Technical and environmental analysis of large-scale pig manure digestion through process simulation and life cycle assessment.

M. Amado[1,2], J. Carrasco[3], L. Ochoa[3], C.J. Rangel[1], A.P. Becerra[3], I. O. Cabeza[3], P. A. Acevedo[3,4]

[1]Department of Process Engineering, Universidad EAN, Bogotá, 110221, Colombia
[2] Aix Marseille Univ, CNRS, Centrale Marseille, M2P2, Marseille, 13451, France
[3]Department of Environmental Engineering, Universidad Santo Tomás, Bogotá, 110311, Colombia
[4]Department of Industrial Engineering, Universidad Cooperativa de Colombia, Bogotá, 111311, Colombia
Keywords: Life cycle assessment, large-scale, anaerobic digestion, aspen simulation.
Presenting author email: mlamadov@universidadean.edu.co

Abstract

The biogas and by-products (digestate) production from anaerobic digestion (AD) of pig manure was evaluated technically and environmentally in an industrial park in Bogotá, Colombia, in order to generate economic opportunities and to reduce environmental impacts. Mass and energy balances were performed using data from literature and developing a simulation of the AD process in Aspen Plus software based on stoichiometric balances. The environmental evaluation of this process was developed using the life cycle analysis methodology. The results of the environmental evaluation show that the stages of transport, consumption of electrical and thermal energy, contribute to the categories of acidification, abiotic, and ozone layer deterioration, for the two scenarios of interest according to the allocation to the product of use final.

1. Introduction

Waste or residual biomass not managed correctly cause substantial environmental impacts and high costs for their treatment and final disposal. The latest research has focused on the search for new technologies that allow the use of residual biomass as raw materials to produce biofuels that allow the generation of heat and electricity. One of the highly studied processes is anaerobic digestion (AD) due to the interest in the generation of biogas, mostly composed of methane gas (Corredor and Pérez 2018). The main reason for the interest in AD is because the process avoids methane emissions and allows obtaining a stabilized digestate, which can be used as fertilizer (FAO 2014).

The AD is a possible response to Colombia's energy need, to increase the percentage of biogas participation within the energy matrix and respond to a large amount of biomass available; according to Piñeros, *et al*. 2018), there is availability of substrates such as pig manure (PM) that has a high potential for bio-methanation. In Colombia, particularly the increase in pig production currently generates approximately eight million tons of manure per year in just one department. Then, bioprocesses can be one of the answers within the Nationally Appropriate Mitigation Actions (NAMAS) for the mitigation of greenhouse gases (GHG); promoting the generation of biogas of agricultural origin for energy use, through the recovery of waste generated in this economic sector (Ministerio de Minas y Energía 2017).

In order to study the biomass conversion and uses, a the technical and environmental viability of producing electric energy (EE) from biogas generated by the AD of pig manure. The study evaluates the scenario in which the manures of several pig farms in the department of Cundinamarca are coupled, and an electric power generating plant is built in an industrial park located near Bogotá, including in the analysis the production of digestate to be marketed as fertilizer. For the environmental evaluation, the LCA methodology and the specialized SimaPro software were used, in which the data of the mass and energy balances were entered, based on the information obtained from the simulated process in the Aspen Plus software.

2. Methodology

The proposed methodology followed three stages: the definition of the technical framework, simulation of the AD and the estimation of environmental performance.

Technical framework

Information was collected from each of the stages, beginning with the transport of the PM; the substrate availability data for the department of Cundinamarca was taken from the study conducted by Piñeros et al. (2018).

AD Simulation in Aspen Plus

Based on the stoichiometric relationships proposed in the ADM1 model, time and operational conditions.

Environmental performance by Life Cycle Assessment (LCA)

This study followed the LCA methodology, described in ISO 14040, which proposes four main stages: definition of objective and scope, life cycle inventory (LCI), life cycle impact assessment (LCIA), and finally, interpretation (NTC-ISO, 2006).

