STUDY OF BIOGAS PRODUCTION FROM ORGANIC WASTE USING A MINIBATCH ANAEROBIC BIOREACTOR

HASIME MANAJ, ANISA DHROSO, SONILA VITO, ILIRJAN MALOLLARI

Department of Industrial Chemistry, Faculty of Natural Sciences,

University of Tirana, Albania

e-mail: hasime.manaj@fshn.edu.al

Abstract

Biological and thermochemical processing of organic waste, plays an important role in the production of useful substances in the agriculture, energy sectors and preserves the environment. This study is focused on the biogas production from various mixed materials obtained by the vineyard and livestock sector, using a minibatch anaerobic bioreactor. Raw materials with different quantity used for the experiments were cow manure, residues from grape processing industry, distilled water and inoculum (cow manure + straw) obtained in a batch pilot scale bioreactor in anaerobic mesophilic conditions for 30 days. Chemical and physical parameters were analyzed, for each mixture: humidity, dry matter, organic matter, ash, carbon content, nitrogen content, electrical conductivity and pH. Mixtures were held in the incubator for 21 days. Based on the experimental data, we evaluated the biogas production process performance of the different receipts. Biogas production was carried out at the same time, every day. According to the results, by increasing the amount of livestock waste for the same amount of vineyards waste, biogas production is increased.

Key words: *organic waste, anaerobic digestion, biogas, pH, temperature, mini bioreactor.*

Përmbledhje

Përpunimi biologjik dhe termokimik i mbetjeve organike, luan një rol të rëndësishëm në prodhimin e materialeve të dobishme për sektorin e bujqësisë, energjisë dhe ruan mjedisin. Ky studim është fokusuar në prodhimin e biogazit nga përzierje të ndryshme të marra nga sektori i *vreshtave dhe blegtorisë, duke përdorur një minireaktor anaerobik. Lëndët e para me sasi të ndryshme të përdorura për eksperimentet ishin plehu i lopës, mbetje nga industria e përpunimit të rrushit, uji i distiluar dhe inokulumi (plehu i lopës + kashtë) i prodhuar në një bioreaktor shkallë pilot në kushte mezofile anaerobe për 30 ditë. Parametrat fiziko-kimikë që janë analizuar për secilën përzierje janë: lagështia, lënda e thatë, lënda organike, hiri, përmbajtja e karbonit, përmbajtja e azotit, PE dhe pH. Përzierjet u mbajtën në inkubator për 21 ditë. Bazuar në të dhënat eksperimentale, ne vlerësuam performancën e procesit të prodhimit të biogazit të përzierjeve të ndryshme. Prodhimi i biogazit analizohej në të njëjtën kohë, çdo ditë. Sipas rezultateve, duke rritur sasinë e mbetjeve blegtorale për të njëjtën sasi mbetje nga prodhimi i verës rritet sasia e prodhimit të biogazit.*

Fjalë kyçe*: mbetje organike, tretje anaerobe, biogaz, pH, temperaturë, mini bioreaktor.*

Introduction

Proper management of waste protects the environment and natural resources. Organic wastes are important in the economic, agricultural and environmental aspects, because the disposal of unsuitable environmental waste is achieved. One way to produce biogas is the use of organic wastes from vineyards and livestock farming. Albania is rich in terms of availability of agro-wastes including vegetable and fruit wastes. Favorable conditions, such as geographic position, climatic diversity, microclimate, soil relief, abundant solar lighting, sufficient active temperature variation, abundant autumn, winter and spring drifts that create enough water resources on land, etc., have caused viticulture to be an important agricultural activity in Albania since old ages. Grapes (*Vitis vinifera. L*) are grown in both temperate and tropical climates. The grape is mainly cultivated in large-scale for wine processing industries and is also consumed as fruits, juice and as raisins. It is rich in sugars, vitamins, enzymes, mineral salts and phytochemicals that account for the major sensory characteristics of wines. (Bunea, et al., 2012) ;(Waterhouse, 2002);(Walzem, 2008)

