U.P.B. Sci. Bull., Series B, Vol. 86, Iss. 3, 2024 ISSN 1454-2331

BIOGAS - A SOLUTION FOR TREATING ANIMAL WASTE RESULTING FROM ZOOTECHNICAL ACTIVITIES

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The increasing volume of waste generated by agriculture is one of the major environmental challenges faced by humanity. The process of producing biogas through anaerobic digestion has become a focus of research and is considered the best solution for managing animal waste, transforming organic waste into green energy and organic fertilizer for agriculture.

Consideration has been given to the possibility of using anaerobic digestion of animal waste to minimize emissions and replace conventional fuels in farming with biogas. If farms were to adopt anaerobic digestion, greenhouse gas emissions would decrease and the resulting methane could be used as fuel on the farms.

Keywords: biogas, animal waste, anaerobic digestion

1. Introduction

In a world marked by climate change and environmental degradation, circular economy and biogas production emerge as solutions to these challenges. Circular economy measures offer the opportunity to meet climate commitments and other sustainability goals while also promoting economic growth and job creation [1].

Circular economy, first and foremost, helps alleviate the pressure on limited natural resources, reduces pollutant emissions contributing to climate change, and creates new business opportunities and jobs. The concept of circular economy aims to shift economic activities away from reliance on natural resources towards renewable resources, eliminating waste and pollution from the system. It proposes a model in which resources are renewable, reusable, and recyclable.

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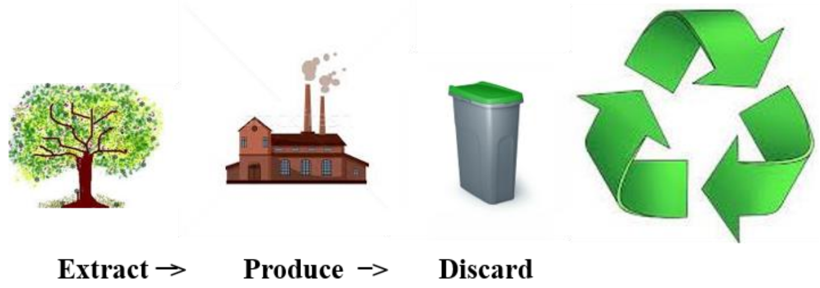

Fig. 1. Circular economy [21]

Through the Circular Economy Action Plan, Romania has begun the transition towards a circular economy but still has much to do to bring about changes in all sectors of the national economy. Among the high-level objectives outlined in the National Strategy on Circular Economy, adopted by the Romanian Government through Government Decision No. 1172/2022, is the promotion, preservation, conservation, and sustainable use of natural resources, waste prevention, and sustainable waste management.

One of the major environmental challenges currently faced by humanity is the increasing volume of waste generated from agriculture. To reduce the number of waste landfills, we need to turn to alternative energy sources that have beneficial effects on the environment, such as biogas production.

Biogas is a renewable fuel that can be produced from organic materials such as animal waste, plant residues, sewage sludge, or household waste. Biogas can be used for electricity and heat generation or as a vehicle fuel. It is a key component of organic farming, offering numerous advantages as a green, harmless, inexhaustible, and more cost-effective energy source than non-renewable conventional sources.

Animal waste has high energy potential for biogas production and is readily available wherever there is livestock farming. Biogas produced from anaerobic digestion of solid/liquid waste, such as cattle and swine excreta, kitchen waste, wastewater sludge, agro-industrial waste, and lignocellulosic biomass, is one of the most favorable sources of bioenergy. [2 - 8]

