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Editorial

Bioenergy Generation from Different Types of Waste by Anaerobic Digestion

Agnieszka A. Pilarska [1,*] and Krzysztof Pilarski [2,*]

1 Department of Hydraulic and Sanitary Engineering, Poznań University of Life Sciences, ul. Piątkowska 94A, 60-649 Poznań, Poland
2 Department of Biosystems Engineering, Poznań University of Life Sciences, Wojska Polskiego 50, 60-627 Poznań, Poland
* Correspondence: pilarska@up.poznan.pl (A.A.P.); pilarski@up.poznan.pl (K.P.); Tel.: +48-61-846-65-93 (A.A.P.)

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One of the problems of the modern world is the generation of increasing amounts of waste by agriculture and various industries. Since the Industrial Revolution, the linear economy has prevailed as a mode of production and general functioning of society based on the consumer model. The sequence of production, consumption and final disposal was seen as the logical path of development for the economy. Today, society is making efforts to move towards sustainability and strengthen the green energy industry. Waste management is the keynote in the ongoing global debate, representing an issue that is as problematic as it is promising in terms of a solution [1–3].

In Poland, more than 10 million tonnes of agricultural waste is managed annually, but the actual mass is much larger. This is caused, inter alia, by the fact that part of the waste is treated as municipal waste by agribusiness owners and is not recorded [4]. Meanwhile, biodegradable organic waste generated in households accounts for 40–50% of all municipal waste. Mainly composting plants, agricultural biogas plants or incineration plants are used to manage agricultural waste [5,6]. Disposal of agro-waste in agricultural biogas plants can be considered a closed-loop method when the resulting digestate is used as fertiliser [7,8]. Agricultural biogas is produced in the process of methane fermentation from agricultural raw materials (targeted energy crops), agricultural by-products, liquid or solid animal excrements, by-products or residues from agri-food processing, forest biomass, or municipal waste [9,10].

In times of a global energy crisis and climate change, the need to save energy carriers and to use low-cost raw materials, alternative to energy crops, is emphasised. Undoubtedly, these are all kinds of waste materials, including biodegradable organic matter. For the most part, this waste contains all the components necessary for microbial growth, such as carbohydrates (cellulose, hemicelluloses, starch, sugars), proteins, fats, as well as biogenic elements, micronutrients and vitamins [11]. If left unprocessed, it may cause sanitation hazards and specific environmental problems.

Given the need to dispose of agricultural waste from an environmental standpoint, as well as its natural origin and chemical composition, the most viable and economical methods of degrading this waste are biotechnological methods, including precisely anaerobic digestion (AD), which allows organic waste to be converted into energy and valuable products, such as the aforementioned fertilisers or fodder. Therefore biogas production from different types of waste through AD proces not only helps manage organic waste but also contributes to renewable energy generation, reduced greenhouse gas emissions, and improved waste management practices. It aligns with sustainable development goals by promoting resource efficiency and environmental protection [12,13]. It is worth noting that currently functioning anaerobic technologies have a high potential for managing a wide range of bio-organic wastes [14]. In addition to the aforementioned fundamental benefits of waste management in methane digestion, other opportunities and advantages of this strategy are also noted, including. (1) recovery of nutrients from the digestate (nitrogen and phosphorus), (2) economic benefits, in terms of job creation and development of the local economy, (3) revenue generation through sale of electricity, heat production and sale of biomethane or digestate as valuable products, as well as (4) energy independence and security ensured by reducing dependence on centralised energy networks and imported fossil fuels. When mentioning the advantages of waste management in AD, one also cannot overlook the limited environmental impact of this method, compared to other methods such as incineration [15].

However, the success of biogas projects depends on many factors, including the availability of raw materials, proper system design, and effective waste management practice. When outlining the problems of implementing and realising anaerobic digestion of waste, it should first be emphasised that the construction of an agricultural biogas plant involves enormous costs [16]. Setting up and maintaining anaerobic digestion facilities can be costly and technically challenging, especially for small-scale operators. Emerging financial incentives in the form of grants and support from governments and organisations should help overcome the initial infrastructure investment barrier, while cooperation between municipalities or regions could increase the feasibility of large-scale facilities. Undoubtedly, a critical point, determining the success of the implementation of the process, is the availability (ensuring continuous supply) and quality of the raw material, including its consistency. A remedy for this is the construction of biogas facilities "at the source" (in the vicinity of manufacturing companies), as well as the implementation of appropriate waste sorting and pre-treatment methods [17,18].

Operational challenges of carrying out AD of organic waste of various origins include: (1) the need to monitor key process parameters, (2) the handling and disposal of the digestate, which, although costly, can improve the economics of the process, (3) the use of biogas upgrading (H_2S treatment), ensuring the production of high-quality biomethane suitable for various applications, including injection into the natural gas network. Other equally important issues for the realisation of waste-based biogas production are regulatory and permit-related obstacles, cooperation with regulatory authorities at an early planning stage, as well as public opinion and acceptance. The community often resists the construction of biogas plants due to concerns about odour, noise and perceived environmental risks, but effective community involvement, clear communication and presentation of the benefits can help build acceptance and support for such projects [1,2,19].

In summary, biogas production via AD offers a versatile and sustainable solution for converting different types of organic waste into valuable renewable energy. By harnessing the energy and nutrient potential of organic waste, this method contributes to a greener and more sustainable future, while tackling the pressing challenges of waste management.

Despite the existing challenges to be overcome, ongoing continuous research, technological advances and supportive policies are paving the way for wider adoption of this environmentally friendly method of energy generation.

Current research within the topic under consideration is largely based on the co-digestion of different types of waste materials. The selection of suitable substrates, according to their chemical composition, offers the opportunity to increase the efficiency of methane fermentation (for example, combining food waste with wastewater sludge). At the heart of the research to optimise the process is the targeted influence on the qualitative and quantitative shaping of microbial communities, as well as the design of improved reactor structures to maximise biogas production with reduced retention times [20,21].

This Special Issue presents papers on many practical and theoretical aspects of waste management in anaerobic biogas production. The papers discuss the conditions and efficiency of the implementation of the processes carried out at laboratory and technical scale, which were aimed at using: (1) lignocellulosic waste from tomato crops in a one-stage vs. two-stage anaerobic digestion process [22,23] (2) biodegradable municipal waste (from households, companies, and gastronomy) collected in a large city [24], (3) confectionery and dairy waste in co-digestion, taking into account the contribution and influence of carrier materials, respectively silica/lignin [20] and diatomaceous earth/peat [21], (4) manure, with attention drawn to the positive effects of its storage for several months in a pile [25], (5) burdensome cigarette butts [26], (6) waste from the production of bioethanol for biogas production, as part of an operational hybrid system [18] and (7) corn bran, as a by-product of maize processing, with particular focus on the effects of methods of pressure-thermal agglomeration, as a pretreatment method [27]. Two articles have been dedicated to the management of digestate, discussing its value and applicability in an experimental study on the production of pellets using digestate solid fraction (DSF) [7] and in a review paper [8]. The Special Issue is summarised in the review paper by Pilarska et al. which discusses all key aspects of food waste management in the AD process along with a review discussion [28].

The valuable and substantive content of the articles that make up the chapter under consideration can complement the knowledge and practical information of readers, as well as inspire further research.

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