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Photofuel - Biocatalytic solar fuels for sustainable mobility in Europe

Deliverable D3.3

Chemostat operation with 120 L reactor and identification of appropriate methodologies to separate excreted fuels during 120 L chemostat operation

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Editorial		
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Publishable Summary

Previous work within the Photofuel consortium has identified three major products: 1-butanol, a potential petroleum fuel substitute, and bisabolene and free fatty acids, which can be readily converted into diesel fuels. However, to commercialise the technology, continuous cultivation of engineered microorganisms and energy-efficient recovery and purification of the excreted products is essential. Consequently, a range of potential separation technologies were identified for each product and assessed through comprehensive process modelling based on both experimental and published results.

A *n*-butanol is highly soluble in the water phase, it is readily excreted into the algae culture. Unfortunately, the subsequent separation of butanol and water is more difficult and energy intensive compared to the other two products. Four different separation technologies, commonly suggested in the literature for the separation of butanol from ABE (acetone-butanol-ethanol) fermentation mixtures were evaluated by estimating the minimum butanol concentrations required to achieve an energy neutral process (separation energy is equal to heating value of butanol). Representing the industry standard, distillation requires a minimum butanol concentration of 9.2 g L^{-1}. Similar results were obtained for pervaporation (9.7 g L^{-1}), whilst gas stripping compared highly unfavorably (15.7 g L^{-1}). The best results were obtained for extraction with ionic liquids (of 4.1 g L^{-1}), and consequently this technology has been selected for lab-scale investigations.

In contrast to butanol, free fatty acid and bisabolene are water insoluble, and non-volatile. As a result, recovery processes are restricted to solvent extraction. However, during growth studies, free fatty acids have been found to be fully excreted from the cells to form floating deposits at the culture surface. As a result, free fatty acid could be first concentrated using gas skimming prior to extracting the dried foam with the solvent. In both cases, we propose the use of the final hydrogenated fuel product (bisabolane and hydrotreated acids) as the extraction solvent, to eliminate the use of an additional solvent/product separation steps. Based on this set-up, the energy requirements for the separation of bisabolene and free fatty acid were evaluated. By combining solvent extraction with gas skimming, the energy requirements for free fatty acid recovery can be substantially reduced, resulting in an energy-positive process at the product concentrations achieved so far. In contrast, due to the high affinity of bisabolene to the cell walls, skimming is not possible for this product, limiting the commercial potential of this product for fuel unless a significant breakthrough in product yields can be achieved.

Based on these results, future work will focus on the optimisation and implementation of ionic liquid extraction and gas skimming/solvent extraction processes for the recovery of *n*-butanol and free fatty acids from large scale production.