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VARIATION OF METHANE YIELD IN A BIOGAS PLANT BY USING DIFFERENT SUBSTRATES

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Abstract

Many biogas systems are too small to handle the available supply of substrates. Knowing the quality and retention time at which maximum methane is produced will help in selecting the mixture of best substrates during co-digestion. In such manner, there will be no need for any increment of infrastructure to raise the capacity of a Biogas plant.
The Biogas in an Anaerobic Digestion Plant is produced from different substrates which vary in terms of quantities and quality. Approximately 55% methane and 45% carbon dioxide is issued alongside of other gases which makes difficult the prognoses of methane production for transforming it into electricity and feeding it to grid in order by optimizing the substrates fed on the fermenter.
The objective of this study is to assess the variation of methane and carbon dioxide yield with methane production, retention time and different quality substrates in a biogas plant.
A good productivity of methane (52,5% by biogas volume) has been obtained from a mixture of corn silage and rye, occurred on the 3rd day of digestion. Additional treatment with 4% fats and 2% leftovers of the total daily feeding substrates produced even higher methane. The production of methane was hindered by the presence of some trace gases as hydrogen sulfide which limited the methane producing bacteria.

***Key words**: anaerobic digestion, methane, substrates, hydrogen sulphide.*

INTRODUCTION

Biogas is a mixture of methane and carbon dioxide, produced by the breakdown of organic waste by bacteria without oxygen (anaerobic digestion) [1]. Production of methane-rich biogas through anaerobic digestion of organic materials provides a versatile carrier of renewable energy, as methane can be used in replacement for fossil fuels in both heat and power generation and as a vehicle fuel, thus contributing to cutting down the emissions of greenhouse gases and slowing down the climate change.
Anaerobic degradation or digestion involves the breakdown of biomass by a concerted action of a wide range of microorganisms in the absence of oxygen. The general principle of anaerobic digestion is the degradation of organic materials (e.g. carbohydrates, protein and fats) under anaerobic condition, where bacteria convert the organic material to methane, carbon dioxide and water. Acetate is the most important intermediate for methane biosynthesis in the anaerobic environment; it forms approximately 55% of the methane, while the remaining 45% of methane is formed directly from hydrogen and carbon dioxide
Ideally Biogas production would benefit from a consistent mix of feedstock materials, chopped and blended to ensure optimum methane yield, mostly coming from agriculture as energetic plants.
In practice, Anaerobic Digestion (AD) may also take into consideration a consistent proportion of food waste. This is a largely beneficial to environment; however as a single feedstock, agriculture products can present challenges because of the continuous rising market price and therefore income.
Yield is an overriding consideration for efficient energy substrate. The key is to use a feedstock mix that allows the digestion

process to function effectively and maximize methane output, given the size, layout and capability of the operation.

The digestion rate of different feedstocks [2,3] within a bio-digester varies from 2 days to two months. Material that has a high level of sugar or starch is quicker to ferment than feedstocks which have more lignin or cellulose (Figure 1) [1].

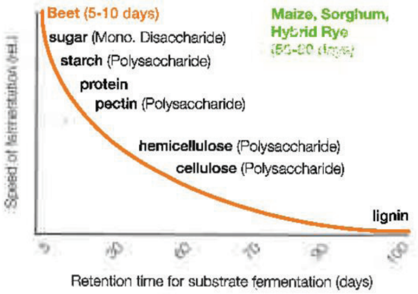

Figure 1. Biogas: relative fermentation characteristics by content

Thuse, substrates like energy beet, used vegetable oil and so will have a shorter retention time[2] in the digester and release more gas over a shorter period of time than wholecrop cereals.

Each individual feedstock component has advantages and disadvantages[5,6]

Table 1. Advantages of different feedstock [5,6]

Feedstock	Advantages	Disadvantages
Mais	- High methane yield/ha - Easy storage and feedout	-Relatively slow retention time
Rye	-High wholecrop yield with high DM -Good in mixture with maize	- Lower methane yield/ha
Manure	Useful starter and mixture product	Low methane output
Waste*	- Pre-treatment necessary - Methane vary much on different type of waste	- Low cost when close to the biogas plant

** to be detailed in the present report*

Table 1 ilustrates some examples of potential mixes in the biogas plant. This shows that, per tone of fresh mass (FM) produced, the most effective mixes for maximum methane yield should comprise maize and some sort of waste[4].