Nowadays, there is a growing interest in the use of waste generated by the wine industry. Biological and thermo chemical processing of vineyards organic waste, plays an important role in the production of useful materials in the agricultural and energy sectors. (Ferrer., et al., 2001) Anaerobic digestion has been considered as waste-to-energy technology, and is widely used in the treatment of different organic wastes, for example: organic fraction of municipal solid waste, sewage sludge, food waste, animal manure, etc (Li R et al., 2009). Different organic waste can be used to produce biogas, but the best result is obtained when several of materials are mixed together. Biogas is a remarkable alternative for generation of electricity and heat production compared to conventional fossil fuels (Rasi S., 2010). Biogas is a form of low cost renewable energy that has been used throughout the world for the past twenty years. The biogas produced contains mainly methane and carbon dioxide, and can be used as a source of renewable energy. It consists of 40 to 60% and 40 to 55% methane and carbon dioxide, respectively (Schweigkofler, & Niessner, 1999). The liquid effluent recovered during the process, known as digestate, can be applied on agricultural land substituting for chemical fertilizers. (Zarkadas et al., 2017) During the production of biogas from various organic wastes, useful residues can be generated for land enrichment in the agricultural sector, such as the vineyard. These residues in viticulture are important due to land poverty, low levels of humus and their exposure to erosion.

The objective of this work was to investigate the biogas potential of organic wastes from vineyards and livestock under thermophilic conditions in batch systems. The raw materials used for this experiment are the residues from the grape processing industry, animal manure and inoculums (cow manure and straw). Mixtures were prepared according to the prescribed recipes, in 250 ml minireactors and held in the incubator for 21 days. The physical-chemical characteristics of the samples were analyzed on the first day and on the last day of the experiment. Biogas production was monitored every day at the same time using a volumetric apparatus.

Material and method

The raw materials used for this experiment are the residues from the grape processing industry, animal manure and inoculum (cow manure and straw) produced in a batch pilot bioreactor in mesophilic conditions for 30 days. All the materials were supplied by an organic farm located in Tirana, which is currently developing farming (vineyards, livestock, etc.). The residues generated in wine-making include grape stalk and grape pomace. These were placed in polyethylene bags and kept under refrigerated conditions in the laboratory.

We prepared six mixtures and monitored them during twenty-one days: four mixtures, with varying amount of cattle manure (10 – 40g): volume of water (30 – 0ml): inoculum of the cow 100 ml: grape waste 30 g; the fifth mixture

30 gr of grape waste: 100 ml inoculum: 40 ml water; the sixth mixture 40 gr of cow manure: 100 ml inoculum: 30 ml water. Also for each mixture, three parallel samples were prepared. The mixtures were prepared according to a certain sequence: inoculum, vineyard residue, cow manure and water. The anaerobic environment in the mini-reactor was accomplished, gagging the nitrogen for 1 minute before being placed in the incubator, in thermophilic condition (55^{o}C). Mixtures after an hour were gagging again with nitrogen to maintain anaerobic conditions. Mini-reactors stayed in the incubator for twenty one days. Every day at the same time, was determined the volume of gas produced with the volumetric apparatus. After each measurement, we mixed intensively the minireactors before placing in the incubator. Physical and chemical parameters of mixture were analyzed on the first and the last day. Solid waste was preliminary treated by drying, grinding and screening, and then analytically examined. The following chemical and physical properties were analyzed: organic matter, moisture, ash, pH, electric conductivity, organic carbon and total concentration of nitrogen. The moisture was calculated by sample weight loss at 105 ^{o}C for 24 h. The pH (PHS-3CW Microprocessor pH/ mV METER) and the electric conductivity (DDS-120W Microprocessor Conductivity Meter) were measured from an aqueous extract. The organic nitrogen was evaluated using the Kjeldahl method (KDN-103F Automatic Nitrogen Determinator). All values were below the limits established by European Guidelines.

Results and discussion

Physical-chemical parameters during the biogas production process

The physicochemical properties of the analyzed raw materials are presented, in table 1. Humidity plays an essential role in the metabolism of microorganisms and indirectly in oxygen supply.Microorganisms can only utilize organic molecules, that are water-soluble. Humidity content, from 40 to 60% is appropriate. If moisture content falls below 40%, the bacterial activity will slow down and will cease completely below 15%.

