ENERGY RECOVERY OF SWINE MANURE WASTE: IN LAB TO FARM EXPERIENCES

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Introduction: ¿What are the Non-Conventional Renewable Energy (NCRE)?

Definition:

NCRE are renewable energy resources available globally with the following characteristic.

Characteristics

- Environmentally sustainable.
- Not used in the country or are used marginally.
- Not widely marketed.

Types of NCRE

- Biomass energy
- Small hydroelectric plants
- Wind energy
- Solar PV energy
- Sea or ocean energy

Source: *law 1715 of 2014. Colombian Ministry of Mines and Energy.*

Introduction: Current energy overview of Colombia

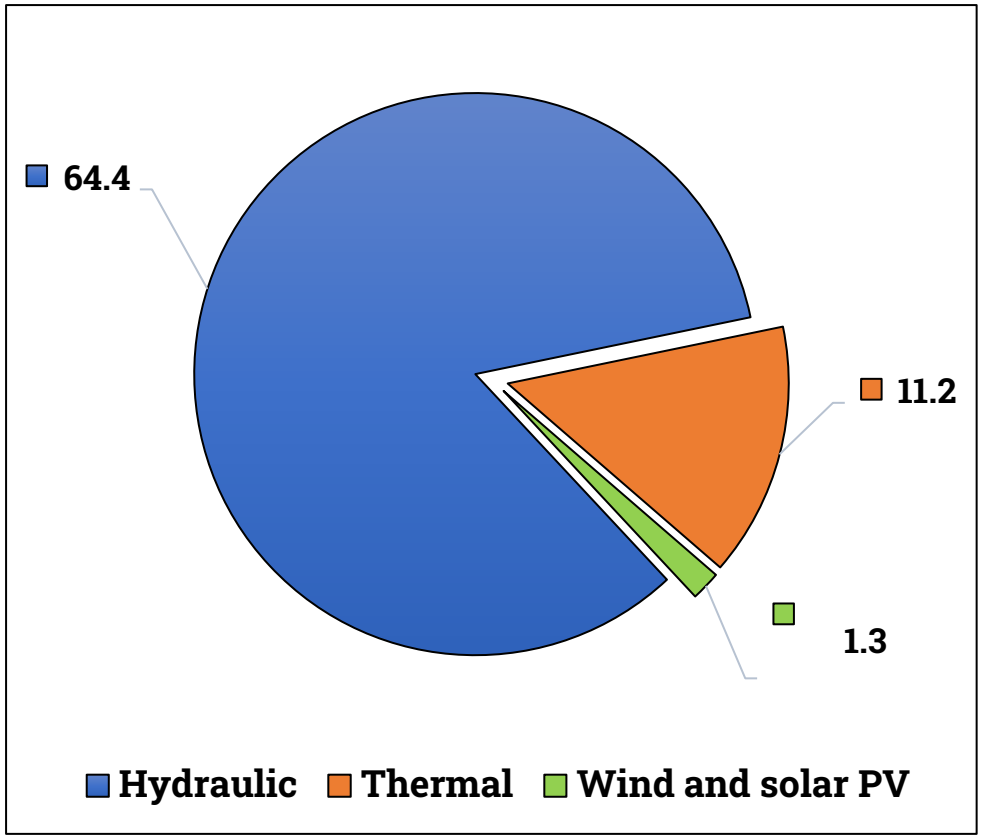


Figure 1. *Energy generation by type of technology 2022 (**GWh**)*

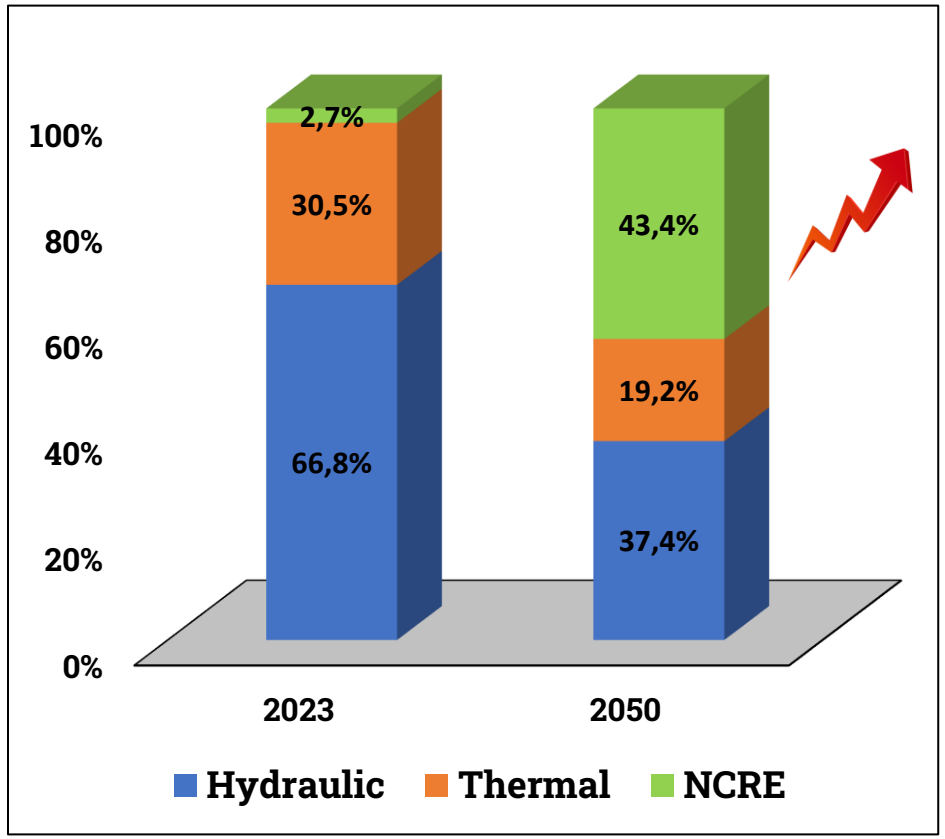


Figure 2. *Expected evolution of installed energy capacity*

2023
18.777 MW

Projection to 2050
42.709 MW

Source: *Informe Perspectiva Sectorial – Energía (Corficolombiana, 2023)*

*NCRE: No conventional Renewable Energy

Introduction: biomass potential for energy generation from biogas

Biomass Potential

Colombia have an estimated technical potential of **53.544 TJ/year** for energy generation through biogas from biomass in 2017 (UPME)

Equivalent to 25% of the natural gas demand for 2016.

