CONSIDERATIONS ON THE POTENTIAL FOR OBTAINING BIOGAS FROM BIOMASS BY ANAEROBIC DIGESTION

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Abstract:

Some of the main environmental problems of today's society are the continuous increase of the amount of organic residues and the consumption of conventional (non-renewable) energy. One way to address these issues is through the processing of this residues and the production of biogas. Anaerobic digestion is considered to be the optimal treatment for various types of agricultural and wood biomass and for a wide variety of organic residues suitable for this purpose, these substrates being thus transformed into recoverable energy and organic fertilizer for agriculture. Anaerobic digestion is a microbiological process of decomposition of organic matter, in the absence of oxygen, applied on a large scale for the production of renewable energy. The paper presents a series of considerations on obtaining biogas through anaerobic digestion from agricultural biomass, wood, energy crops and food waste.

Keywords: *biomass, biogas, anaerobic digestion, methanogenesis.*

JEL classification: *Q10*

INTRODUCTION

One of the main environmental problems of today's society is the continuous increase in the amount of organic waste. The past practices of uncontrolled waste disposal are no longer acceptable today. Even landfilling or incineration of organic waste is not the best practice, because environmental protection standards have become much stricter nowadays, and energy recovery and recycling of nutrients and organic matter a necessary thing.

In an agricultural farm, in addition to primary production, a series of secondary products (by-products), also known as waste, can be neutralized through the process of anaerobic digestion (methanogenesis) to obtain biogas.

Biogas (or fermentation gas) is the term used to name the energetic gas obtained by anaerobic fermentation (in the absence of oxygen) of organic matter (Deublein & Steinhauser, 2011).

The production of biogas through anaerobic digestion (AD) is considered to be the optimal treatment in the case of animal waste, as well as in that of a wide variety of organic waste suitable for this purpose, because in this way the respective substrates are transformed into recoverable energy and organic fertilizer for agriculture. At the same time, the elimination of the organic fraction from the total amount of waste increases both the efficiency of the energy conversion through the incineration of the remaining waste, as well as the stability of the landfills.

Biogas (bioenergy) is seen as a key solution for encouraging the sustainable development of rural areas, which can support the production of non-food goods and the cultivation of energy plants and the afforestation of abandoned land.

It was observed that Romania has a very high potential in terms of the generation of materials usable as raw material for biogas production as follows:

- presents a very high potential in terms of biogas production through the use of waste from primary production;
- the potential for biogas production from animal waste is somewhat lower;
- the potential for biogas production from solid urban waste is also very high;
- the potential for biogas obtained from sewage sludge is also very high;
- somewhat lower is the potential for biogas from food processing waste.

Methanogenesis is a biochemical process, through which complex organic substrates (vegetable biomass and waste, animal waste, organic waste, waste water, sludge from the sewage system, etc.) are decomposed, in the absence of oxygen, to the stage of biogas and digestate, by various types of anaerobic bacteria. The process of methanogenesis is found in many natural environments, such as oceanic sediments, ruminant stomachs or peatlands.

If the substrate subjected to anaerobic digestion consists of a mixture of two or more raw materials (for example, animal waste and organic residues from the food industry), the process is called co-digestion. Numerous types of biomass can function as substrates (raw materials) for the production of biogas through the anaerobic digestion process. The most common categories of raw materials are the following: manure; residues and secondary agricultural products; digestible organic waste from the food industry and agro-industry (of vegetable and animal origin); organic household and catering waste (of vegetable and animal origin); sewage sludge; energy crops (for example, corn, Chinese cane - Miscanthus, sorghum, clover).

The biogas produced by the AD process is cheap and constitutes a source of renewable energy, it produces, after combustion, neutral CO_2 and offers the possibility of treating and recycling a whole variety of residues and by-products of agriculture, of various bio-residues, of organic waste water from industry, domestic water and sewage sludge, in a sustainable and "friendly" way with the environment (Jones, 2006; Nzila et al., 2012).

The paper presents a series of considerations on the potential of Romania for obtaining biogas from biomass materials.

MATERIALS AND METHODS

Biomass considered to be suitable for anaerobic digestion is known as “substrate” or “feedstock”. It is known that the process of anaerobic digestion has been used to treat liquid wastes, with or without existing suspended solids, eg. manure, sewage, industrial wastewater and sludge from biological or physical- chemical treatment. Solid wastes such as agricultural and municipal solid waste started to be used in the anaerobic digestion sector around fifty years ago due to the high organic matter content and therefore its high potential for biogas production (Mata-Alvarez, 2003, Vogeli et al., 2014).

Among the chemical components of organic matter, celluloses, hemicelluloses and fats have higher degrees of conversion into biogas, while proteins show lower and variable degrees of conversion. Lignin does not contribute to the formation of biogas or contributes very little, being practically not degraded by anaerobic fermentation (Li et., 2011).

