Physicochemical characterisation of an anaerobic biodigestion process fed with agricultural wastes

Caracterización fisicoquímica de un proceso de biodigestión anaerobia alimentado con residuos agricolas

AYALA, Alberto*†, HERRERA, Gabriel, GUTIERREZ, Elizabeth and RANGEL, Ulises

Instituto Tecnológico Superior de Irapuato. Mexico.

ID 1st Author: *Alberto, Ayala*

ID 1st Co-author: *Gabriel, Herrera*

ID 2nd Co-author: *Elizabeth, Guitierrez*

ID 3rd Co-author: *Ulises, Rangel*

DOI: 10.35429/EJRN.2020.11.6.1.4 Received June 10, 2020; Accepted December 30, 2020

Abstract

Contamination of water and soil for chemical fertilizers creates the need for efficient and economic alternatives of fertilization of soil, which decrease the negative impact of chemical fertilizers. A viable alternative is the use of vegetable waste through the anaerobic biodigestion, obtaining biogas and effluent solids and liquids such as by-products, with the latter being a potential of organic fertilizer residue. In order to use the organic waste and transform them waste to fertilizers, was carried out this work. It used 3-bio-digesters scale laboratory, which consist of a camera input of polyethylene of 3.8-litre capacity, one output of the same material and capacity of the first PVC tube, and a pair of valves of output, one for sampling and the remaining for the emission of biogas and thermometer. Determinations of physicochemical parameters were pH, cod, total phosphorus, total nitrogen, potassium, total volatile solids, total solids, fixed and volatile suspended solids. The first biodigester fed on remains of tomatoes and inoculum in a 2:1 ratio respectively, the second with cucumber waste and the proportions and the third was charged with a proportional mixture of both vegetables and inoculum.

Biodigester, Organic waste, Liquid effluents

Resumen

La contaminación de agua y suelo por los fertilizantes químicos genera la necesidad de encontrar alternativas económicas y eficientes de fertilización de suelo, que disminuyan el impacto negativo de los fertilizantes químicos. Una alternativa viable es la utilización de residuos vegetales, mediante la biodigestión anaerobia, obteniendo biogás y efluentes sólidos y líquidos como subproductos, siendo este último un residuo con potencial de fertilizante orgánico. Con el objetivo de utilizar los desechos orgánicos y transformarlos de residuos a biofertilizantes, se realizó el presente trabajo. Para ello, se utilizaron 3 biodigestores escala laboratorio, los cuales constan de una cámara de entrada de polietileno de 3.8 L de capacidad, una de salida del mismo material y capacidad del primero, PVC tubular, y un par de válvulas de salida, una de ellas para el muestreo y la restante para la emisión del biogás y termómetro. Se realizaron determinaciones de parámetros fisicoquímicos: pH, DQO, fósforo total, nitrógeno total, potasio, sólidos totales, solidos totales volátiles, sólidos suspendidos fijos y volátiles. El primer biodigestor se alimentó de restos de jitomates e inóculo en una relación 2:1 respectivamente, el segundo con desechos de pepino y las mismas proporciones y el tercero fue cargado con una mezcla proporcional de ambas hortalizas e inóculo.

Biodigestor, Residuos orgánicos, Efluentes líquidos

Citation: AYALA, Alberto, HERRERA, Gabriel, GUTIERREZ, Elizabeth and RANGEL, Ulises. Physicochemical characterisation of an anaerobic biodigestion process fed with agricultural wastes. ECORFAN Journal-Republic of Nicaragua. 2020. 6-11:1-4.

* Correspondence to Author (Email: alayala@itesi.edu.mx)
† Researcher contributing first author.

Introduction

Global waste production has reached extremely high levels in recent years. Most of this waste is organic and represents up to 60% of total household waste, which is not recycled. These wastes are deposited in landfills or dumps where they occupy large spaces or are incorporated into the environment as a pollutant of water, soil, and atmosphere, due to their large volumes. (KRELING, 2006).