Table 1. *Energy potential of prioritized sectors in 2017.*

Sector	Activity	Potential from biogas (TJ/year)
Livestock	Poultry	3.601
	Pork	**2.120**
Agricultural	Palm Oil	3.073
Urban	Urban solid waste	2.608
Industrial	Vinasse (sugarcane)	3.268

Source: *Estimación del potencial de conversion a biogás de la biomasa en Colombia y su aprovechamiento (Universidad Nacional y UPME, 2017)*

Introduction: current situation of the pork sector in Colombia

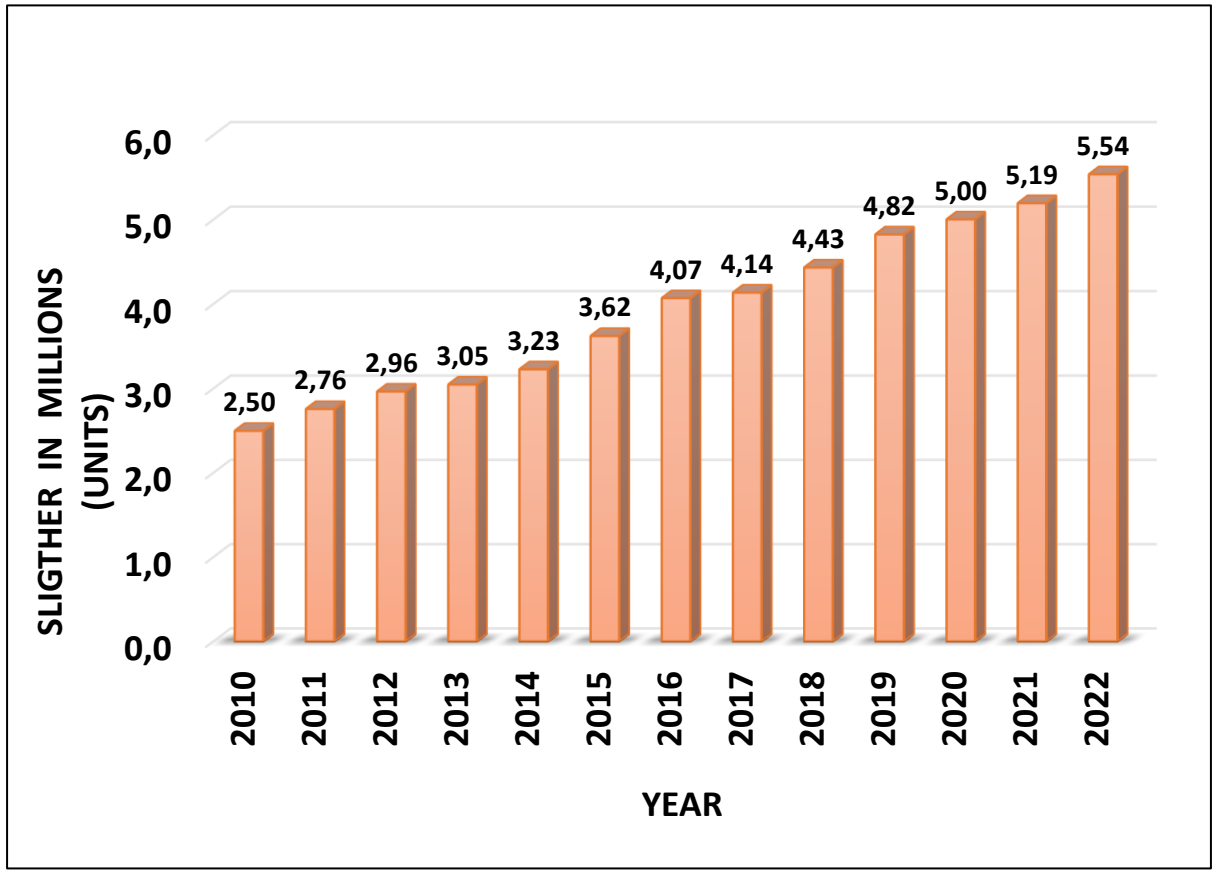


Figure 3. *Pork production in Colombia over time*

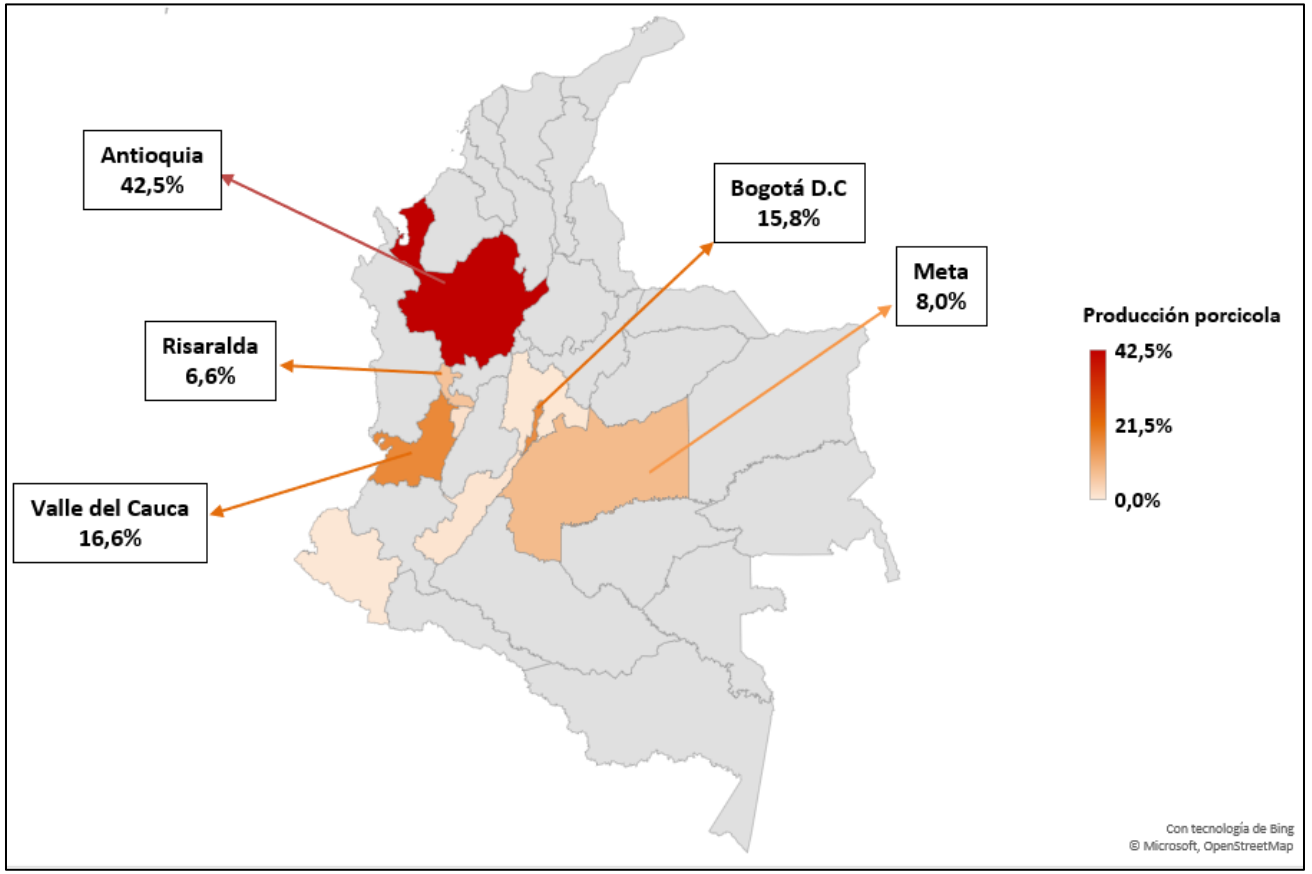


Figure 4. *National distribution of pork production*

Source: *PorkColombia - Asociáción Nacional de Porcicultores en Colombia.*

Reactor types for Anaerobic Digestion (AD) for pork sector

Reactors for AD process

Low Rate

- **Plug Flow**
- Anaerobic pond
- Hindu type biodigester

High Rate

- Continuous Stirred Tank (CSTR)
- **Up-Flow Anaerobic Sludge Blanket (UASB)**
- Anaerobic baffled

Figure 5. *Plug flow reactor in pig farm commonly used in Colombia Source: PorkColombia, 2023.*

Figure 6. *UASB reactor from porciCES. An experimental farm of CES University.*

Source: *PorkColombia- Asociáción Nacional de Porcicultores de Colombia and Eurocarne.com*

Research project objective

To implement the biogas production process in UASB reactor at pilot scale, using swine manure as substrate.

Methodology

- Measurement of methanogenic potential of swine manure.

- Reactor tracking and monitoring:

  ✓ Biogas production and characterization.

  ✓ Measurement of pH, COD, TS, VS, VFA and ALK.