However, the mixture utilization of the traditional agriculture substrates and waste has a positive effect on methane output mostly by keeping the necessary micronutrients of the fermentation process into the required range[4]. As well, care does not need to be taken to ensure that the viscosity of the mix enables good functionality of the plant.

The fast conversion rate of some feedstock helps to grow the gas production, raising the pH inside fermenters plant, encouraging bacterial conversion of the complete feedstock to methane. Furthermore, waste produces a cleaner source of biogas than agriculture feedstock which enables more efficient conversion from methane to electricity&heat trough the Combined heat and power (CHP) unit.

Plant operators will also find that there are significant benefits from the synergies provided by using multiple feedstock types. Such synergies are difficult to quantify and will vary with plant type. However, the experience on biogas plant operations by using different wet or dry substrates proves that are significant benefits in terms of methane production by synergy results.

MATERIALS AND METHODS

In order to highlight the variation of methane yield of the Anaerobic Digestion plant by using different substrates, the following substrates have been used: fish oil, gelatin – pharmaceutical industry, yeast – beverage industry, sludge – waste treatment plant, wheat draff – alcohol industry, sugar beet pulp – sugar industry, corn silage – agriculture.

The methane content of the biogas has been measured by a multi-channel measuring device with an integrated gas conditioning unit for analyzing methane, oxygen, carbon dioxide and hydrogen as well as the concentrations of hydrogen sulfide. The device, SSM 600 Classic, produced by PRONOVA (see picture 2), is designed for both discontinuous and continuous operation for up to four internal measuring points.

Picture 1: SSM 600 Classic PRONOVA

Samples of each mentioned above have been sent to a lab for reveal the potential in terms of biogas and methane as single feedstock source by measuring the pH, biogas yield, [Nl/kg FM], methane yield [Nl/kg FM].
In order to determine the potential of feedstock mixture and benefit of using a combination of feedstock materials, experimental tests have been done at Genesis Biotech Biogas Plant in Romania.
Genesis Biotech Biogas is a 1MWel cogeneration biogas plant, owned by Genesis Biopartner Group and placed in Prahova County, Filipestii de Padure Village.
The plant is daily feeding a quantity of 50 to of biomass, different provenience, agriculture and food industry.
All measured parameters of the test have been registered separately during a biomass feedstock trial and results were implemented in the same objective, in order to rise the productivity of the plant (Picture 1)

Picture 2: Genesis Biotech Biogas Plant

RESULTS AND DISCUSSIONS

The results of the batch test of each substrate sample can be shown in Table 2, below:

Table 2: Biogas/methane yield
of feedstock reference substrates

Sample	pH	biogas yield	methane yield	Methane from biogas
	-	Nl/kg FW	Nl/kg FW	%
fish oil	7,58	584	395	68
gelatine - food industry	7,64	245	146	60
Yeast - beverage industry	7,30	89	62	70
sludge - waste treatment plant	7,25	239	117	49
wheat draff	7,21	186	108	58
sugar beet pulp	3,50	110	57	52
Rye	6,9	200	120	60
corn silage	6,80	220	117	53

As shown on Table 2, the methane values vary from 49% to 70% by using different FM substrates but, of course, these substrates cannot ne used as single feedstock, except the corn silage because of the micronutrients content (Cobalt, Cooper, Iron, Manganese, Molybdenum, Selenium – the most important elements[3]) which can only be found on a wide range into corn silage.
Therefore, it is demanded to find the optimum ratio between corn silage and the rest of waste types nominated above.
In the graphics below it can be seen Dthe cumulative biogas/methane yield of the substrates from waste categories which are going to be mixed with corn silage in order to determine the mixture synergy.