It is considered that only the organic biodegradable fraction contributes to biogas production from f the total dry matter content (Figure 1). This organic dry matter is referred to as “Volatile Solids” (VS), being the parameter usually used for characterizing the organic waste for anaerobic digestion. Normally, the organic dry matter content ranging from 70 % to more than 95 % of the TS is considered to be suitable biowaste substrates (Müller, 2007).

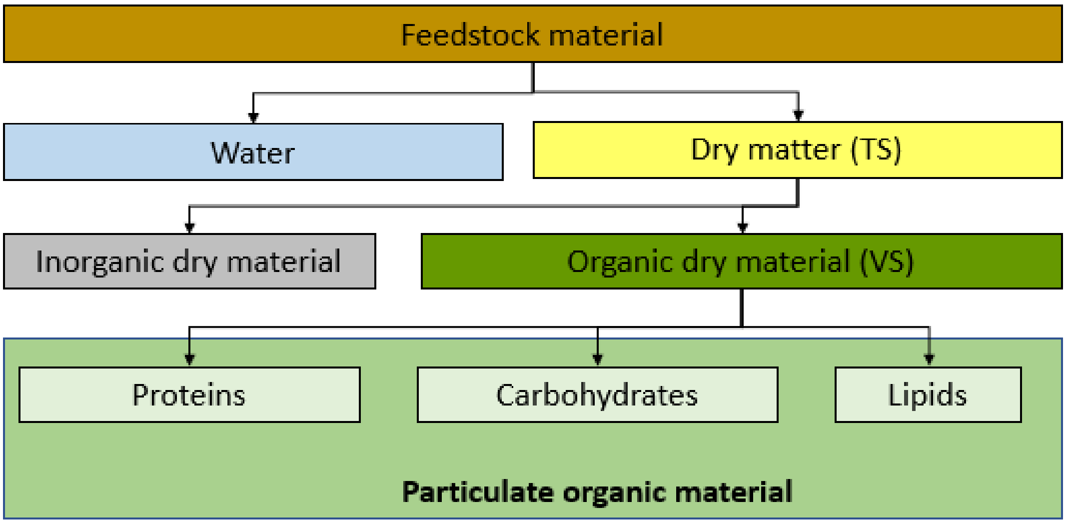

Figure 1. Classification of feedstock material (adapted from Müller, 2007)

For biomass potential in Romania, a first distinction can be made taking into consideration the origin of biomass coming from various sectors, such as: agricultural sector, silviculture, industrial sector and the urban sector. Another classification can be made according to their nature: energy crops, agricultural, forestry and residues and various wastes.

Table 1. Indices of biomass production from energy crops: overview (Ener-supply, 2012)

Energy crop	**Biomass type**	**Biomass production t_{dm}/ha)**	**Moisture at harvesting (%)**	**Inferiors calorific power (MJ/kg_{dm})**
Annual herbaceous crops				
Corn	Corn residues	8.34-10.60	59-64	17
	Silage corn	19	34.5	17
Industrial hemp	Stems, leaves	5-15	50-60	18-25.6
Clover and other herbaceous fodder crops	Stems	8 1-6; 3.5	80 84.5-83.50	10.2 2.4
Perennial herbaceous crops				
Arundo Donax (giant reed)	Stems, leaves	20-30 15-35 20-35, 28 8.68	- 55-70 40 -	16-17.1 16-17 17.5 -
Miscanthus spp.	Stems, leaves	11-34 15-25	- 50-60	17.6 17.3-17.6

Energy crop	Biomass type	Biomass production t_{dm}/ha)	Moisture at harvesting (%)	Inferiors calorific power (MJ/kg_{dm})
		15-30, 23	15-30, 25	17.0
Panicum Virgatum	Stems, leaves	14-25, 19 10-25 10-25, 18	- 50-60 34-40, 35	- 17.4 15.9
Cynara Cardunculus (artichoke)	Stems, leaves	17-30 10-15, 12 7.12-14	- (20-30) 20	- 15.6 14-18

Souce: Barbieri S. *et* al, 2004, Sacco *et* al.,2007, Casagrande et al., 2005, Cioffo, 2009, Mardikis *et* al., 2000, Jodice R., 2007, Candolo G., 2009, Foppa Pedretti *et* al., 2009

Annual herbaceous crops. Grasses (monocots) make up most of modern large-scale agriculture. Perennial grass crops include cereals such as barley, oats, rye, other minor cereals: sugar beet, sugar cane, fodder crops such as clover. The seeds of these cereals, the stems and tubers of other plants are a good source of starch that can be used in technological processes for the production of energy and biofuels.