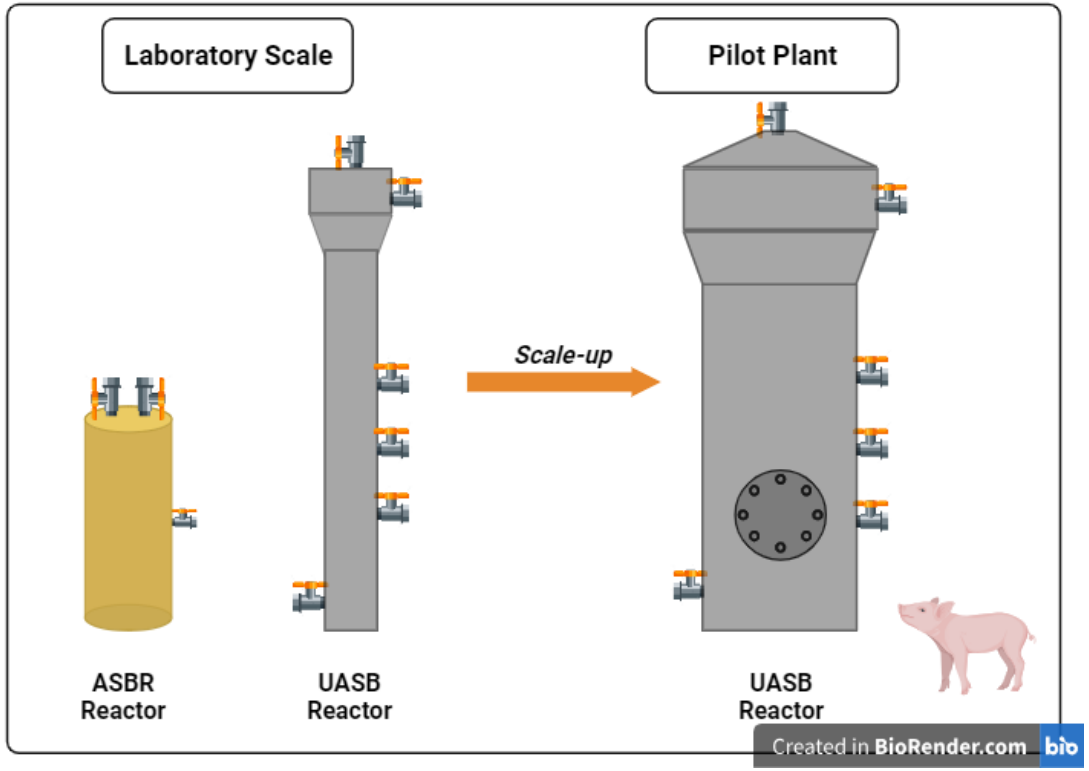
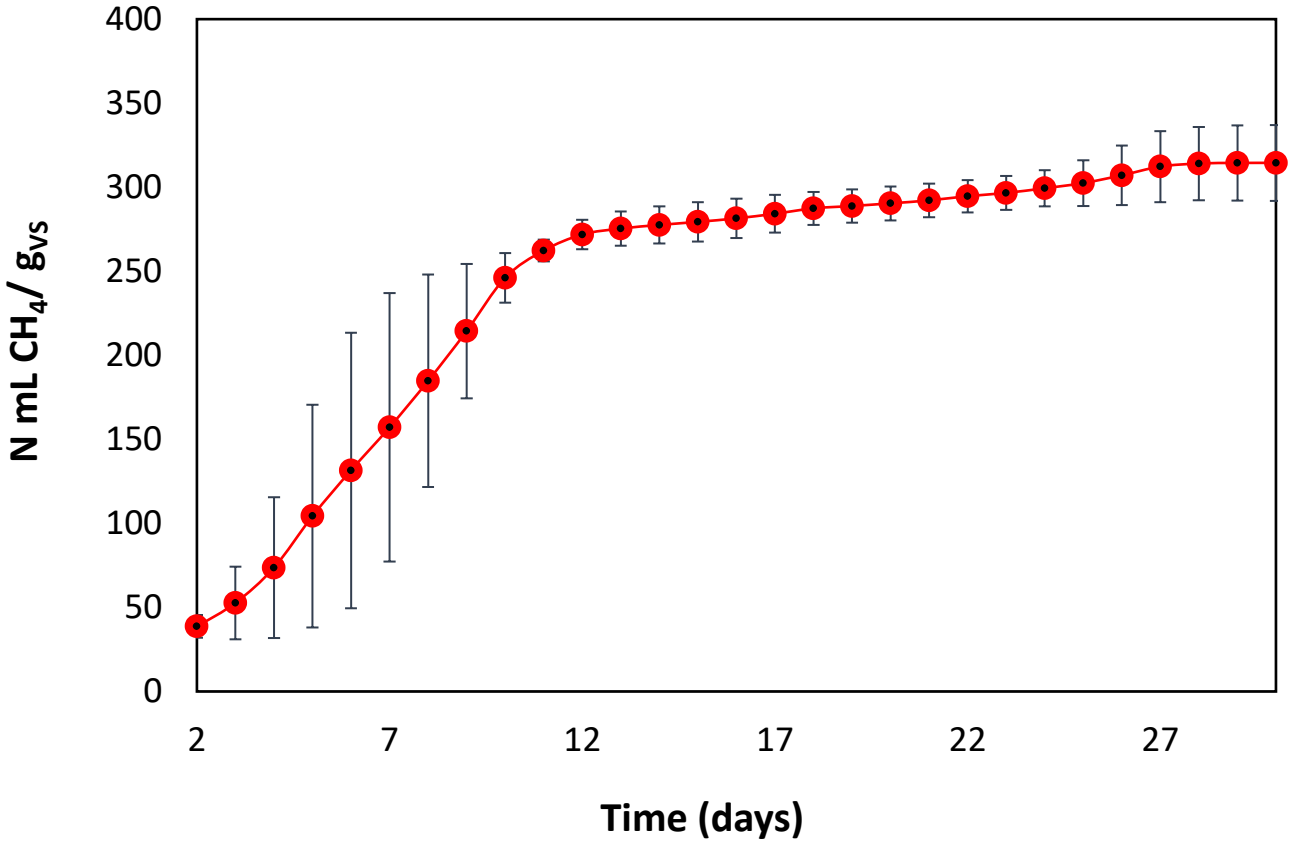


Figure 7. Workflow sequence.

Results

Substrate	pH	COD (mg O_2/L)	Moisture (%)	TS (mg/L)	VS (mg/L)
Swine manure mixture (1:6)	7.38 ± 0.08	35,270 ± 9310	97.44 ± 0.31	25,633 ± 3135	18,991 ± 2527



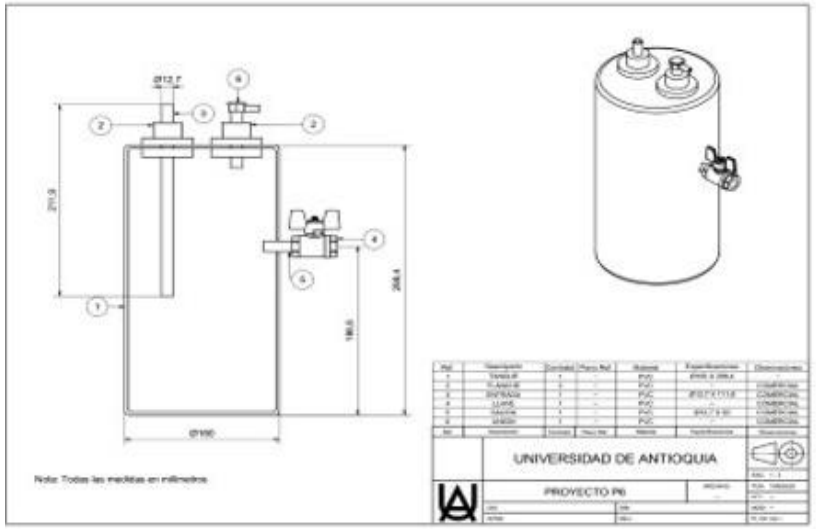
Methanogenic potential of swine manure:

