PhD Project Advertisement

Project title: BIO-ESPRESSO: Bio-Electrochemical System for Product Recovery from Spent Substrate Coffee waste
Project No: FBS2022-02-Avignone Rossa-sc

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Project description:

This project aims at the conversion of waste coffee, an abundant sub-product of the coffee industry, into value-added compounds through the application of bioelectrochemical systems called microbial fuel cells (MFCs). In MFCs, the metabolic activity of microbial communities attached to an electrode converts energy-rich organic matter into an electric current. In these systems, modifications in the operation conditions can be applied to direct the activity of the community, towards the synthesis of compounds of interest. This project will explore the feasibility of using coffee waste as feedstock for MFCs, with the view of developing a scalable technology for production of added-value biochemical or platform chemicals.

Why coffee waste? Coffee is one of the world's largest agricultural commodities: approximately 8bn kilograms are grown annually worldwide. The European Union is the largest importer of coffee, part of which is re-exported either as green or processed coffee. In 2013, the EU imported 3bn kilograms of coffee, accounting for approximately 45% of all exports of coffee.

The main residue produced by the coffee industry is called waste coffee ground (WCG), obtained in the industrial production of instant coffee and in the domestic and commercial coffee preparation. This residue is highly polluting due to their high content of organic matter, and potential toxicity, due to the presence of caffeine, tannins, and polyphenols.

WCG contains high amounts of cellulose, hemicellulose and lignin, free sugars, protein fat, and oils, lipids, triglycerides, and fatty acids. It also contains compounds of potential interest, such as antioxidants (e.g. caffeic, ferulic, p- coumaric, sinapic, and 4-hydroxybenzoic acids) and essential oils and terpenes.

Current methods of disposal of those residues only convert organic matter into unrecoverable (unusable) products. Coffee waste is mostly discharged into sanitary landfill or anaerobic digestion processes, and, at domestic scale, composting. However, the composition of the residue suggests their use as a source of precursors for specialty and platform (bio)chemicals. Due to the complexity of the system, conversion based on chemical processes is not possible without pre-treatment. Nevertheless, it should be possible to utilize the highly specific metabolic reactions present in microorganisms to convert those substrates into value-added compounds or their precursors.

We propose to use Bioelectrochemical systems to obtain value-added compounds from coffee waste used as feedstock in microbial fuel cells. Based on the chemical composition of coffee waste, we will identify which of the compounds could be obtained by the concerted metabolic activity of microbial species. Using bioinformatic tools, we will analyse natural microbial communities to identify the metabolic pathways able to convert a given substrate into a given product. We will also study pre-treatment strategies to improve the degradability of the waste by the selected microbial communities . The combination of all those approaches will allow us to design MFCs fed with solid and liquid feedstocks and careful selection and manipulation of operation parameters, will direct the process towards the production of added value molecules, decreasing the organic content of the original material and generating a less toxic product with lower content of pollutants.

This is a multi-, cross-disciplinary research proposal, as it straddles from microbial metabolism to biochemical engineering, through the combination of chemistry, microbiology, and bioelectrochemistry. This project involves Systems Biology, through the application of metabolic modelling, bioinformatics and the analysis and design of intercellular processes for bio-production; Synthetic Biology, through the rational design of microbial communities with specific and directed metabolic capabilities; a combination of biotechnological and chemical approaches, to inspire, guide, and deliver the transformation of bio-based building blocks into high added value molecules; application of bioinformatics and computational biology tools (e.g. bio-prospection, data analysis, metabolic modelling) for the identification and utilization of metabolic pathways to exploit microbial metabolic capabilities for bioprocess development.

Training opportunities:

The Systems Microbiology lab at the University of Surrey has extensive experience in design and optimization of microbial bioprocesses employing metabolic, biochemical, and computational tools, and more than 15 years of experience in application of microbial electrochemical technology for environmental bioremediation and depollution of agroindustrial waste and domestic and industrial wastewaters. The Centre for Climate and Environmental Protection at Cranfield has extensive experience in waste management and chemical analysis to understand waste characteristics, novel analysis techniques, and recovery of value and energy from waste materials.

A broad and specialised training programme, aligned to the project aims, will be provided through the University of Surrey's expertise in microbiology, biochemistry and bioinformatic and computational biology, and Cranfield University's expertise in chemical analysis and valorisation of waste. Through the balanced combination of those skills, and the design of a suitable research programme based on their scientific background, the successful applicant will acquire key research skills in all relevant areas.

Specific training courses:

Surrey

- Computational analysis of microbial metabolism, metabolic modelling and bioinformatics
- Experimental microbiology and applications of microbial electrochemical technology
- Principles of circular economy, life-cycle analysis, and bio-based economy.

Cranfield

- Chemical and biochemical analysis
- Bioprocess design and operation
- Project and data management

Student profile:

The successful applicant should have a background in either Microbiology or Microbial Biotechnology, or Chemical, Biochemical or Environmental Engineering. Appropriate training will be provided to complement the scientific background of the applicant. Interest and engagement with scientific research, possibly demonstrated by a successful undergraduate research project or a training placement.

Funding particulars:

For up to date information on funding eligibility, studentship rates and part time registration, please visit the FoodBioSystems website.