Table 1. Physical-chemical characteristics of raw materials

	Grape Marc	*Grape stalk*	*Cow manure*	*Inoculum*
Organic matter (%)	95.45	93.03	89.66	66.5
Ash content (%)	4.55	6.97	10.34	33.5

Organic carbon (%)	53.02	51.68	49.8	36.95
Total Nitrogen (%)	1.21	1.14	3.9	3.5
C:N ratio	43.8	45.33	12.77	10.52
pH	4.22	5.67	6.58	8.71
EC (mS/cm)	3.32	4.36	13.13	3.07

When the moisture content exceeds 60%, air volume is reduced, anaerobic conditions are created, decomposition slows down, as happened in our case. In anaerobic conditions, moisture content reaches >80%. Initially, we have determined the average moisture content of the mixtures, to see if the calculated value is within the allowed range or need to be corrected. Experimental values from the first mix in the sixth, on the first day were respectively 94% - 86%, while on the twenty-one day they varied between 90% and 79%. During the process, the sample agility is reduced as a result of the thermophilic conditions created in the anaerobic minireactors, whereby some of the water will evaporate. Dry matter is increased as a result of moisture reduction. Organic matter in the various mixtures formed, on the first day show, that the experimental value decrease from the first mix to the sixth from 96.32% to 86.09%, as a result of the recipes created. Although in all recipes it has been seen the decrease in the value of organic matter from the first day on the twenty-first day of incubation, indicating that the anaerobic process has been efficient, but we note that they still need to stay in these conditions to achieve optimal results.

The first mix on the twenty-first day resulted 95%, while the sixth mix resulted 84%. During the biogas production process, the carbon content from the first day on the twenty-first day decreases, figure 1. Experimental values for mixtures from the first to the sixth on the first day range from 53.53 to 47.82%. On the twenty-first day, the results range from 52 to 46%. During the process, the nitrogen content for each mixture is increased. On the first day, experimental values range from 2.16 to 2.87%, while on day twenty-one values range from 2.33 to 3.12%. The C / N ratio, is another important parameter. The C/N ratio decreases, when composting organic waste due to carbon and nitrogen conversion. In Figure 2, the experimental values of the C/N ratio for the six mixtures are presented, from day one to day twenty-one.

