Wet biowaste from agriculture pretreated by enhanced hydrothermal pretreatment into energy fuels

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The European Commission's REPowerEU plan, launched in 2022 to save and produce RES and diversify its supply, aims to increase the annual production and use of biomethane in the European Union to 35 billion m^3 by 2030. Such an assumption is associated with about 10 times higher production compared to recent years. In Poland, the potential of unused organic waste from agriculture, agri-food industry, sludge and municipal waste and others is estimated for the construction of up to several thousand installations of various sizes producing biogas, and from it energy in cogeneration or biomethane. The fuel industry, represented by ORLEN, PGNiG and PAK, is interested in this market and plans to build its own networks of agricultural biogas plants for the production of biomethane, and ultimately also green hydrogen. In Poland, there are currently only about 300 biogas plants, of which about half are agricultural biogas plants, and the rest are facilities in landfills and sewage treatment plants The crucial aspect of sustainable management of agriculture biowaste in order to increase their biomethane potential is its proper pretreatment e.g. by hydrothermal pretreatment (Mikusińska et al. (2024). Other, rather effective method of agriculture waste pretreatment is steam explosion which leads to break the structure of lignocellulose (Zhong et al. (2025). To maximize the effect of pretreatment the application of combination of different methods is required (Qiu and Chen, (2012)).

The aim of the study is to analyze the energy and ecological efficiency of the wet organic waste management, mainly biowaste from agriculture e.g. straw, with the use of hydrolysis combined with steam explosion to optimize technological parameters for this process. Therefore, the preliminary study of hydrolysis is carried out at 175°C, at autogenous pressure, for 0.5 and 2 h, without and with a catalysts and treated by quick wave of steam explosion. The main advantage of this process is the lighter or deeper decomposition of the complex organic matter into smaller compounds, including water-soluble ones. The hydrolysis process results in a significant increase in the biomethane potential of the pretreated feedstock. Dried feedstocks and hydrolysates are going to be tested in terms of their physical and chemical properties, including thermal and sorption properties, using the following instrumental techniques: ultimate and proximate analyses (Figure 1), and higher heating value. The study is supported by more advanced techniques such as determination of hemicellulose, cellulose and lignin contents. Thermal analysis is going to be employed to study the combustion performance and to determine key combustion temperature and parameters. SEM or FTIR are going to be studied to describe the morphological structure of studied samples. In addition, toxicity of hydrolysates are going to be determined. The leachates are tested to determine: COD, dry organic matter, analysis of physical, biogenic and bacteriological indicators, chemical composition, pH, conductivity, viscosity, alkalinity, density and biomethane potential.

The sample were labelled according to time and catalyst addition e.g. H_0.5h_cat is referred to hydrolysate performed through 0.5 h with an addition of catalyst, whereas H_0.5h is hydrolysate performed through 0.5 h without addition of catalyst.

Table 1. Ultimate and proximate analysis of straw and its hydrolysis dried solid products.

Sample	Carbon (%)	Hydrogen (%)	Nitrogen (%)	Ash (%)	VM (%)	FC (%)
straw	41.56	6.44	0.58	4.50	78.97	9.56
H_0.5h	42.36	6.40	0.63	4.99	75.48	8.95
H_0.5h_cat	41.98	6.18	0.64	8.19	79.25	11.53
H_2h	43.56	6.07	0.77	6.10	73.38	12.52
H_2h_cat	34.51	7.13	0.55	7.17	80.16	11.72

The summary of the research work is the development of the correlation between the properties of the input material, the technological parameters of the process and the properties of their products. Furthermore, the performance of energy and environmental valorization of this process will be determined.

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