The lack of final management of agricultural waste in Mexico and the massive contamination due to the improper use of chemical fertilisers represent a serious environmental problem that is increasing day by day. This problem has led research into the search for a solution, and one of the various options found is anaerobic biodigestion, by means of which bioproducts such as methane gas and effluents are obtained. The latter have a positive impact on agriculture.

Biodigested organic matter added to the soil as a fertiliser or soil conditioner tends to produce significantly beneficial physical and chemical changes, the type and importance of which depends on many factors, including the quantity and quality of the organic matter applied.

Among the importance of organic fertiliser is its positive effect on the environment, since when applied in adequate proportions to soils that have lost their original characteristics (fertility, porosity), it helps the soil to recover them and contributes to preventing progressive deterioration of these soils.

This translates into the reincorporation of organic matter waste into the natural cycles, taking advantage of the available resources in almost their entirety, this at a low cost, contributing to sustainable environmental development.

Benefits in the use of biodigested effluents as biofertiliser:

Provides macro and micronutrients to the soil for direct consumption by plants. Increases ion exchange capacity. It achieves a buffer effect on soil pH. Reduces soil losses due to erosion. Prevents the loss of mineral nutrients (provided by chemical fertilisers) through leaching.

Development

The analyses (physical, biological, and chemical) were carried out in the laboratories of the Intituto Tenológico Superior de Irapuato with international methods applicable to our environment. The samples came from laboratory-scale batch-scale biodigesters located within the laboratory. The materials loaded into the biodigesters were agricultural vegetable wastes (tomato and cucumber).

Methodology

Sampling was performed only when determining physicochemical parameters, which were: Total Nitrogen, Total Phosphorus, Chemical Oxygen Demand (COD), Potassium, Total Solids (TS), Total Volatile Solids (TVS), Total Suspended Solids (TSS) and Volatile Suspended Solids (VSS).

The equipment used for the measurement of parameters were:

Total phosphorus: Reactor HI839800 and photometer C 214 Multiparameter Bench Photometer hanna brand.

Total nitrogen: HI839800 reactor and hanna brand C 214 Multiparameter Bench Photometer.

Chemical Oxygen Demand (COD): HI839800 reactor and hanna brand C 214 Multiparameter Bench Photometer.

The standards used for the other parameters analysed were as follows:

Determination of dissolved solids and salts in natural, waste and treated wastewater: NMX-AA-034-SCFI-2001.

Results

The physical and chemical characteristics of influents and effluents at the beginning, during and after the biodigesters are shown in the following tables 1 to 3:

Parameter	Unit	Start	During
pH	$(H_3O)^+$	6.8	5
DQO	mg/L	24300	15460
Nitrogen	mg/L	250	7.1-7.2
Phosphorus	mg/L	1950	*
Temperature	°C	27	25
S.S.T.	mg/L	*	935
S.S.V.	mg/L	*	495
S.T.	mg/L	*	1570
S.V.T.	mg/L	*	1.17
NOTE: * = Could not determine			

Table 1 Biodigester No.1 Tomato

Parameter	Unit	Start	During
pH	$(H_3O)^+$	6.5	5
DQO	mg/L	24700	15715
Nitrogen	mg/L	745	460
Phosphorus	mg/L	600	*
Temperature	°C	27	25
S.S.T.	mg/L	*	215
S.S.V.	mg/L	*	225
S.T.	mg/L	*	710
S.V.T.	mg/L	*	0.485
NOTE: * = Could not determine			

Table 2 Biodigester No. 2 Cucumber

Parameter	Unit	Start	During
pH	$(H_3O)^+$	6.7	5
DQO	mg/L	25501	16225
Nitrogen	mg/L	360	1470
Phosphorus	mg/L	140	*
Temperature	°C	27	25
S.S.T.	mg/L	*	2140
S.S.V.	mg/L	*	1860
S.T.	mg/L	*	2480
S.V.T.	mg/L	*	3.92
NOTE: * = Could not determine			

Table 3 Biodigester No. 3 Tomato and Cucumber

Analysis

These results show a trend in the operation of the biodigester, as there is a clear decrease in COD and BOD5 as the process progresses. This means that the organic matter load that the system receives from the plant waste feed is being transformed, presumably into methane, carbon dioxide and biomass mainly. Although there is a slight increase in the organic load during the process, which could be due to the increase in bacterial biomass that makes the transformation possible, the decrease in the initial load is significant, slightly higher than 90% for COD and 70% for BOD5, which speaks of an efficient process as the removal is extremely high.