In the LCA evaluation, two scenarios were considered. The first scenario, since the study aims to generate EE, is based on a 100% allocation for biogas. For this scenario, it was selected as a functional unit (UF) 1 kWh of generated energy. On the other hand, the second scenario has an allocation percentage of 100% to the digestate obtained; since, in the results of the economic evaluation, most of the income corresponds to its sale. The selected UF was 1 kg of digestate produced.

3. Results

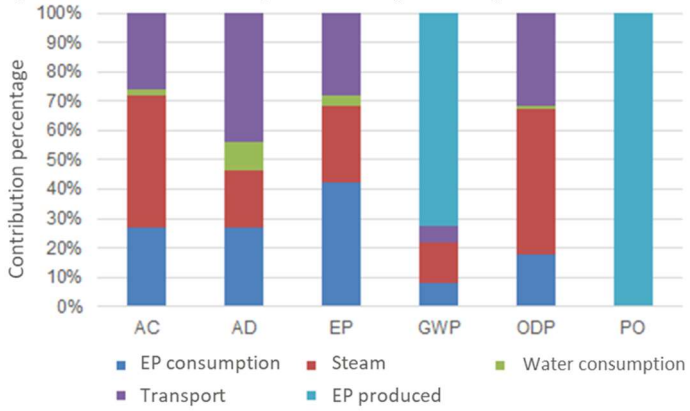
Piñeros et al. (2018) presented the availability of pig manure study for the department of Cundinamarca. Using the information and considering the use of the plant at 80%, the reactors were sized, and the amount of biogas was calculated according to the bio-methanation potentials calculated in previous studies.

Initially, the simulation was performed in Aspen Plus Software, where water and energy inputs were evidenced. Due to a large amount of manure for anaerobic digestion, it was established that the process would be carried out in two batch biodigesters, each of 3702 m^3.

Regarding the results from the LCA, it was obtained that the categories related to the stages of steam, manure transport, and energy consumption are those with the most significant impact contribution to the two scenarios studied. The environmental impact profile diagram of the first scenario is presented in Fig 1.

.

Fig.1 Contribution of stages to the impact categories in scenario 1



4. Conclusions

This study presents the technical and environmental evaluation related to the DA process, using pig manure as the only substrate. The plant has a capacity for 2,312 tons of substrate and was divided into two biodigesters of 3702m3 size. Biomethane and digestate production for a single cycle was, respectively, 3.8 Tn and 37Tn. The LCA presented that the stages of the most significant impact are transport, consumption of electric energy, and the use of steam for both scenarios.

5. References

Corredor YAV, Pérez LIP (2018) Aprovechamiento de residuos agroindustriales en ell mejoramiento de la calidad del ambiente. Rev Fac Cienc Básicas 59–72 . https://doi.org/10.18359/rfcb.3108

FAO (2014) Bioenergía y seguridad alimentaria, evaluación rápida, residuos agrícolas y residuos ganaderos. http://www.fao.org/3/a-bp843s.pdf

Ministerio de Minas y Energía (2017) Potencial de mitigación de gas efecto invernadero GEI del sector minero - energético. In: MINMINAS. https://www.minenergia.gov.co/documents/10192/23966980/240118_potencial_mitigacion_GEI_SME.pdf/76f31f95-3ec5-4db2-9d7f-fff54f070c9ehttps://www.minenergia.gov.co/documents/10192/23966980/240118_potencial_mitigacion_GEI_SME.pdf/76f31f95-3ec5-4db2-9d7f-fff54f070c9e. Accessed 5 Feb 2020

Piñeros, V.; Melo, k; Acevedo, P.; Cabeza, I. (2018) Integración de Modelos de Evaluación de Viabilidad Económica e Impacto Ambiental a Modelos Empíricos y Técnicos del Proceso de Codigestión Anaeróbica