Perennial herbaceous crops. This type of biomass can be used as raw material for bioenergy production when it is economically viable. Fast-growing reed and reed species (such as Arundo Donax, Elephant Grass) are examples of herbaceous crops that can make good use of available nutrients to increase biomass productivity; but, at the same time, other agronomic characteristics still represent weak points, such as floral sterility, prohibitive costs for establishing the culture, relatively low mechanization of harvesting, high humidity of the harvestable product and high ash content. Artichoke (Cynara) and Elephant Grass (Mischantus) are other energy crops with low water content: for this reason, they are very interesting from an energy point of view and therefore many agronomic and genetic research programs are being carried out to improve production.

Oil crops. Oil crops include annual oil seed crops and perennial oil tree crops.

- Oilseed crops: The most representative oleaginous crops in European areas are sunflowers and soybeans. The oils from these cultures also contain other constituents of the seeds (proteins or starch). The lignocellulosic part of oilseed crops, which is traditionally used as mulch or feed, can also be burned for energy or heating, while vegetable oils can be used for higher value bioenergy applications.
- Oleaginous trees: Currently, there are several trees that produce oil: palm, coconut and macadamia. Palm oil in particular is used in developed countries to produce both edible oil, biodiesel, biogas.

Biomass from residues and waste. The analysis of biomass from residues and waste is more complicated, due to the complexity of the materials and the sectors of origin (from the agricultural sector to the urban sector).

Waste is that generated in the production process, industrial waste and solid municipal waste. Typical energy content is 10.5 to 11.5 MJ/kg (Khalid et al., 2011).

Part of the biomass is therefore classified as waste from industrial, agricultural, forestry and urban activities: it is simple to apply the concept of "waste management hierarchy" to all residues or waste included in the field of biomass, as shown in the next section.

Biomass from residues and waste includes residues from plants and animals. These are represented by agricultural residues, such as straw, vegetable and fruit peels, forest residues and waste, such as leaf litter, sawmill residues, food waste and the organic component of municipal solid waste. Energy can be produced from these wastes, because, globally, several billion tons of biomass are contained in them. (Abbasi & Abbasi, 2010).

There are many options available for converting residues and waste to energy. These technologies are: waste storage, incineration, pyrolysis, gasification, anaerobic digestion and others.

RESULTS AND DISSCUSION

Biomass from agriculture can be an important source of raw material for biogas production. From this point of view, Romania has a used agricultural area of 13.9 million hectares, which represents approximately 60% of the country's total area. More than 4.3 million farms are distributed on this surface.

Currently, agriculture, the food industry, animal husbandry, water treatment plants and urban and individual households are the main sectors and activities producing organic matter whose energy can be recovered through human-directed processes. According to a calculation made by Jewel (1980), it follows that of the amount of 45.4 kg of residues, which returns on average per capita in the USA, organic matter represents 34 kg. In relation to the source, organic matter is found, approximately in the amount of 2.3 kg in urban garbage, 0.09 kg in sewage sludge and almost 30 kg in residues from animal husbandry and secondary products from agriculture. A quantity of energy of 1260 Kcal can be extracted from each kg of residual organic matter from agriculture. In the secondary production of wheat and soybeans, energy is stored approximately 12 times higher than the energy consumed to obtain these crops.

The average potential value of biogas production in cubic meters per ton of organic matter is shown in figure 2 (based on data from the literature and those already available from WP 6 of the Big-East project).

Figure 2. Potential biogas production in Romania (Al Seadi T. et al., 2008)

The production and use of biogas presents multiple advantages for farmers, as well as on a national scale, being able to make a non-negligible contribution to achieving the objectives of sustainable development, through:

- the integration into organic agriculture, creating a closed circuit of organic matter, ensuring a superior utilization of manure animals and plant residues, by producing through their anaerobic fermentation, an organic fertilizer that is much more favourable to plants in relation to the main elements (nitrogen-N, phosphorus-P, potassium-K potassium), and especially regarding the content of nitrogen, in its two forms directly assimilated by plants: nitrate (NO_3) and ammoniacal nitrogen (NH_4-N, which has a 20-30% higher weight in fermented, compared to the content in fresh manure);
- contribution to energy independence, ensuring green energy production by replacing fossil fuels for the production of thermal and electrical energy, as well as the reduction of energy consumption required for the production of chemical fertilizers (1 kg of synthetic N product requires 2.6 l of oil, equivalent to approx. 93 MJ of energy).
- climate protection by reducing methane emissions (CH_4), a gas with greenhouse effect, having a potential effect 21 times greater than carbon dioxide (CO_2); In this case, a reduction of 4.5 $m^3 CH_4/m^3$ fermented biomass can be obtained (Kulisic & Par, 2009).

CONCLUSIONS

Romania has a very high potential in terms of the generation of materials that can be used as raw material for biogas production through anaerobic digestion as follows:

- a very high potential for biogas production using waste from primary production;
- a high potential for biogas production from urban waste (mainly household waste);
- a lower, but still high potential for biogas production from animal waste (manure);
- a lower, but still high potential for obtaining biogas from sewage sludge;
- a low to average potential for obtaining biogas from food processing waste.

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