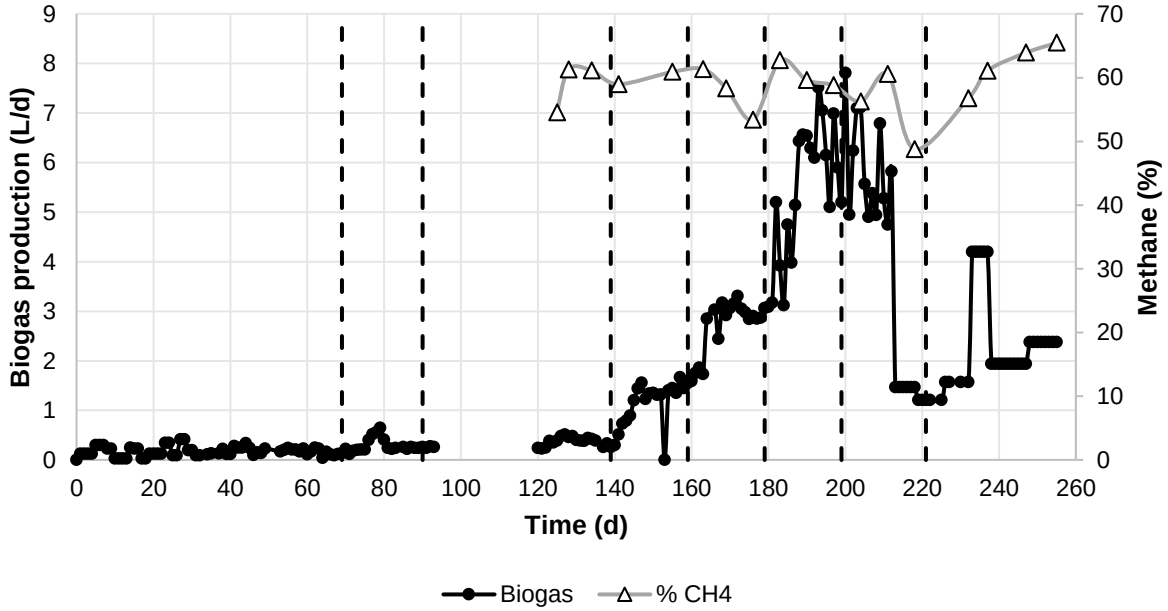
240 N mL CH_4 /g_{VS}

Results: prototype #1 (2021)

Operation Parameters

Type: ASBR reactor
Operation mode: Batch
Volume capacity: 5 L
Inoculum: sludge from San Fernando's water treatment plant.
Feed: ratio 1:4 (swine manure:water)





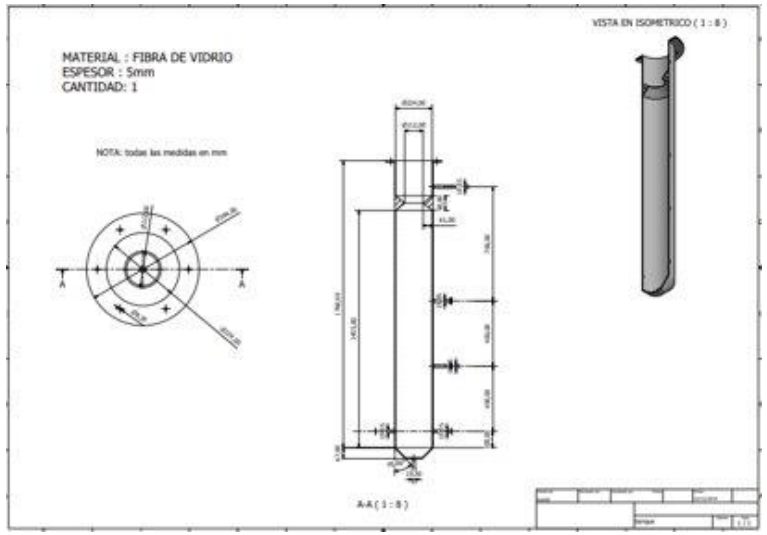
Results

Average CH_4: 59%
Maximum biogas production: 7.81 L/day
OLR: 0.2-5.2 g_{VS}/L d

Results: prototype #2 (2021)

Operation Parameters

Type: UASB reactor
Operation mode: continuous
Volume capacity: 24 L
Feed: ratio 1:4 (swine manure:water)
Flow rate: 1.2 L/day



Results for UASB reactor	
Tracking time (days)	110
Maximum biogas production (NL_{biogas}/day)	**13,10**
Yield ($L_{biogas}/kg_{Swine\ manure}$)	54,62
HRT (days)	20
COD remotion (%)	86%

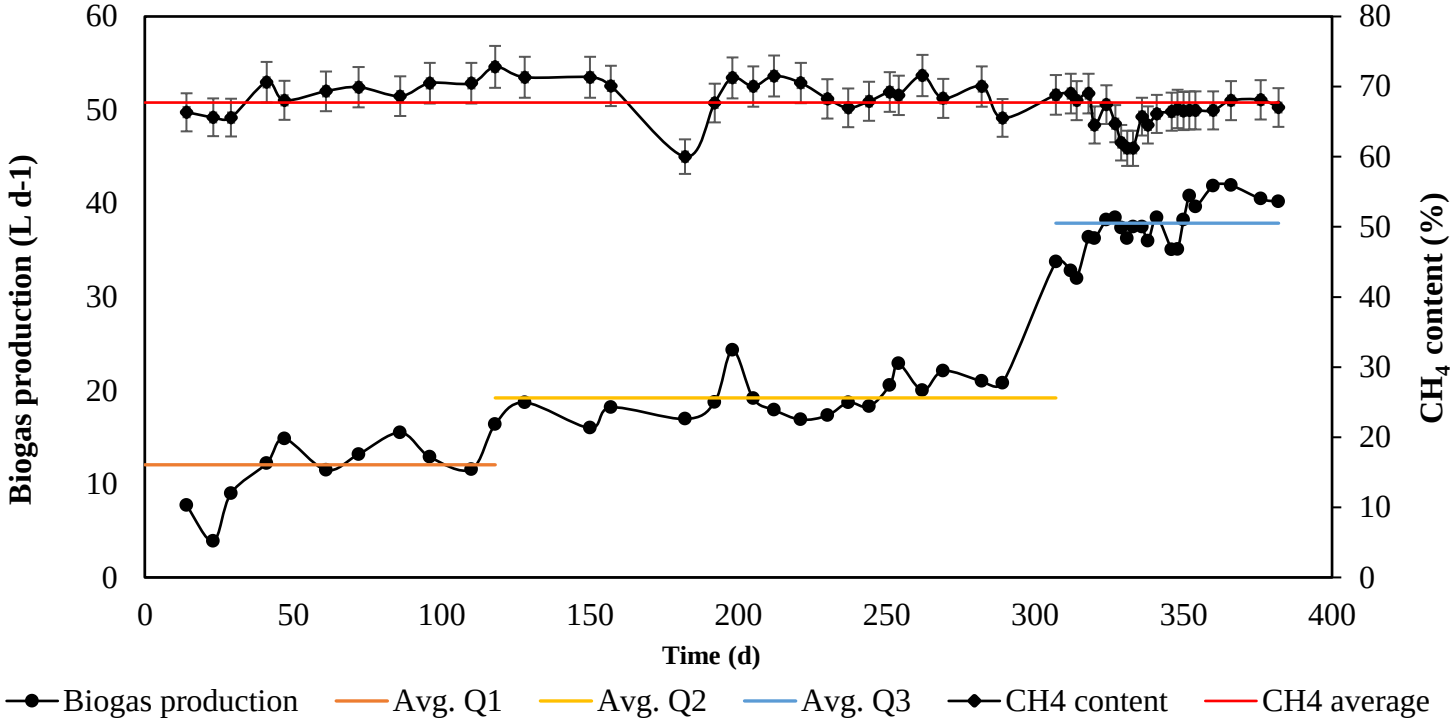
Results: UASB prototype #3 (2022)