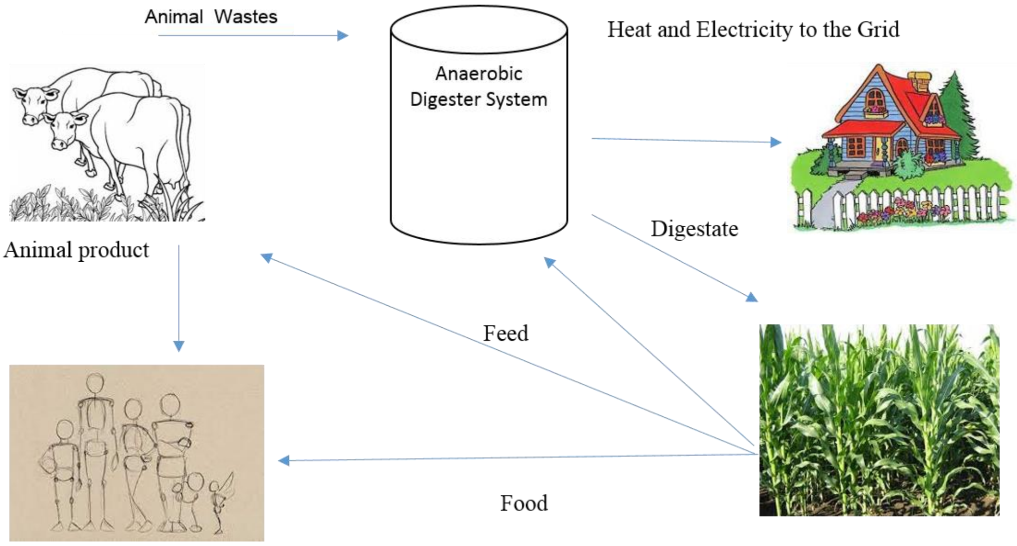

Fig. 2. Production of biogas with various applications: fertilizer, lighting, and electricity [22]

The process of obtaining biogas through anaerobic digestion is a focus of research and is considered the best solution for managing animal waste, transforming organic waste into green energy and organic fertilizer for agriculture.

2. Anaerobic digestion

Anaerobic digestion is a biochemical process of fermenting organic matter in the absence of oxygen. During this process, anaerobic bacteria break down organic matter into gases, including methane, carbon dioxide, and hydrogen. The anaerobic digestion process is influenced by several factors, including the feedstock (the composition of the feedstock significantly affects the anaerobic digestion process), temperature (the optimal temperature is 37°C), pH, pressure (the optimal pressure is 1 atm.), and moisture (the optimal moisture content is 70%).

In the absence of air, biogas is produced through the anaerobic digestion process by various species of microorganisms, in four main stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis [9 - 10]. Anaerobic digestion of biosolids involves the biological conversion of soluble organic matter into biogas, volatile fatty acids, alcohols, and nitrogen-rich organic residues [11].

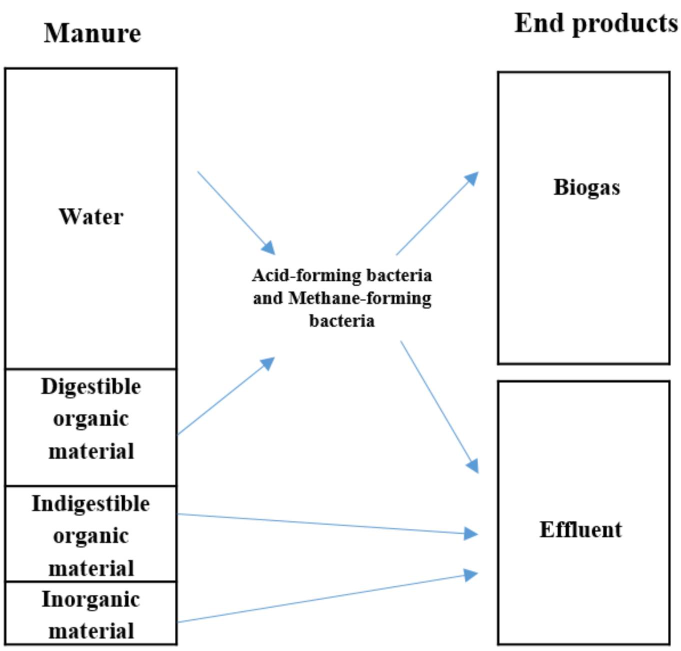

Fig. 3. Separating manure in an anaerobic digester [23]

There are various biogas production installations that can be classified by size, technology used (static anaerobic digestion installations, continuous anaerobic digestion installations, and fluidized bed anaerobic digestion installations), and the feedstock used (installations for biogas production from animal waste, installations for biogas production from plant waste, installations for biogas production from sewage sludge, installations for biogas production from household waste).

