Biogas Production in Laboratory Scale from Different Organic Wastes Using Primary Sludge as Co-substrate

Holta Prifti and Tania Floqi

***Abstract* — Biogas production technology not only constitutes a biofuel source, but also can be a mitigation measure for the various environmental pollutants. This technology, i.e., anaerobic digestion is a biological process that takes place naturally when microorganisms break down organic matter in the absence of oxygen. In an enclosed chamber, controlled anaerobic digestion of organic matter produces biogas which is predominantly methane. The produced methane then can be directly used; or after certain conditioning, can be used in onsite power generation, heating homes or as vehicular fuel. Besides, organic waste is increasingly becoming a major problem in every society imposing serious economic and environmental concerns. For this reason, many contemporary researches are emphasizing in finding sustainable solutions to recycle and produce energy from such waste. In this context, this paper aims to investigate the potential of cow and chicken manure, and olive waste for biogas production obtained through the anaerobic digestion process.**

The substrates were placed in laboratory scale digesters without pretreatment. The retention time in the digesters was 30 days. The samples of the tested substrates were collected and analyzed for pH, total solids, ash, and the content of volatile solids (VS). Under mesophilic conditions, all combinations of cow and chicken manure, and olive waste with sludge by an anaerobic pond of a trickling filter treatment plant, as co-substrate, significantly improved biogas, and methane yields. The experimental results showed that chicken manure (CM) is the most suitable for anaerobic digestion (AD).

The next step of the study will consist in implementing a large scale of biogas production plants and we will estimate the national potential of green energy produced by this technology and map the areas that need digesters.

***Index Terms* — anaerobic digestion, biogas, co-substrate, methane.**

I. Introduction

The use of renewable energy sources in Albania is very limited. The application studies on biogas production from different kind of wastes produced by human activities such as: animal manures, industries organic wastes, food waste, etc., should be increased.

At the current time, thirteen wastewater Treatment plants (WWTP) have been constructed in Albania of which most of them are full operating.

The inevitable consequences of this expansion in wastewater treatment capacity **will be increasing quantities of sludge that will require safe and economical disposal.** [1], [2].

Besides, **organic waste is increasingly becoming a major problem in society imposing serious economic and environmental concerns.**

In this context, using the co-fermentation technology is the best solution for our country. This technology is a simultaneous digestion of homogenous mixture, in our case off two co-substrates (e.g., chicken manure and sludge). The co-digestion can lead to significant increase of gas production, because of the organic feedstock has lower water content and high contents of energy-rich substances, such as carbohydrates, proteins, and fats. [1], [3], [5] Consequently it has become a multipurpose process serving at the same time waste upgrading, energy production, improvement of fertilizers quality and environment protection.

II. Materials and Methods

As above mentioned, the study aims to optimize the production of biogas from cow and chicken manure; olive waste, using primary sludge from wastewater treatment plant (trickling filter) of Kavaja city.

The experiments are carried out in the laboratory of biogas of the Environmental Engineering Department of the Civil Engineering Faculty.

The methods applied are the same methods used some years ago for biogas production in laboratory scale [2], [6].

The duration of the laboratory work was thirty days. The organic waste was experimented without pretreatment [5], under mesophilic condition at 35ºC±1 ºC.

III. Results and Discussion

The quantitative and qualitative data of the co-substrate are very important for the digestion process. The quantity of the organic matter compound of the substrates is directly related with the quantity of biogas produced by the anaerobic co-fermentation.

Results, presented in the table and graphics, showed that the biogas production depends on the content of the dry

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matter (DS) and organic matter (volatile solid) of the substrates [4].

The biogas production from primary sludge is lower (average 0.75 Nm^3/t) than the other samples because the dry matter (DS) is lower (average 10.29%). The three other samples containing different co-substrate (cow manure, chicken manure and olive waste) & sludge, result in various biogas production.

The highest biogas production (53.7 Nm^3/t) was obtained from sample three (see Table I & Fig. 3) which contains co-substrate of olive waste & sludge, because of the highest quantity of dry matter (average 82.80%) and the highest organic one (volatile solid) (average 84.98%).

The co-substrate of chicken manure & sludge produce 29 Nm^3/t biogas with the quantity of dry matter (average 82.6%) and organic one (volatile solid) (average 37.23%), the co-substrate of caw manure & sludge produce 18 Nm^3/t biogas with the quantity of dry matter (average 15.62%) and organic one (volatile solid) (average 97.77%).

The behavior of different substrates during co-digestion operation might be due to the different substrate degradability.

As showed in the graphics, the best co-digestion operation was the co-substrate of chicken farm manure and sludge (see Fig. 2).