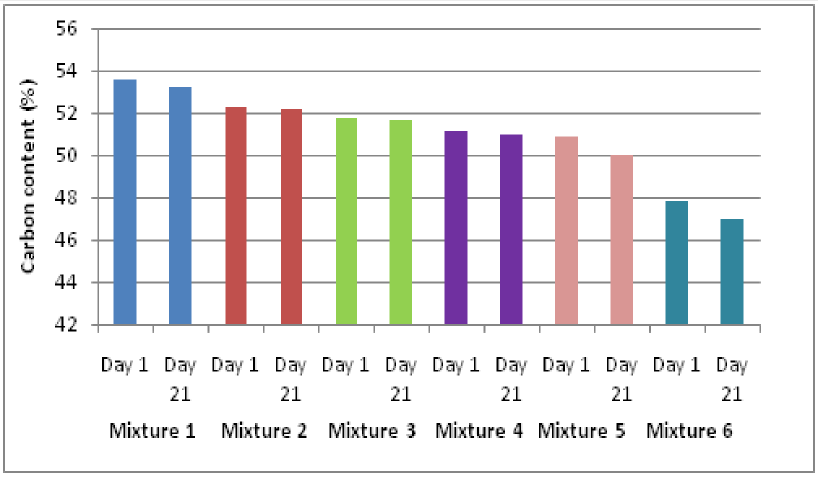

Figure 1. The carbon content performance during the process

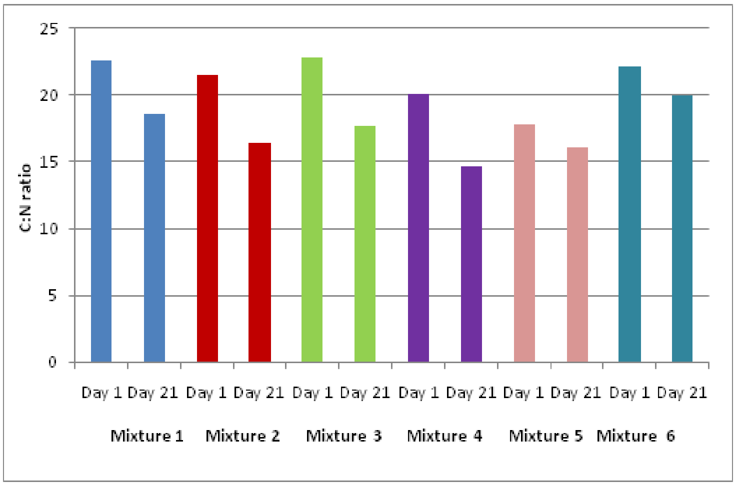

Figure 2. The C:N ratio performance during the process

Biogas production performance during treatment of various organic wastes

Gas production rate and total production of biogas are a function of the feedstock's organic content and biodegradability (Macias-Corral M. et al., 2008). Biogas production, cumulative production, and methane content were measured for each experiment. In figure 3, are presented the experimental values of daily and accumulative biogas of all sixth mixture, during the 21 days digestion. During the batch digestion was observed that the biomethane production initiated rapidly. Comparing the daily productivities of the substrates, mixture 4 offered the highest production with approximately 100 mL CH_4 to be produced within the first date of the experiment. This can be justified by high concentration of manure. The highest specific cumulative production offered by mixture 4 (Figure 3.D) 590.5 ml CH_4 with highest value of manure, followed by mixture 3 (Figure 3.C) 472 ml CH_4.

The mixture 5 (Figure 3.E) represents the lowest gas production, because it does not contain the fresh animal waste that could help in its production. In the figure 3.F, are presented the experimental values of daytime and accumulative biogas of mixture 6, where there are no residues of viticulture. Production of this mixture can be compared with the production of mixing D, since they have the same amount of manure. This mix has produced smaller amounts of biogas, because the contribution of viticulture waste has been missed. This observation indicates that organic matter of wine residues is easy degradable and affects the biogas production.

