

IMPROVEMENT OF BIOGAS PRODUCTION IN ANAEROBIC DIGESTION PROCESS THROUGH NUMERICAL MODEL PREDICTIONS

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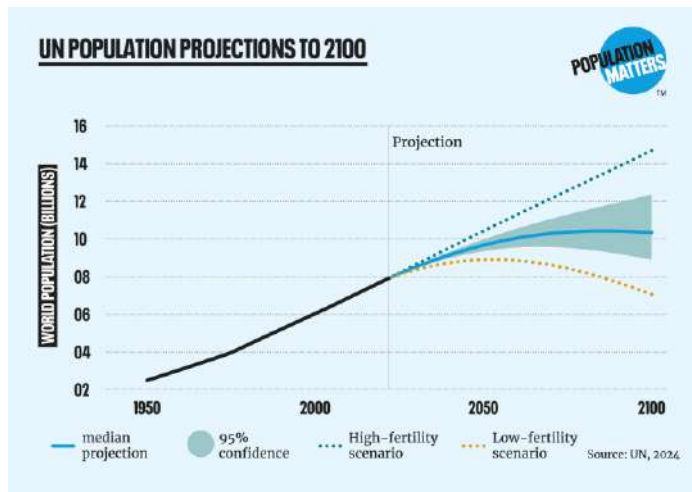
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Increase in wastewater production and energy consumption

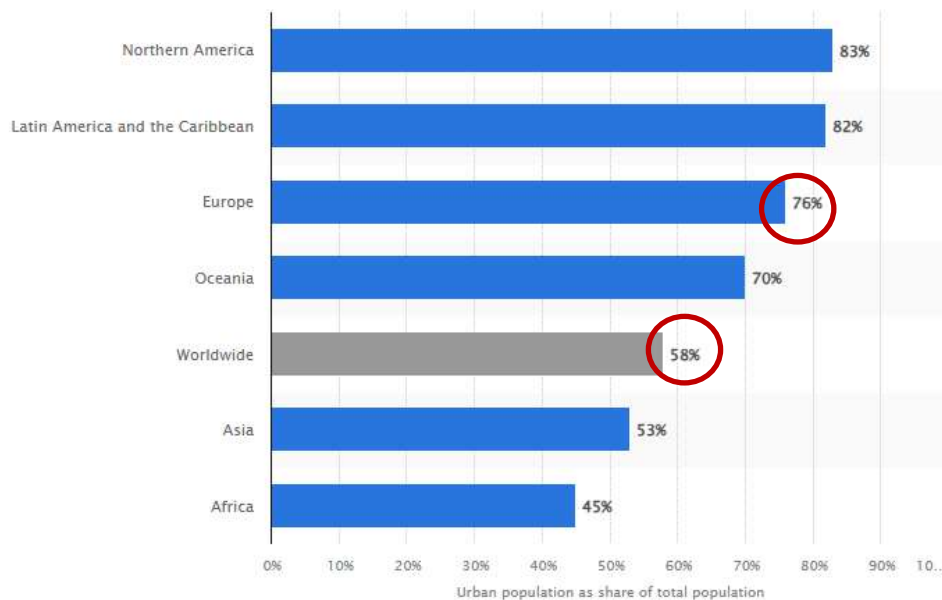
Factors:



Population growth

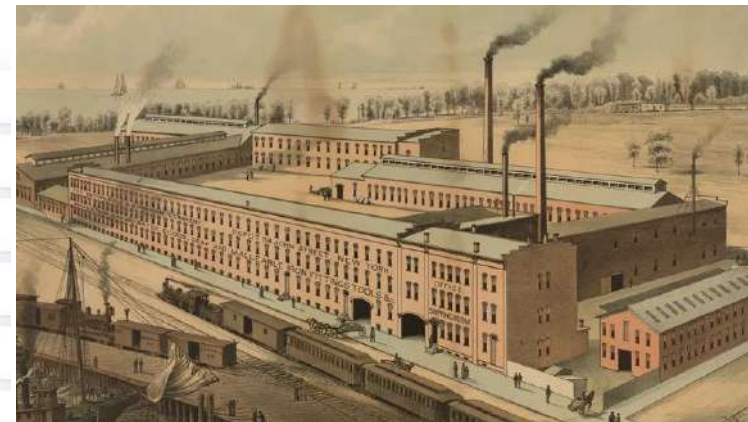
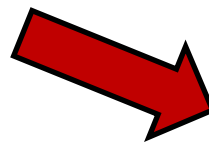
World's population - peaking at approximately 10.3 billion by the mid-2080.

Population Matters, 2025



Statista, 2025

Rapid urbanization



Industrialization



Climate change

United Nations, 2025

MTSantos, 2025

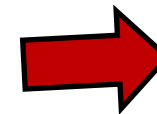
Sustainable Development Goals



SDG 6 is to “Ensure availability and sustainable management of water and sanitation for all”.

Global **demand for renewable energy sources** and effective **waste management strategies** has intensified research into sustainable approaches that address both energy recovery and environmental protection, to contribute to circular economy.

WWTP



Sewage sludge

EU (27) - 10.14 million t of dry matter.

