# Energy recovery of swine manure waste: In lab to farm experiences

**Juan M. Delgado[1], Ana M. Mosquera[1], Mariana Peñuela[1]**

[1] Bioprocess Research Group, Department of Chemical Engineering, Faculty of Engineering, Universidad de Antioquia, Medellín, Colombia. e-mail: martin.delgado@udea.edu.co

**Highlights**

- Biogas production from swine manure is a novel technology that offers numerous benefits, including energy generation, efficient waste management, significant reduction of greenhouse gas emissions, and production of a valuable fertilizer
- The use of swine manure for biogas generation can reduce environmental costs and generate non-operational income for pig farms
- The treatment of swine manure through anaerobic digestion to produce valuable products like biogas and effluents that have the potential to be used as fertilizers, is a key contributor to the circular economy of pig farms.

**Keywords:** Swine manure; Non-Conventional Renewable Energy; Biogas; Waste management; Circular economy.

## Introduction

Colombia has a substantial capacity to produce energy due to its distinct geographical and climatic features. In addition, the country also has access to Non-Conventional Renewable Energy (NCRE) sources such as biomass, small hydroelectric plants, wind, geothermal, and solar power. According to the Mining and Energy Planning Unit (UPME), NCREs could supply up to 46% of the national energy demand, equivalent to more than 500,000 TJ per year. Despite this potential, a large portion of agricultural residual biomass is not being utilized for energy purposes, as is the case with pig manure. Despite its energy potential, pig manure is mainly used as an artisanal fertilizer or improperly discarded, resulting in environmental contamination. According to sectorial statistics from PorkColombia, the swine industry has maintained an average annual growth rate of over 7% for the past decade, reaching a production of 5.2 million pigs in 2022. This equates to an estimated production of 2.7 million tons of residual biomass, which can generate between 25 to 60 $m^3$ of biogas (60-70% $CH_4$) per ton. This implies a potential energy generation of 175-420 Kw-h per ton of swine waste.

## Material and Methods

The aim of this research project was to valorize the by-products of the pig industry for energy purposes. To this purpose, an initial study was conducted on the generation of biogas in a 5 L capacity Anaerobic Sludge Batch Reactor (ASBR). Subsequently, the experiment was scaled up to 26 L and the reaction system was changed to an Upflow Anaerobic Sludge Blanket (UASB) reactor. Following the evaluation of preliminary results, adjustments were made to the UASB system design to construct a 40 L reactor with improved performance (Figure 1). The substrate used to feed the reactors was a 20% w/w porcine slurry solution prepared every 5 days. The porcine slurry was collected every 20 days from the gestating adult female pen at a pig farm located in Yarumal, Colombia, at an average temperature of 12°C and an altitude of 2800 m.a.s.l. the inlet flux and Organic Load Rate-OLR were evaluated in a range of 1.2-1.9 L/d and 1.4-3.0 gVS/L*d, respectively.

After this, the production process was scaled up to a reactor installed in a real environment, with a daily treatment capacity of 1.3 $m^3$ and a Hydraulic Retention Time (HRT) of 18 days. The physicochemical parameters of the substrate and reactor effluent were established using the quantification methods of Total Solids (TS) and Volatile Solids (VS), as described in Standard Methods for the Examination of Water and Wastewater. Chemical Oxygen Demand (COD) was measured with the Test'n tube high range plus, based on the Hach 8000 method. Volatile Fatty Acids (VFA) and Alkalinity (ALK) of the effluent were determined according to the Kapp method. The quantification of the produced biogas was carried out with a conventional gas flow meter, and the volumetric composition on a dry basis of the biogas was established with a biogas analyzer (MRU AIR Optima7). At the end, an economic evaluation of several

biogas production scenarios, including fertilizers used, to establish economic feasibility on large scale was realized.

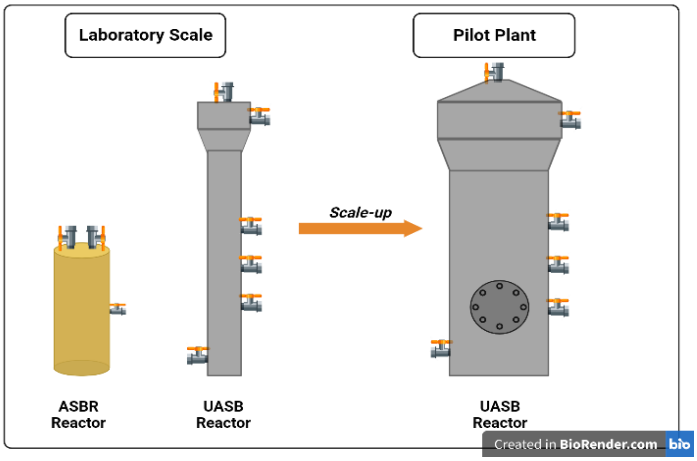


**Figure 1.** *Scale-up of the biogas production process using swine manure as substrate.*

## Results and Discussion

The most relevant results of the adaptation process of sludge to the porcine substrate and the laboratory scaling up process are summarized in Table 1.

***Table 1.*** *Operating parameters obtained from the evaluated reactors*

| Operation index \ Prototype | ASBR | UASB $V_1$ | UASB $V_2$ | UASB PILOT SCALE |
|---|---|---|---|---|
| Reactor Capacity (L) | 5 | 26 | 40 | 20,000 |
| Biogas Productivity (L/day) | 3.36 | 10.26 | 13.93 | the operation begins on May 6/2023 |
| Average content of $CH_4$ (%) | 60.25 | 67.21 | 70.6 | |
| Biogas Yield (L/kg) | 22.06 | 46.26 | 53.59 | |
| Specific Methanogenic Yield ($CH_4$/kg.SV) | 240 | 319 | 417.16 | |
| Organic Matter Removal (%) | 76% | 82% | 92% | |

**The substrate used to feed the reactors was a 20% w/w swine manure and crude water. The inlet flux of substrate and Organic Load Rate-OLR were evaluated in a range of 1.2-1.9 L/d and 1.4-3.0 gVS/L*d, respectively.*

The average biogas composition achieved to date is 70.6% $CH_4$, 20.4% $CO_2$, 0.9% $O_2$, and 8.0% $N_2$, with 1000 ppm $H_2S$. The UASB reaction system is capable of removing more than 90% of the organic load in COD present in substrates prepared with swine manure, generating biogas and a fertilizing bio-slurry simultaneously.

The preliminary economic study of a 20 $m^3$-scale energy generation system from swine waste suggests that simply selling the generated energy to the local transmission network is not sufficient. The most favorable scenario is one where the farm consumes the produced energy and uses the generated biol as a substitute for nitrogen fertilizers.

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