Operation mode: continuous
Feed: ratio 1:4 (swine manure:water)
Flow rate: 1.2 – 2.08 L/day.
Temperature: 24-26 °C

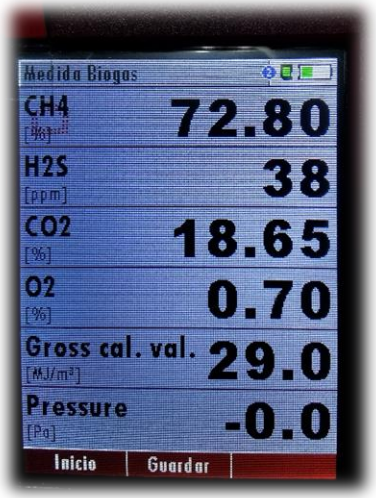
Swine manure	Units	Value
COD	mgO_2 L-1	**39,154**
TS	%w/w	3.35
VS	%w/w	2.39
VS/TS	-	0.71
Alk	$mgCaCO_3$ L-1	2,510
pH	-	7.71

This reactor UASB was manufactured in glass fiber and PVC pipe accessories. Total height 1.7 m, a wall thickness of 0.4 cm, diameter 0.17 cm and a volume capacity of 40 L.

Results: UASB prototype #3

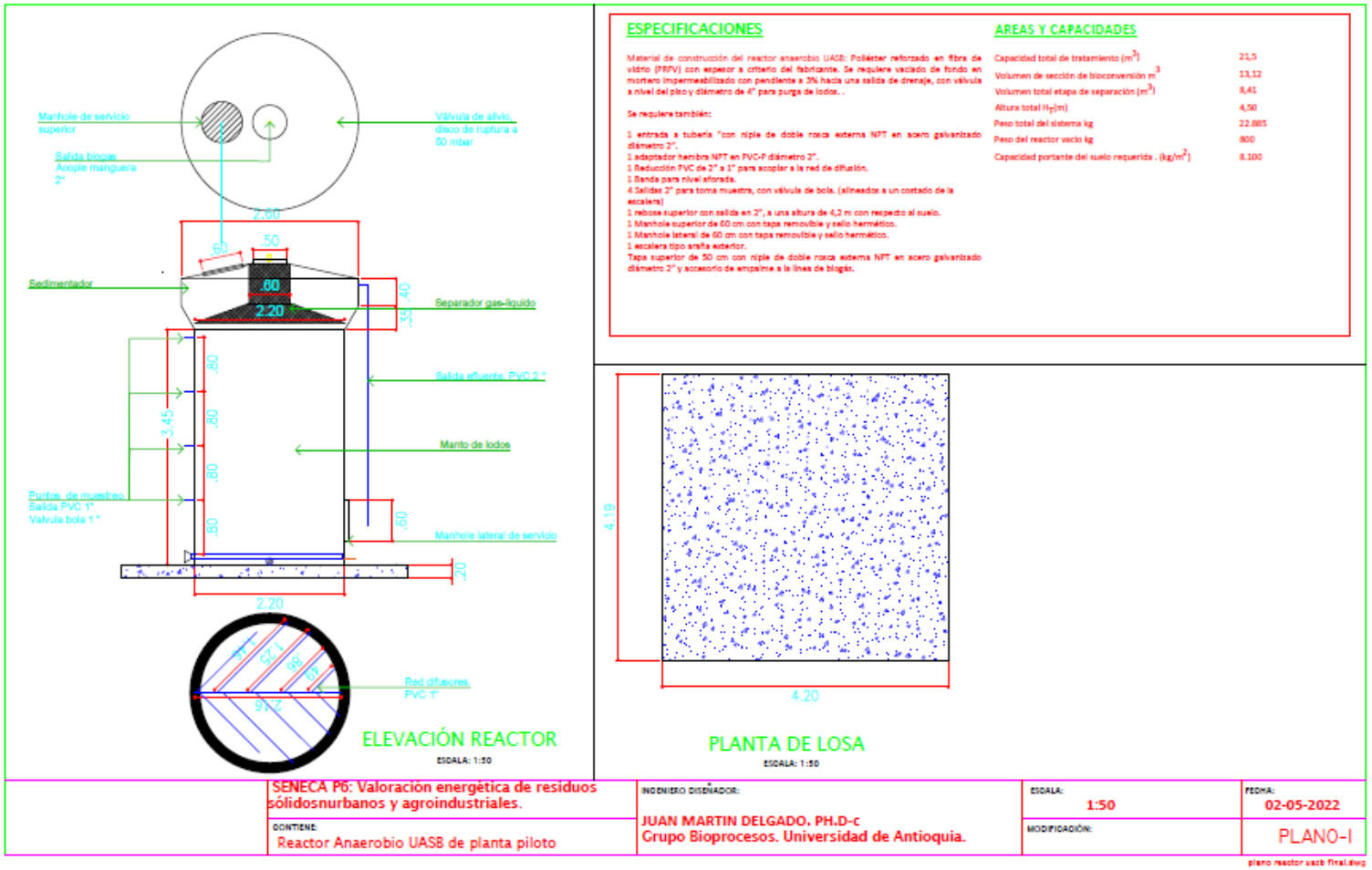


Flow (L d^{-1})	VS (%)	COD_{Feed} (gO_2 L^{-1})	OLR (gCOD L^{-1} d^{-1})	HRT (d)
1.30	2.18	42.28	2.11	31
1.63	2.09	35.81	2.24	25
2.08	3.36	53.27	4.27	19



Results for UASB	
Tracking time (days)	362
Maximum biogas production (NL_{biogas}/day)	**43,6**
Yield ($L_{biogas}/kg_{swine\ manure}$)	104,7
Yield (NmL CH4 gVS^{-1})	685
COD remotion (%)	90%

Results: prototype #4. Pilot plant (2023)



Start up parameters	Value
Swine manure misture	1:9
Feed Flow rate(m^3/day)	1.31
OLR (g_{COD}/L.d)	0.5

Results: prototype #4. Pilot plant

This prototype UASB was manufactured in glass fiber and PVC pipe accessories. Total height **4.5 m**, a wall thickness of 0.8 cm, diameter 2.2 m, weight **22,000 kg** (filled), volume capacity of **21,500 L** and biogas storage capacity **26,000 L.**

Pilot plant prototype.

