One of the recent trends in anaerobic digestion (AD) is the addition of various carbon materials (CM), such as biochar, hydrochar, and activated carbon, to various methane fermentation substrates, including food waste (FW). The amount of generated FW shows an annual exponential growth, becoming one of the main global environmental problems. One of the ways to solve this problem is anaerobic digestion (AD). There is a niche for the determination of the real nature of the mechanism of the CM influence on biomethane production, and the contribution of each of the properties in this microbial mechanism.

The scientific aim of the project is the discovery of the real nature of the microbial mechanism of the influence of CMs on biomethane production efficiency and kinetics and the possibilities of CMs properties modification to achieve the highest yield of the biomethane.

The following hypotheses have been put:

- The CM with the higher buffering capacity (BC) will stabilize the conditions preferable for methanogenic microorganisms
- The CM with the highest sorption capacity (SC) will mitigate the toxic by-products of anaerobic digestion and regulate the biodegradable organic compounds availability for microorganisms
- The CM with the highest electric conductivity (EC) will enhance the direct interspecies electron transfer.
- The CM with lower zeta potential (ZP) will increase. the densification of methanogens in the solution and exclude other groups of microorganisms.
- It is possible to determine for the first time the qualitative and quantitative model describing the microbial mechanism of CMs influence on anaerobic digestion, allowing the intentional modification of CMs properties for AD optimization.

The overall research plan can be divided into 4 main work packages:

- Work package 1. Production and characterization of carbon materials – where the biochar, hydrochar, and activated carbon will be produced from wheat straw due to thermochemical treatment. The produced CM will be analyzed in a wide range of physical and chemical properties.
- Work package 2. Biomethane production from glucose (pure compound being an acetate precursor) with application of different carbon materials in batch and continuous flow reactors, with the addition of the produced in WP1 CMs. The biomethane potential and kinetics of its production will be determined. The characterization of substrates and residual digestate will be analyzed in a wide range of physical, chemical, and microbiological parameters.
- Work package 3. Mechanism analysis for biomethane production enhancement by carbon materials – where the advanced statistical evaluation, with the application of neural networks and fuzzy systems, will be applied to identify which of the particular CM properties enhancing the biomethane production and to build the mathematical model of these dependencies. Additionally, advanced multi-omic analyses will be applied for the identification of the microbial mechanism of CM influence on methane fermentation.
- Work package 4. Optimization of the anaerobic digestion process by application of carbon materials – where finally the possibility of biomethane production optimization by application of intentionally modified CM will be checked both in the batch and continuous flow lab-scale reactors fed by FW. The same range of analyses will be applied as in WP 1 and 2, and the same tests will be applied as in WP3.

The innovative nature of the research involves the systemic approach to indicate the mechanism of the CM influence on biomethane production, to indicate the most important properties enhancing the AD efficiency, and finally to use of the intentional modification of selected properties of CM and its application for the enhancement of AD of food waste. To our knowledge, no one carried out such an experiment, therefore new knowledge will be derived. Additionally, it is expected, that the possibility of intentional modification of the CM for the enhancement of yield and kinetics of biomethane will be examined, which may have an importance for the optimization of biogas plants and implement the approach of the circular economy.