Generally, a biogas production installation consists of several main components:

- Digester (the tank where the anaerobic digestion process takes place)
- Feedstock supply system (supplies the digester with the feedstock needed for anaerobic digestion)
- Biogas evacuation system (collects and evacuates biogas from the digester)
- Biogas treatment system (removes impurities from biogas, such as hydrogen sulfide)
- Biogas combustion system (used for electricity and heat generation)

The stability of the anaerobic digestion process is strongly influenced by the composition of the feedstock used in the bioreactor. Many different types of substrates can be used as feedstock in the anaerobic digester for biogas production, including animal manure (36%), agro-industrial waste (30%), and municipal solid waste (34%) [12]. Animal manure contains a high nitrogen content, such as fresh goat manure (1.01%), poultry manure (1.03%), dairy manure (0.35%), and pig manure (0.24%) [13].

Animal manure is rich in nutrients that promote bacterial growth. However, due to its low carbon-to-nitrogen ratio, using it as a sole fertilizer, without other mixtures, may not be the most efficient way to produce biogas.

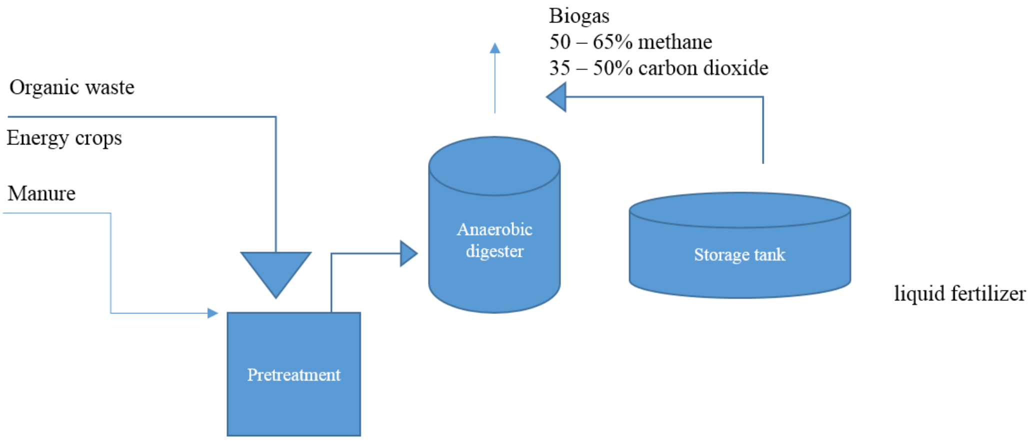

Fig. 4. Biogas production and fertilizer production [24]

According to the Mid-West Plan Service publication [14], the carbon-to-nitrogen (C/N) ratio for pig manure is approximately 6 to 8, which is too low for anaerobic digestion. In such cases, it is recommended to use a co-digestion approach, combining animal manure with crop residues to maintain a balanced C/N ratio, enhance bacterial growth, and reduce the risk of inhibition and ammonia acidification [15 - 16].

Biodegradable waste is rich in lipids, cellulose, and proteins. Many scientific studies have shown that combining different organic wastes for anaerobic co-digestion results in a better-balanced substrate. Researchers have reported significant increases in biogas production by co-digesting carbon-rich agricultural residues with pig manure [17]. The organic mixture that provides the substrate for the anaerobic digestion process can encompass a wide variety of organic carbon sources, ranging from raw sewage sludge to municipal waste or biomass materials, such as plant and crop residues [18].

Various residues from the food industry or fruit processing can be used as biogas feedstock in co-digestion with animal waste. The interest in using lignocellulosic waste lies mainly in its chemical compositions, which have a high carbohydrate content, in the form of cellulose and hemicellulose (~70%), suitable for bioenergy production (Gupta and Tuohy, 2013) [2].

Sousa Lima et al. (2018) published the effect of different thermal treatments and inoculum selection on the methane yield from sugar cane. They observed that using a combined inoculum consisting of anaerobic sludge (UASB) and fresh cattle manure (FBM) was more efficient in maximizing methane production during the anaerobic digestion of sugar cane (SB) than biomass pre-treatment processes [2].