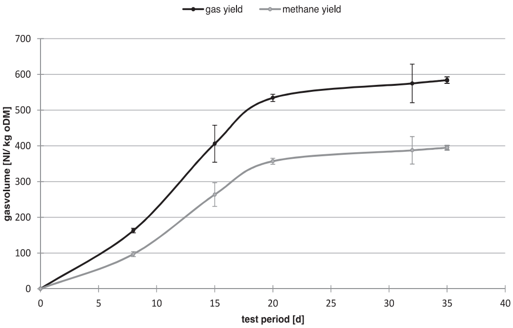

Fig. 2: Dynamics of methane production from fish oil

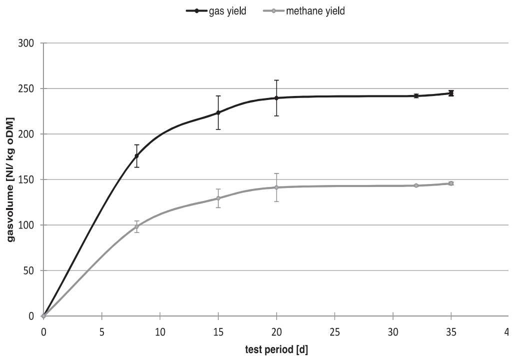

Fig. 3: Dynamics of methane production from gelatin

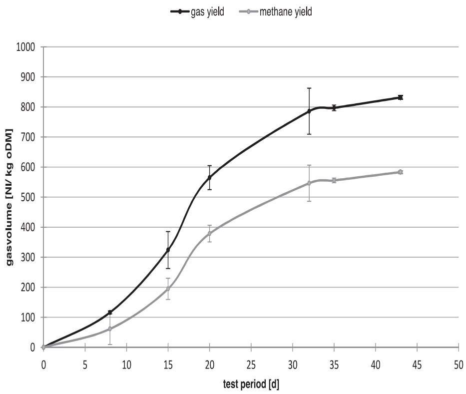

Fig.4: Dynamics of methane production from yeast

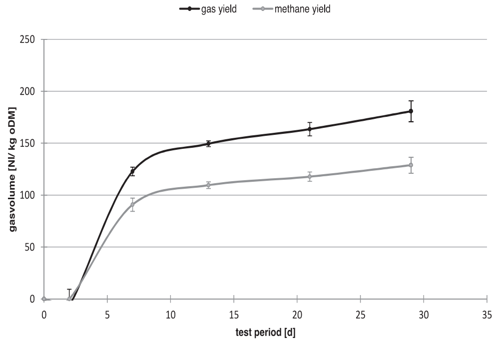

Fig. 5: Dynamics of methane production from sludge

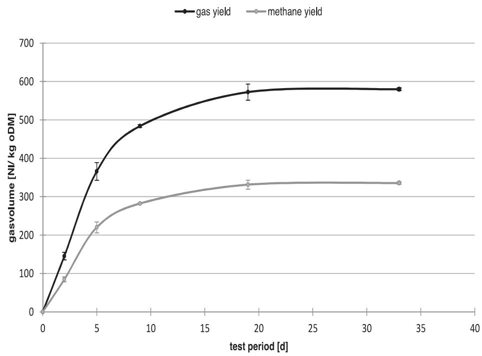

Fig.6: Dynamics of methane production from wheet draff

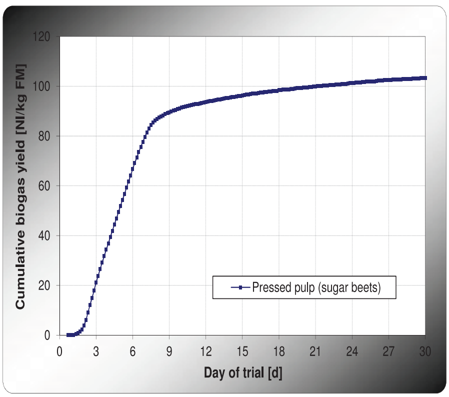

Fig. 7: Development of biogas production – sugar beet pulp

The tests which have been done into the Genesis Biogas Plant revealed some increment of biogas volume as well as methane quantity by mixing them in a certain balance as follows:
Four Mixture types have been tested during 60 days each, performing the following proportion:

Mixture A.
1. Corn silage 88,9%
2. fish oil 3,7%
3. yeast 7,4%

Mixture B.
1. Corn silage 82,5%
2. gelatin 2,5%
3. wheat draff- 15%

Mixture C.
1. Corn silage 72,5%
2. gelatin 2,5%
3. sugar beet pulp - 25%

Mixture D
1. Corn Silage – 75%
2. Rye – 25%

Table 3:Mixture Feedstock to be analyzed

Mixture	biogas yield (theoretic)	biogas yield (measured)	Biogas increment by mixture	Methane yield
	Nl/kg FW	Nl/kg FW	%	%
A	223,7	226,5	1	54,3
B	215	231	7	52,6
C	193	220	14	52,2
D	215	249	15,8	53,5

