatively small-scale from different sources and locations allows a distributed production system to be realised. A centralised biorefinery may be conveniently located on a large sewage works, for example, to take advantage of local VFA production as well as the existing infrastructure such as roads, wastewater treatment and power supply. A distributed biofuel production system based on the VFA route is illustrated by Figure 1. Be mindful of the permit requirements of such a process. And in the economics consider the distances travelled as VFA movement will require a number of vehicles.

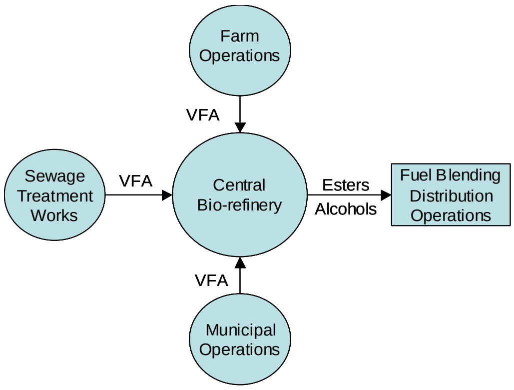

Figure 1: Alcohol and/or ester production

Technology Challenges

Many substrates, waste activated sludge in particularly, are only slowly biodegradeable. Hydrolysis is often the rate-limiting step in the overall VFA production process. Pre-treatment is the key to maximising yield and rate of the fermentation process. There are large numbers of technology options with varying degree of effectiveness for substrate pre-treatment. Many of these technologies are well proven with many full-scale sites in operation around the world. Although thoes technologies are very different in their modes of operation, they all have the same aim, to increase the renewable energy production by increasing the volatile solid (VS) destruction. VS is a measure of the organic content of the substrate.

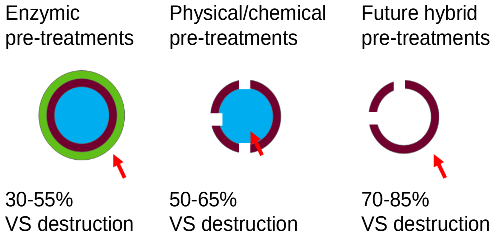

***Figure 2*:** Modes of operation of substrate pre-treatment technologies and their effectiveness

As illustrated by Figure 2, enzyme-type pre-treatments tend to target the outer coating of the bacteria cell whereas the more aggressive physical and chemical pre-treatments could break down cell wall and target the intra-cellular materials. Currently the best pre-treatment technologies offer a 65% VS destruction rate maximum. In order to achieve greater VFA yield greater VS destruction rates are desirable. Future pre-treatment methods are likely to be hybrids of enzymic and the physiochemical treatments that will be optimised to deliver greater efficiencies with up to 85% VS destruction presently regarded as a realistic target.

VFA from wastes is a new concept; there are still considerable technical challenges to overcome before it can be put into practical applications. Significant progress in VFA production from sewage sludge has already been made and reported (Le et al, 2006 and 2007). A major hurdle to its development is believed to be the economic recovery of the compounds. The key to the solution is likely to be the ability to achieve consistent VFA yields in a high concentration. Table 3 provides some encouraging early results from the large-scale fermentation trials (80 m3 batch runs) of VFA production for sewage sludge. The fermented liquor contains high level of VFA (up to 6,370 mg/L as C after 6 days fermentation for an un-thickened sludge).

Table 3: Summary of the VFA fermentation process trials (unit: mg/L)

Sludge feed	DS %	VS %	pH	total COD	
Average of 7 runs	4.52	72.15	5.72	51,450	
Fermented sludge	SS%	tVFA	pH	total COD	sCOD
Average of 7 runs	2.34	5,580	5.18	41,600	9,392
Fermented liquor	HRT, d	pH	Amm N	COD	tVFA
Batch 4	4	5.2	538	9,360	4,150
Batch 8	6	4.9	450	11,200	6,370
Fermented cake	pH	DS%	*E. coli*	*Salmonella*	
	5.54	27.0	Not Detected	Not Detected	

VS destruction = 67% (Van Kleeck)
TS destruction = 48%
COD destruction = 9850 mg/L (20% of total)

Conclusions

VFA offer a possible and convenient route for biofuel production from waste organic streams. The chemical intermediates may be economically produced on relatively small-scale from different waste sources and locations to allow a distributed production system to be realised. To make VFA suitable for use as a transport fuel, they need to be converted to alcohols or esters, ideally through hydrogenation. The hydrogen source for such a conversion process may be readily provided by the fermentation of up to15% of the VFA. The remaining challenges include more efficient substrate hydrolysis to achieve greater VFA yield; effective VFA recovery and low cost catalysts as well as more innovative reactor designs for economical fuel production.

References

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