

## **Investigation of the mechanism and kinetics of integrated dark fermentation and hydrothermal carbonization of food waste**

One of the recently intensively researched sustainable technologies, to recover energy from waste biomass is hydrothermal carbonization (HTC). The HTC is a chemical conversion of organic compounds in aqueous slurry at temperature (ca.180°C) and pressure (1MPa) into coal-like hydrochar and liquid fraction rich in readily biodegradable organics and small amount of gases. Hydrochar can be used in energy or agriculture to fertilize the soil. Traditionally, the most of the research on the HTC has focused on obtaining hydrochar but recently the rising interest in HTC integration with anaerobic digestion (AD) is observed. AD is well established biotechnology, producing biogas through metabolic pathways in archaeobacterial consortia, which make up the final waste product – digestate sludge (DS). However, there is rather little data in the literature regarding the combination of HTC with dark fermentation (DF), the main product of which is biohydrogen  $\text{bioH}_2$  - a clean fuel alternative energy carrier to fossil fuels. Producing  $\text{bioH}_2$  via DF is the most environmentally friendly and sustainable way but its yield needs to be much enhanced and production cost should be reduced. The main production cost is of raw material, which can be minimized. Therefore, food wastes seems to be the proper substrate for DF. Food waste (FW) in most European countries was envisaged to rise to almost 130 million tons in 2020. FW is the largest component of municipal solid wastes, representing about 45% of the average global composition. Unfortunately, FW contain recalcitrant organic residues (ROR), especially lignin, peptidoglycan etc., which are not degraded in DF and reduce  $\text{bioH}_2$  production. Conventional FW processing facility generates 30% of ROR from the total FW material during biological treatment. Furthermore, the integration of the biohydrogen - DF bioprocess with HTC may be an appropriate approach to a more complete and value-added use of acid fermentation for the production of  $\text{bioH}_2$ . The integration of HTC and DF complies with the requirements of the circular economy.

The research object will be a mixture of FW and digestate sludge, the optimal composition of which (e.g. appropriate C/N ratio in the substrate) should ensure the maximization of  $\text{H}_2$  production. Not only liquid product of HTC, but also the solid hydrochar will undergo fermentation. It is expected its positive impact on  $\text{bioH}_2$  production due to its adsorption properties of toxins formed during HTC and the facilitating immobilization of bacteria. It is very important the proper sequence of both the chemical (HTC) and biological (DF) processes of FW. Therefore, two variants will be tested: (1) first stage is the DF of FW, from which the liquid phase will be sent to methane fermentation (MF), and the slurry to HTC; (2) first stage is the HTC of FW, from which the liquid phase will be directed to DF, the liquid phase after dark fermentation to methane fermentation (MF).

It is very important to study the mechanisms and kinetics of the DF biochemical process and the integrated HTC hydrothermal process, because it will be possible to optimize this system in terms of energy recovery, the practical implementation of which should be the subject of implementation project.

The determination of reaction kinetics of HTC of FW, has a key role in reaching the main goal of energy recovery from wet biomass wastes. Up to now several kinetics modeling of HTC have been proposed for pure substrates like glucose, fructose, etc. and complex waste biomass like sewage sludge, digestate but not so far the FW or their mixtures. The kinetic parameters of HTC of the mentioned substrates have been determined under various process conditions, however further research is required to develop more reliable models and formulate more precise reaction kinetics. One of the serious problem in intrinsic kinetics determination is a heating-up period in which temperature increases from the starting condition up to the desired HTC temperature. However, this heating-up period cannot be dismissed in most cases. There are few reports available on DF  $\text{bioH}_2$  production from pretreated FW using mixed consortia. Additionally, a few research works have been reported on the effect of feedstock treatment on reaction kinetics. Moreover, the knowledge about reaction kinetics and mechanisms involved in the integrated HTC and DF is fragmented and affected by mass and heat transfer. There is also no exact DF kinetics, with a complete mass balance of individual components in all three phases, and a description of changes in the composition of the bacterial consortium and the kinetics of their growth.

Proper sequence of the process stages, knowledge of the kinetics of HTC integrated with DF, the appropriate selection of the composition of raw materials, the residence time in the HTC reactor and the process temperature will allow for the optimization of energy recovery from wet biomass wastes and maximization of  $\text{bioH}_2$  production. The obtained results will contribute to broadening the basic knowledge about the processes of hydrothermal carbonization and dark fermentation and will enable further scale-up of these biorefinery processes using wet food waste.