Before

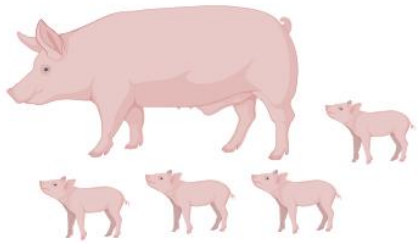
After

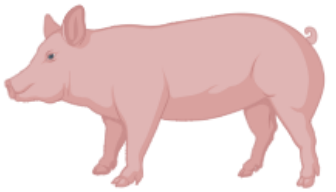
Effluent Parameters	Results
P (mg/L P)	9.93
Amonia Nitrogen (mg/L N-NH3)	182.08
Total Nitrogen Kjeldahl (mg/L N-NTK)	210.42
K (mg/L) K	261.41
Nitrates (mg/L N-NO3)	3.66

¿THE END?

Prototype 4: (behind the process).

The reality of Colombian swine farming.

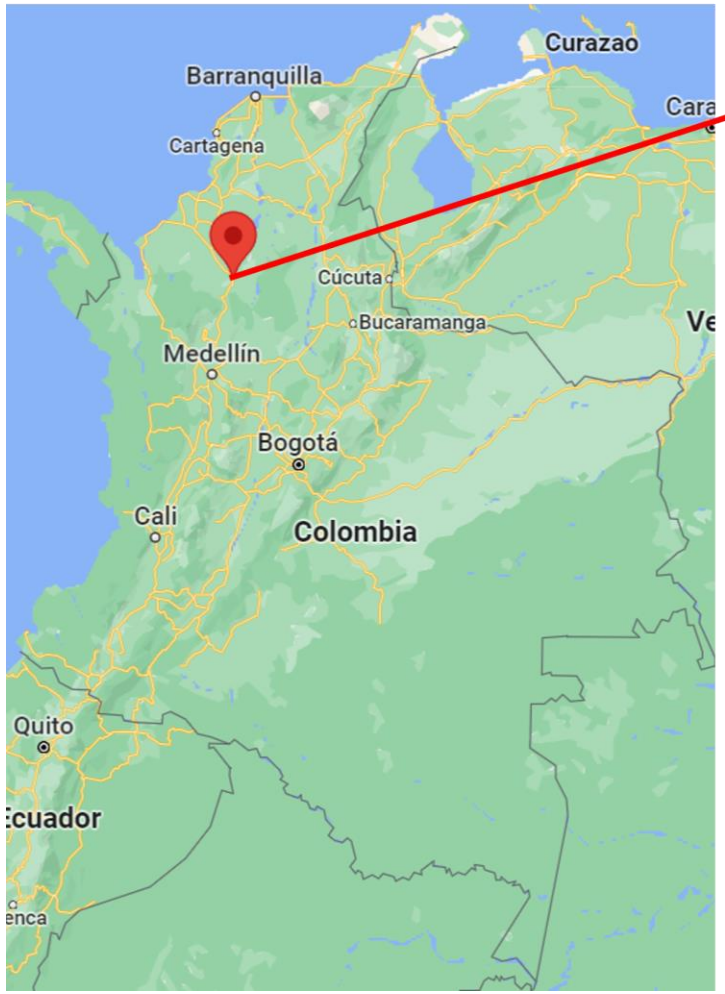




Farm category	Quantity	Distribution		
Technified farms	788	0,4%	>100	>600
Commercial Industrial	4086	2,1%	100-10	600-100
Family Business	37107	19,2%	10-3	100-15
backyard	150884	78,2%	<3	<15
Total farms (2022)	**192865**			

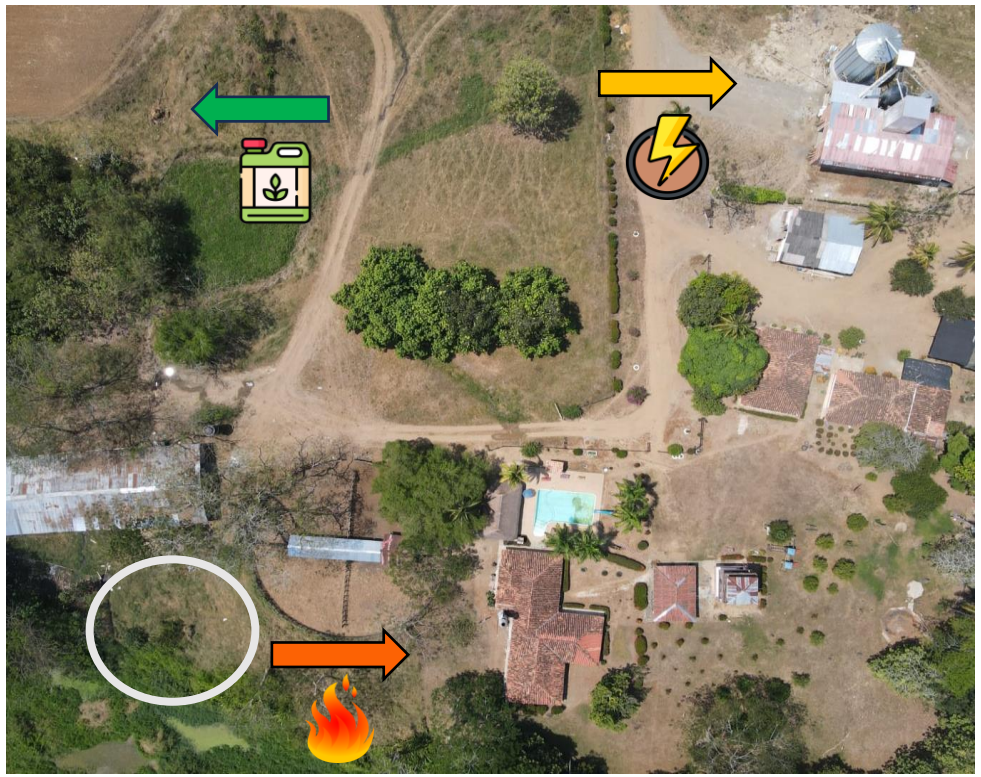
Table 3. Cense of *Pork Colombian farm. Porkcolombia 2023.*

Prototype 4: (behind the process).

