

Population growth, excessive resource consumption and high levels of pollutions are among the three most important causes for global climate change and deterioration of natural environment. Wide adoption of circular-economy model may offer a potential solution to the problem. It becomes necessary to maximize the use of bio-based renewable resources and minimize waste production. In order to facilitate this, the design of technologies for low-energy, environmentally-friendly biochemical conversions of waste streams is needed.

In 2015 global plastic production reached 381 million tonnes per year and it is estimated that almost 6.3 billion tonnes of plastic waste has already been generated, including 79% of which has ended up in landfills or the natural environment. Polyhydroxyalkanoates (PHA) biopolymers are recognised as excellent candidates to replace conventional petroleum-derived polymers. Currently, the production of simplest and most common form of PHA – poly-3-hydroxybutyrate (PHB) involves fermentation using pure strains and plant-derived carbon sources, most typically sugars. However, PHB is a low performance bioplastic that is crystalline and brittle with poor elastic properties, limiting the potential applications of this biopolymer. Consequently, many research groups are investigating the potential of using a number of more sustainable substrates and production of polyhydroxyalkanoates with superior toughness and elasticity.

Methane is used primarily to provide energy or heat via combustion. Almost 566 Tg methane per year is produced from anthropogenic sources, which constitutes 60% of annual global emissions. These, among others include the generation by the use of fossil fuels, landfilling and livestock farming. Increased emissions have negative consequences as methane is a greenhouse gas with approximately 20 times the impact of carbon dioxide. However, methane represents also an enormous resource and can be treated as a platform chemical for conversion into a range of higher value products. This is especially encouraging when methane from sustainable sources like landfills or anaerobic digesters are used or otherwise sources that are not economical to process for conventional heating. These economic incentives and the changing attitude towards sustainable production of both fine and commodity chemicals results in the growing interest in the biological conversion of methane.

Potentially, PHA copolymers with more desirable properties (such as PHBV copolymer) could be produced using mixed cultures of methanotrophic bacteria and methane as a feedstock. In most of the traditional biotechnological processes, pure cultures of microorganisms are used – either naturally isolated or genetically modified. This allows easier optimization and increase of the product yield. However, the fundamental flaws related to such processes include the requirement for sterile operations, as well as the necessity to use high quality and pure substrates. An interesting alternative is the controlled use of open mixed cultures of microorganisms. Due to immense diversity and complexity of common microbial consortia it is possible to utilize a number of more complex feedstocks for conversion into a variety of high-value products.

The general aim of the project is determine the molecular mechanisms determining the composition of PHA copolymers in mixed methanotrophic microbial communities and investigate the symbiotic interactions within the consortia. In the proposed research we aim to investigate the strategy to control the PHA copolymer composition, by adjusting the concentration and identity of the carbon source fed to the reactor in turns with methane. Increasing the molar content of monomers with longer carbon chains, such as 3-hydroxyvalerate is the secondary objective. While simultaneous co-feeding strategies of methane and carbon sources like propionate and valerate were previously investigated, the goal in this study is to use methane as a primary carbon source.

In the long term, the outcome of the project will help to build-up a method for upgrading of methane into a range of renewable, environment-friendly plastic products with superior properties. Moreover, methanotrophic communities can be steered/engineered to produce a large number of other products. The bioupgrading of methane is still in its infancy and the number of possible products very limited at the moment. In the future, it is also expected that results from this project will lay foundation for conversion of other methane-based gases, e.g. landfill or natural gas. The application of the proposed strategies may also constitute the basis for further development of technologies leading to production of PHA from methane, whose wider adoption offers a potential solution to carbon sequestration and green house gases (GHGs) reduction.