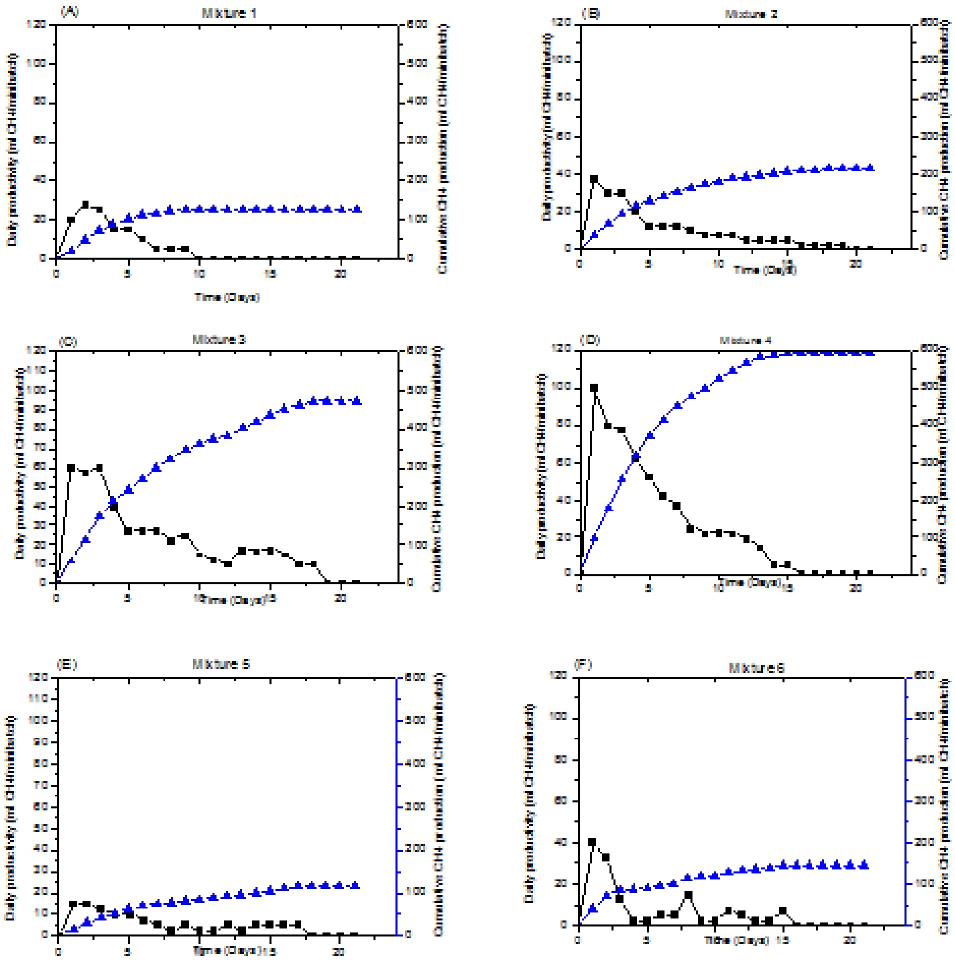

Figure 3. Biogas production performance during the process

(A)Mixture 1, (B)Mixture 2, (C)Mixture 3, (D)Mixture 4, (E)Mixture 5 and (F)Mixture 6

Conclusions

Anaerobic digestion of dairy cow manure, inoculum (cow manure + straw) obtained in a batch pilot scale bioreactor, residues from the grape processing industry and distilled water, was investigated under thermophilic conditions in batch systems. Based on the results achieved, it was estimated that by increasing the amount of livestock waste for the same amount of vineyards, biogas production is increased. Wine making has traditionally been an important sector of agriculture in Albania. Winery residues are not a significant environmental problem, although they currently remain an unused organic material. Although winemaking waste has sufficient biogas potential its usage for energy production is not widespread. So, based on experimental results we can say that winery residues are suitable substrates for biogas production in the anaerobic fermentation process.

References

Bunea, C. I., et al., Carotenoids, total polyphenols and antioxidant activity of grapes (Vitis vinifera) cultivated in organic and conventional systems. Chem Cent J 6.1, pp 66, 2012.

Ferrer, J., et al., Agronomic use of biotechnologically processed grape wastes. Bioresource Technology 76.1, 39-44, 2001.

Li, R., Chen, S. and Li, X., Anaerobic co-digestion of kitchen waste and cattle manure for methane production. Energy Sources. 31, pp 1848-1856., 2009.

Macias-Corral, M., Samani, Z., Hanson, A., Smith, G., Funk, P., Yu, H., Longworth, J., Anaerobic digestion of municipal solid waste and agricultural waste and the effect of co-digestion with dairy cow manure, Bioresource Technology 99, 8288–8293, 2008.

Rasi, S., Lehtinen, J., and Rintala, J., Determination of organic silicon compounds in biogas from wastewater treatments plants, landfills, and co-digestion plants. Renewable Energy 35.12, pp 2666-2673, 2010.

Schweigkofler, M., and Niessner, R., Determination of siloxanes and VOC in landfill gas and sewage gas by canister sampling and GC-MS/AES analysis. Environmental science & technology 33.20, pp 3680-3685, 1999.

Zarkadas, I. S, Georgopoulos, N., Kaldis, F., Pilidis, G., Sarigiannis, D., Assessing the biomethane potential of three pickling and canning semi-solid wastes under thermophilic conditions; Fresenius Environmental Bulletin, volume 26, No. 1, pp 392-398, 2017.

Walzem, R. L., Wine and health: state of proofs and research needs. Inflammopharmacology 16.6, pp 265-271, 2008.

Waterhouse, A. L., Wine phenolics. Annals of the New York Academy of Sciences 957.1, pp 21-36, New York, 2002.