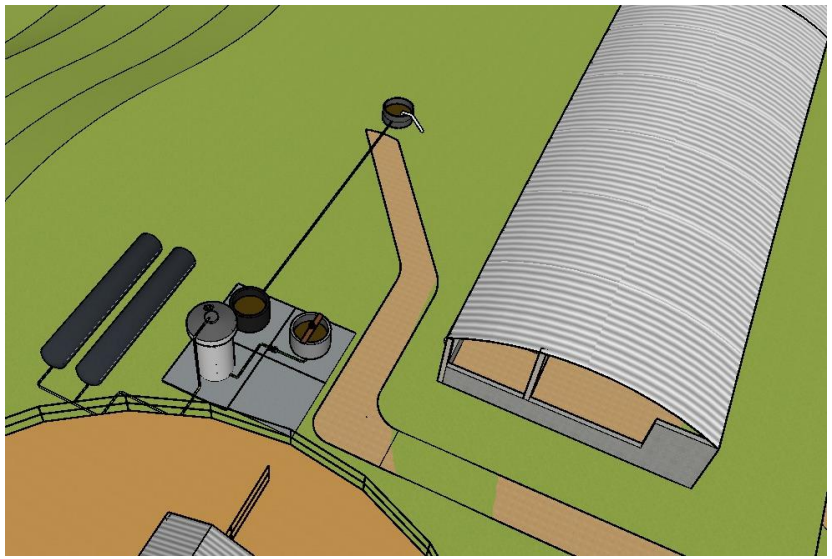


Caucasia location in Colombia

Location: Caucasia, Antioquia
Reference Height: 50 m.a.s.l
Maximum T: 38 ºC
Minimum T: 22ºC



Possible locations for pilot plant



Pilot plant location diagram

Prototype 4: (behind the process).

Constructive challenges

prototype 4: (behind the process).

Substrate availability

A real case…

600 adult swines in farm

theorical feces 1350 kg/day

Reality… **less than 600 kg/day**

Prototype 4: (behind the process).

Technology available on the market

Controlling devices

Biogas Power Plant

RETIE

Required (5 Kw) vs available (>100 Kw)

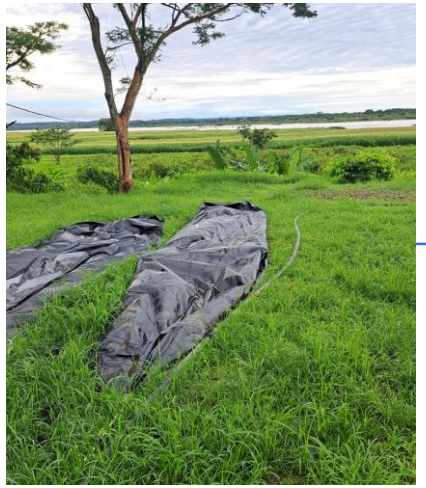
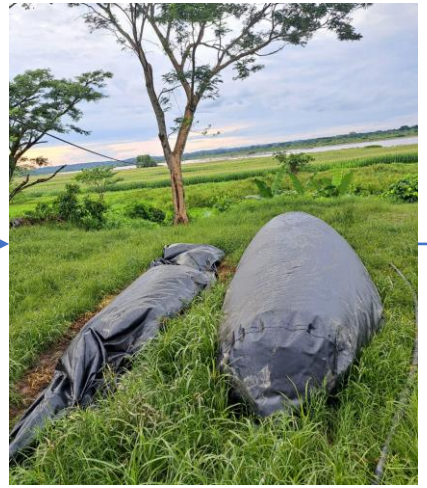
Prototype 4: (behind the process).

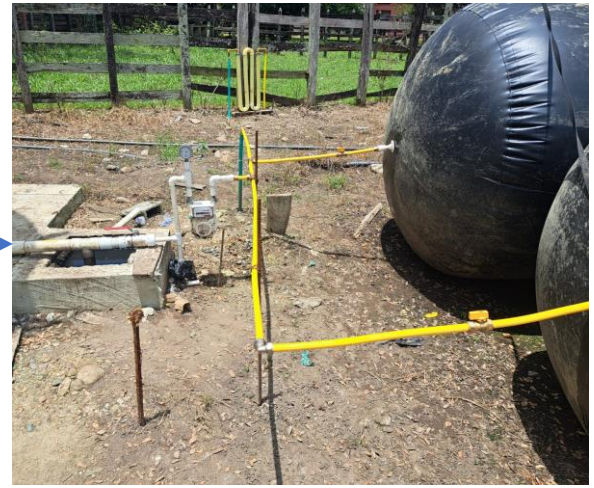
Standard condition of swine manure mixture (pH 6.8-7-3)

the foam was caused by river water with low pH (<5)

Prototype 4: (behind the process).

Dealing with low pressure systems




2 months were needed to see a flame generated by biogas.

Conclusions

- The energy recovery model for swine manure is suitable for agricultural companies with a vertical integration model.
- A study of the actual substrate availability on site is essential for appropriately sizing a biogas production plant.
- Local low and medium capacity technological solutions need to be developed to install renewable energy generation units.
- Producing biogas from swine manure is most viable when biofertilizers, thermal energy and electrical energy are integrated together on the same farm to optimize efficiency and sustainability, resulting in a cost effective process.

Acknowledgments

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Ciencias

El Llano S.A.S

Todos por el Campo

Asociación porkcolombia

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