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 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.

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. 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. The duration of the laboratory work was thirty days. The organic waste was experimented without pretreatment under mesophilic condition at 35°C±1 °C.

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

Tania Floqi. Department of Engineering and Architecture, Faculty of Engineering, Informatics and Architecture, UE, Tirana, Albania.
(e-mail: floqitian@yahoo.com)
matter (DS) and organic matter (volatile solid) of the substrates [4].

The biogas production from primary sludge is lower (average 0.75 Nm³/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 Nm³/t) was obtained from sample three (see Table I & Fig. 3) which contains co-substrate of olive waste & sludge (average 82.80%) and the highest organic one (volatile solid) (average 84.98%).

The co-substrate of chicken manure & sludge produce 29 Nm³/t biogas with the quantity of dry matter (average 82.6%) and organic one (volatile solid) (average 37.23%), the co-substrate of cow manure & sludge produce 18 Nm³/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 |
| Average DS (%) | 10.27 | 10.32 |
| 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 |
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.

REFERENCES

[1] IEA Bioenergy, Sustainable biogas production in municipal wastewater treatment plants, ISBN 978-1-910154-22-9, 2015. 19 pages.
[2] Martin Wittmaier – Institut für Energie und Kreislaufwirtschaft an der Hochschule Bremen GmbH – Fermentation of waste and organic substances from agriculture – technical possibilities and potential for the production of generative energy. Germany 2010. 30 pages.
[3] Teodorita Al Seadi, Dominik Rutz, Heinz Prassl, Michael Köttner, Tobias Finsterwalder, Silke Volk, Rainer Janssen. Biogas handbook. Denmark 2008.
[4] Stanley E. Manahan Green Chemistry and the Ten Commandments of Sustainability, Chem Char research, Inc. 2005.
[5] Gracia Silvestre Tormo, Sewage Sludge Anaerobic Digestion – Study of synergies and operational strategies of co-digestion, Universitat Politecnica de Catalunya, Barcelona 2015. Pages 39-41.
[6] Mirel Mico, Tania Floqi, Olton Marko, Ana Tomorri, Rodon Miraj, Some data on biogas production in laboratory scale from different albanian substrates, 2nd International Conference - Research and Education in Natural Sciences, Proceedings book Volume 2, BENA, Shkodër Albania 2013. Pages 107-113.
[7] Organizational set up for an effective organic waste management system for energy profit, ‘Sustainable landscape and planning and safe environment’, BENA Istanbul Conference, Istanbul Turkey, 2012.
[8] Waste Framework Directive, Directive 2008/98/EC.
[9] ISO 14001:2015 Environmental Management Systems.
[10] ISO 14031:2013 Environmental Performance Evaluation.
[11] Directive 2008/98 EC “On waste” (19.11.2008) E.U Regulation No. 1170/2012.
[12] Directive 1999/31/EC of 26 April 1999 “On the Landfill of Waste”.
[13] Directive 2000/76/EC “On Incentration of Waste” (04.12.2000).
[14] National Strategy on Integrated Waste Management (2018-2030).

Holta Prifti was born in Albania, graduated in Environmental Engineering, Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana, Master degree in Environmental Science. Now in the phase of completion of PhD degree. She works at the National Agency of Protected Areas, Ministry of Tourism and Environment, Albania in the project sector. She follows the implementation of projects in Protected Areas in Albania; She has been lector in the Department of Environmental Engineering for three years. My mentor in PhD studies is Prof. Dr. Tania Floqi, co-Authors in this paper, Head of Environmental Department, Faculty of Civil Engineering, and Polytechnic University of Tirana, Albania. Recently, member of European University of Tirana Albania.

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

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

TABLE VI: DRY AND ORGANIC MATTER OF THE SUBSTRATES

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

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

| Sample | Empty flasks weight (gr) | Cow manure weight (gr) | Sludge weight (gr) |
|--------|-------------------------|------------------------|-------------------|
| S7     |                         |                        |                   |
| S8     |                         |                        |                   |
| S9     |                         |                        |                   |

TABLE VIII: ORGANIC CONTENT OF THE SUBSTRATES

| Sample | Vessel weight (gr) | V + Sub. (gr) | Sub (gr) | DS + V (gr) | DS (gr) | Sub-DS (gr) | DS (%) | Average DS (%) | Inorg. Matter + V (gr) | Org. mat (gr) | L. org (%) | Averag org. m (%) |
|--------|-------------------|---------------|----------|-------------|---------|-------------|--------|---------------|----------------------|---------------|-------------|-------------------|
| P7     | 3.22              | 59.2          | 73.69    | 11.8        | 8.58    | 47.4        | 15.33  | 15.62         | 4.35                 | 54.85         | 97.98       | 97.77             |
| P8     | 3.24              | 59.2          | 73.69    | 11.8        | 8.58    | 47.4        | 15.33  | 15.62         | 4.35                 | 54.85         | 97.98       | 97.77             |