TABLE I: DRY AND ORGANIC MATTER OF THE SUBSTRATES
SAMPLE 1: PRIMARY SLUDGE OF WWTP OF KAVAJA

	P1	P2
Vessel weight (gr)	3.24	3.14
V + Sub. (gr)	87.08	88.25
Sub (gr)	83.84	85.11
DS + V (gr)	11.85	11.92
DS (gr)	8.61	8.78
Sub-DS (gr)	75.23	76.33
DS (%)	10.27	10.32
Average DS (%)	10.29	
Inorg. Matter + V(gr)	9.08	8.87
Inorg. mat (gr)	5.84	5.73
Org. mat (gr)	78	79.38
L.org (%)	93.03	93.27
Averag org. m (%)	93.15	

TABLE II: QUANTITY OF THE SUBSTRATES (GR) OF EACH SCHOTT FLASK

Sample	Empty flasks weight (gr)	Sludge (gr)	Schott flasks + sludge weight (gr)
S1	307.31	299	606
S2	313	303	616
S3	316.3	313.7	630

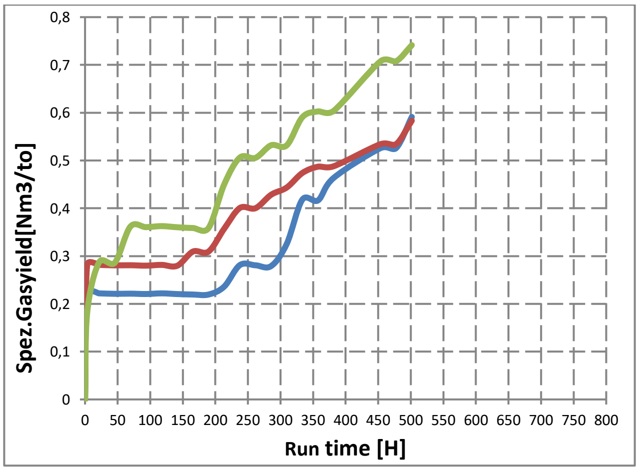

Fig. 1. Diagram of biogas production of the sludge WWTP of Kavaja.

TABLE II: DRY AND ORGANIC MATTER OF THE SUBSTRATES
SAMPLE 2: CHICKEN FARM MANURE

	P3	P4
Vessel weight (gr)	3.2	3.16
V + Sub. (gr)	49.42	45.61
Sub (gr)	46.22	42.45
DS + V (gr)	41.88	37.81
DS (gr)	38.68	34.65
Sub-DS (gr)	7.54	7.8
DS (%)	83.69	81.63
Average DS (%)	82.66	
Inorg. Matter + V(gr)	33.22	28.88
Inorg. mat (gr)	30.02	25.72
Org. mat (gr)	16.2	16.73
L.org (%)	35.05	39.41
Averag org. m (%)	37.23	

TABLE III: QUANTITY OF THE SUBSTRATES (GR) OF EACH SCHOTT FLASK

Sample	Empty flasks weight (gr)	Chicken farm manure (gr)	Sludge (gr)	Schott flasks+chicken manure+ sludge (gr)
S4	309	40	310	662
S5	301.2	50	300	652
S6	308.39	60	315.46	684

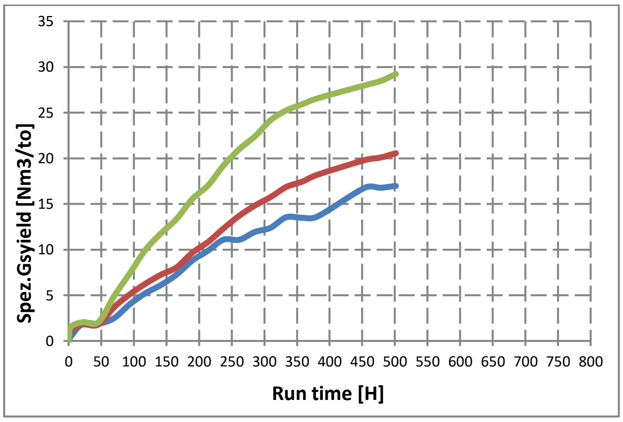

Fig. 2. Diagram of biogas production from sludge and chicken farm manure.