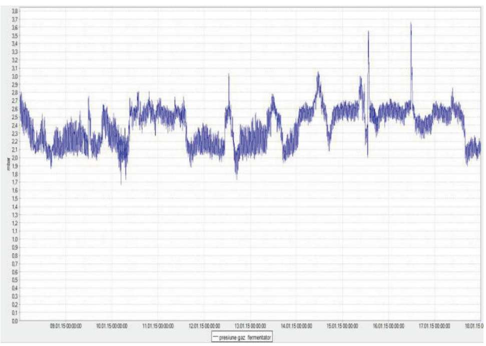

Fig. 8: Feddstock mixture A (corn silage – 88,9%; fish oil – 3,7%; Yeast – 7,4%)

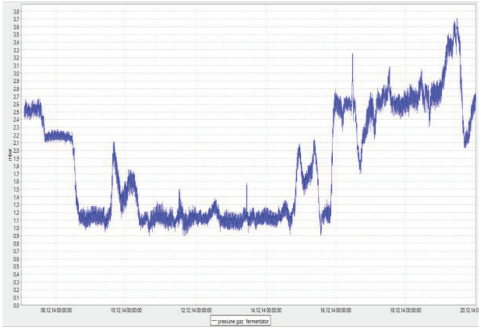

Fig. 9: Feddstock mixture B (corn silage – 82,5%; Gelatine– 2,5%; wheat draff – 15%)

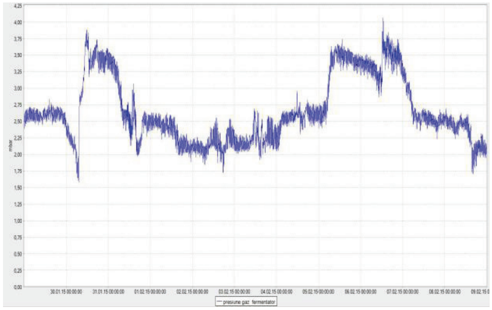

Fig. 10: Feddstock mixture C (corn silage – 72,5%; Gelatine– 2,5%; sugar beet pulp – 25%)

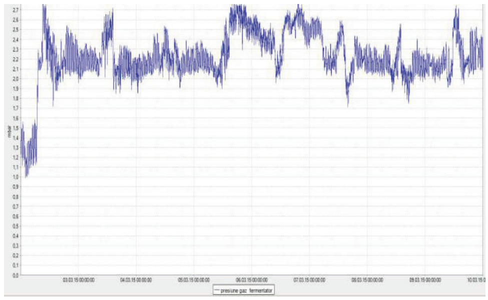

Fig. 11: Feddstock mixture D (corn silage – 75%; Rye– 25%)

CONCLUSIONS

The four test which has been performed on the mentioned feedstock mixtures as shown above, have been performed by replacing the 100% corn silage quantity by an equivalent quantity in terms of biogas calorific power production. The results are as following:
Mixture A: corn silage – 88,9%; fish oil – 3,7%; Yeast – 7,4% - According to Table 3, fig. 8 there is a slight increment on biogas volume of 1% and an improvement of

methane concentration (54,3%) which brings the Cogeneration Heat and Power Central to a better efficiency compared with full corn silage feeding.

Mixture B: corn silage – 82,5%; Gelatine– 2,5%; wheat draff – 15% - According to Table 3, fig. 9 there is a consistent increment on biogas volume of 7% and a decrement of methane concentration (52,6%) which brings the Cogeneration Heat and Power Central to diminish its efficiency compared with full corn silage feeding.

Mixture C: corn silage – 72,5%; Gelatine– 2,5%; sugar beet pulp – 25% - According to Table 3, fig. 10 there is a good increment on biogas volume of 14% and a decrement of methane concentration (52,2%) which brings the Cogeneration Heat and Power Central to diminish its efficiency compared with full corn silage feeding.

Mixture D: corn silage – 75%; Rye– 25% - According to Table 3, fig. 11 there is a very good increment on biogas volume of 15% as well as an increment of methane concentration (53,5%) which brings the Cogeneration Heat and Power Central to diminish its efficiency compared with full corn silage feeding.

As a general conclusion of the present research it can be seen that there are a lot of possibilities to identify the right synergy between mixture feedstock ratio in order to improve the gas output in terms of methane and volume on a AD Biogas plant but what should also be taken into consideration is the cost of waste collection compared with cost of usual feedstock as energetic plants as corn, rye, sorghum, triticale which is strongly dependent by the cost of transport an the biogas gate, not often very cheap.

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