The quantitative determination of nitrogen and phosphorus shows a decrease in the amounts not so high since both elements can remain in the liquid phase, because the catabolism of the system favours the production of methane over ammonia, for example. Thus, both nutrients should remain in the effluent; if a high proportion is maintained in this liquid product, this effluent can be considered as an excellent organic fertiliser, as it would contain the proportions of both parameters like commercial inorganic fertilisers.

Elements	Percentages %	Elements	Percentages %
Total Nitrogen (N)	11.470	Timide hydrochloride	0.004
Phosphorus (P_2O_5)	8.000	Sulfur (S)	0.230
Potassium (K_2O)	6.000	Calcium (CaO)	0.025
Boron (B)	0.036	Cobalt (Co)	0.002
Copper (Cu)	0.040	Manganese (Mn)	0.036
Iron (Fe)	0.050	Magnesium (MgO)	0.025
Molybdenum (Mo)	0.005	Indoleacetic acid	0.003
Zinc (Zn)	0.080		

Table 4 Composition of Bayer's Bayfolan® Fertilizer

The composition of the fertiliser is shown in Table 4. It could even be used as a feed source for the cultivation of microalgae with the potential to produce biodiesel or other commercially important bioproducts such as carotenoids or other biofuels.

Undoubtedly, generating biogas and a biofertiliser from this process fed with organic matter is a remarkably interesting result to close process cycles and recycle nutrients such as carbon dioxide, nitrogen and phosphorus. It also generates new value chains and economics to agricultural systems, making them sustainable.

The results obtained show a clear decrease in COD (Chemical Oxygen Damage) as the process progresses. This means that the organic matter load that the system receives from the feeding of plant residues is transformed into methane and biomass. It should be noted that the decrease could be due to the increase in bacterial biomass that makes the transformation possible.

It was not possible to determine the results of solids and dissolved salts, for fear of air entering the biodigester process.

ISSN-On line: 2414-8830

The proportions of the waste could affect the functioning of the process, so it is necessary to investigate the design of biodigesters, as well as to determine other physicochemical parameters: metals such as iron, calcium and microbiological parameters such as total coliforms and faecal coliforms (Escherichia coli) to determine their safety and whether it is feasible to use them in soils.

Acknowledgements

We would like to thank the company 4e Power and Fuels S. de R.L. and Ing. Jesús Alberto Crespo Quintanilla for their valuable support. We also thank the CONACYT project for the grants awarded.

Conclusions

So far, the physicochemical analyses COD, BOD5, total nitrogen and phosphorus for the biodigestion process used by the company 4e Power and Fuels S. de R.L. have been carried out.

These results show an effective reduction of the organic load, measured as COD and BOD of up to 90%, so the biogas production should be very efficient as well.

The capacity of the biodigester to be fed with a higher flow rate will have to be analysed to determine the limit of maximum reduction of organic matter to transform it into biogas and generate useful biofertiliser.

Four laboratory-scale biodigesters were constructed to monitor and obtain data related to this process. The proportions of the waste could affect the functioning of the process, so it is necessary to investigate more experimental designs and carry out other physicochemical determinations, such as the content of total solids, soluble solids, volatiles, various metals such as potassium, iron, calcium, among others, and microbiological determinations in the biofertiliser to determine its safety or the need to carry out some other treatment.

Undoubtedly, generating biogas and a biofertiliser from this process fed with organic matter is a very interesting result to close the process cycles and recycle nutrients such as carbon dioxide, nitrogen and phosphorus. It also generates new value chains and economics to agricultural systems making them sustainable.

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