TABLE IV: DRY AND ORGANIC MATTER OF THE SUBSTRATES
SAMPLE 3: OLIVE WASTE

	P5	P6
Vessel weight (gr)	3.19	3.2
V + Sub. (gr)	20.07	24.27
Sub (gr)	16.88	21.07
DS + V (gr)	17.18	20.63
DS (gr)	13.99	17.43
Sub-DS (gr)	2.89	3.64
DS (%)	82.88	82.72
Average DS (%)	82.8	
Inorg. Matter + V(gr)	6.01	6.01
Inorg. mat (gr)	2.82	2.81
Org. mat (gr)	14.06	18.26
L.org (%)	83.29	86.66
Averag org. m (%)	84.97	

TABLE V: QUANTITY OF THE SUBSTRATES (GR) OF EACH SCHOTT FLASK

Sample	Empty flasks weight (gr)	Olive Waste (gr)	Sludge (gr)	Schott flasks + Olive waste+ sludge (gr)
S1	307.4	20	302.96	630.7
S2	299.4	30	300.23	629.63
S3	315.66	40	300.2	655.6

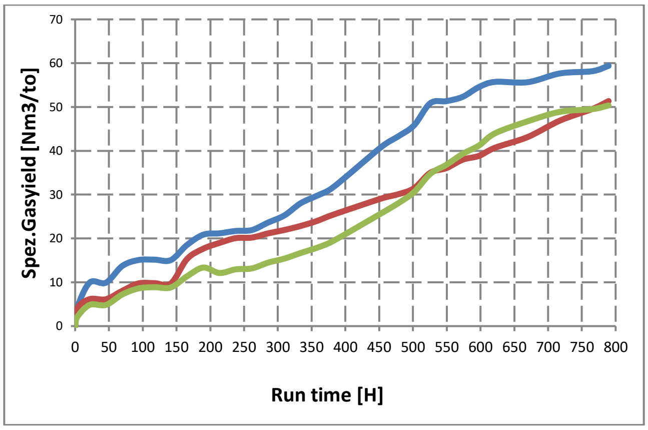

Fig. 3. Diagram of biogas production from sludge and olive waste.

TABLE VI: DRY AND ORGANIC MATTER OF THE SUBSTRATES SAMPLE 4: COW MANURE

	P7	P8
Vessel weight (gr)	3.22	3.24
V + Sub. (gr)	59.2	73.69
Sub (gr)	55.98	70.45
DS + V (gr)	11.8	14.45
DS (gr)	8.58	11.21
Sub-DS (gr)	47.4	59.24
DS (%)	15.33	15.91
Average DS (%)	15.62	
Inorg. Matter + V(gr)	4.35	4.95
Inorg. mat (gr)	1.13	1.71
Org. mat (gr)	54.85	68.74
L.org (%)	97.98	97.57
Averag org. m (%)	97.77	

TABLE VII: QUANTITY OF THE SUBSTRATES (GR) OF EACH SCHOTT FLASK

Sample	Empty flasks weight (gr)	Cow manure (gr)	Sludge (gr)	Schott flasks + Cow manure + sludge (gr)
S4	315.53	40	301	656.2
S5	309.44	50	301.13	660.83
S6	309.42	60	301	671

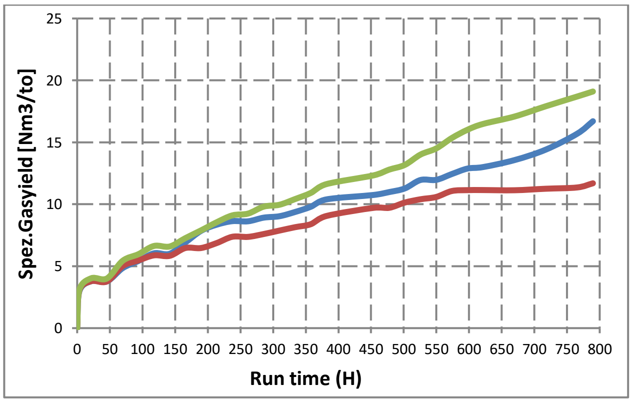

Fig. 4. Diagram of biogas production from sludge and cow manure.

IV. CONCLUSION

- The highest biogas production was obtained from co-substrate and primary sludge, which is related to the highest value of dry matter (DS) and organic matter (volatile solid).
- The best behavior regarding biodegradability during co-digestion operation was occurred for co-substrate chicken farm manure and sludge.
- Taking into account that the organic waste such as: chicken, kettle, cow, pig manure, food waste, food industries waste, sludge, etc., is becoming a major problem in our country, biogas production technology can be one of the best solutions regarding renewable sources of energy, reduce greenhouse gas emission, contribute to EU energy, environmental policies and sustainable waste management strategies and is in harmony with the EU Directive 2008/98/EC [11]-[14].
- Based on the above data, we have a good scenario to judge designing a digester plant that would have a good return on investment.

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