The literature reports results from the anaerobic co-digestion of agricultural by-products with animal manure or wastewater (El Achkar et al., 2018; Guerini-Filho et al., 2018; Patowary and Baruah, 2018; Sousa Lima et al., 2018; de la Lama et al., 2017; Riggio et al., 2015; Aylin-Alagöz et al., 2015), introducing two or three cosubstrates into the biodigester [2].

Biogas production through anaerobic digestion offers multiple benefits, such as an alternative fuel source, high-quality fertilizer, electricity, heat, waste recycling, greenhouse gas reduction, and environmental protection [19].

Biogas production occurs in three phases: hydrolysis, acid formation, and methane formation. Generally, any factor affecting the microbiological bacteria responsible for biogas formation also affects biogas production. Bacteria require specific temperature and pH values to sustain their vital activities. Methanogenic bacteria are not active at very high or very low temperatures. Therefore, the temperature within the bioreactor where biogas production takes place directly influences biogas production. Temperature inside the reactor also determines residence time and reactor volume.

Temperature can be classified into three ranges:

- Psychrophilic temperature range = 12°C−20°C
- Mesophilic temperature range = 20°C−40°C
- Thermophilic temperature range = 40°C−65°C [20]

Optimal biogas production occurs within two temperature ranges. Mesophilic bacteria thrive at temperatures around 35°C, while thermophilic bacteria flourish between 49°C and 60°C.

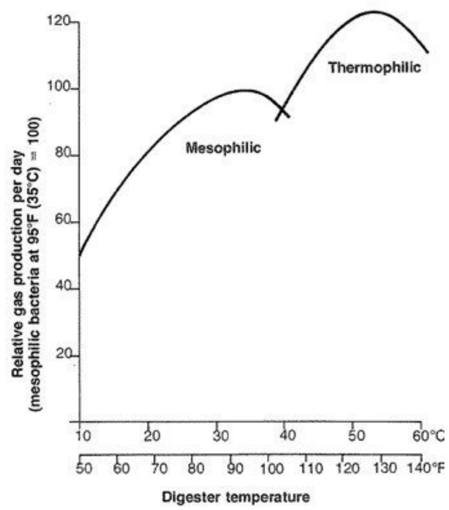

Fig. 5. The Effect of Temperature on Gas Production Rate. [25]

As seen in Fig. 5, biogas production decreases when bacteria are exposed to temperatures outside these ranges. While thermophilic bacteria produce slightly more gas, often the increase in temperature from 35°C to 49°C is not required.

Consideration has been given to the possibility of using anaerobic digestion of animal waste to minimize emissions and replace conventional fuels used on farms with biogas. If farms were to adopt anaerobic digestion, greenhouse gas emissions would decrease, and the resulting methane could be used as fuel on the farms.

In recent years, significant progress has been made in the development of biogas production technologies, leading to a reduction in biogas production costs, making it increasingly competitive compared to other energy sources.

Biogas has the potential to significantly contribute to reducing greenhouse gas emissions and diversifying energy sources.

3. Conclusions

The increasing number of animals in response to growing demand for farm animal products results in the production of enormous quantities of organic waste on farms and in slaughterhouses.

Animal manure can be an alternative energy source for livestock farmers.

Treating animal waste through biogas technology can generate large quantities of renewable energy in the form of biogas, partially transforming manure into energy-containing methane. Furthermore, the digestate (treated organic matter) could be used as a biochemical substance and fertilizer for agricultural lands.

Animal waste has the potential to be a less expensive source of energy and can be efficiently used for energy production using biogas, including electricity production. Biogas has been suggested as a fuel for cooking, home heating, water heating, crop drying, refrigeration, irrigation, and electricity generation.

Biogas can significantly contribute to reducing greenhouse gas emissions. The use of biogas can improve air quality and reduce greenhouse gas emissions.

Moreover, treating animal waste through anaerobic digestion significantly reduces the negative impact of these wastes on the environment.

The possibility of co-digesting different feedstocks in anaerobic digestion for biogas production could further promote the use of a cleaner fuel. The use of digestate from animal waste has proven to be a genuine means of biogas production through anaerobic processes, eliminating environmental pollution resulting from meat production and agricultural activities.

Acknowledgement

The results presented in this article has been funded by the Ministry of Investments and European Projects through the Human Capital Sectoral Operational Program 2014-2020, Contract no. 62461/03.06.2022, SMIS code 153735.

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