Portugal

2016 - 429 thousand t

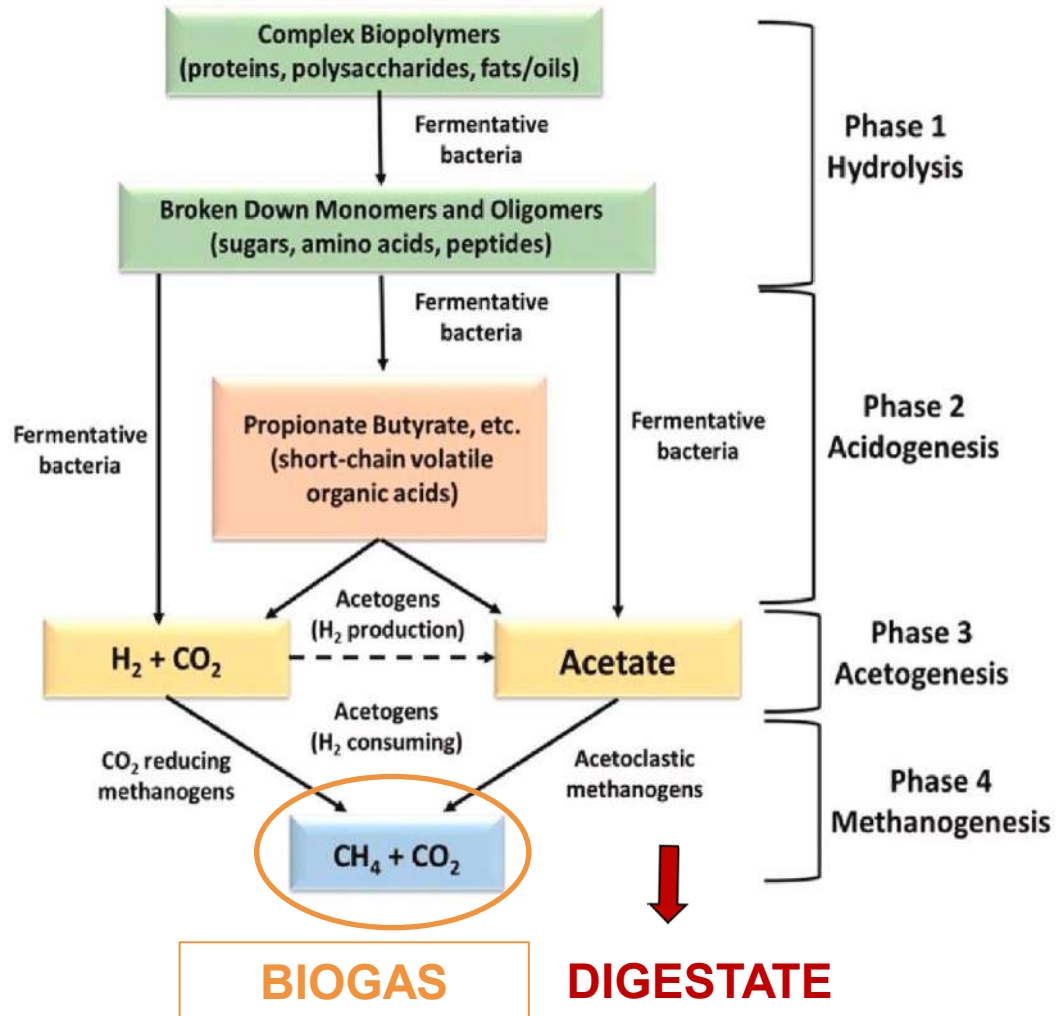
2019 - 531 thousand t

Biogas in WWTP - 31 million of kWh.

Composition of WWTP sludge

Substrate	TS (g/m ³)	VS (g/m ³)	C/N	pH	TKN (g/m ³)	(P _t) (g/m ³)	Metals (mg/kg ST)							COD (g/m ³)	BOD ₅ (g/m ³)	References
							Cu	Zn	Pb	Cr	Ni	Cd	Hg			
Secondary Sludge	18,000	16,000	8	6.5	3,000	600	300	900	80	90	40	2.0	1.0	50,000	25,000	Appels <i>et al.</i> , 2008
Activated secondary sludge	30,000	20,000	8	6.8	2,500	800	-	-	-	-	-	-	-	60,000	30,000	Le <i>et al.</i> , 2019
Co-digestion of sewage sludge with orange peels	24,870	14,820	-	7.9	2,033	547	-	-	-	-	-	-	-	24,700	22,400	Szaja <i>et al.</i> , 2022
Primary sludge with microalgae and agricultural waste	18,000	12,690	6.6	7.1	711	529.2	-	-	-	-	-	-	-	19,500	-	Ahmed <i>et al.</i> , 2019
sludge primary and secondary	98,370	52,460	27.92	6.5	1110	600	-	-	-	-	-	-	-	37,000	18,000	Dahou <i>et al.</i> , 2023
Sewage sludge	32,000	20,000	-	7.2	-	-	-	-	-	-	-	-	-	31,386	-	Lizama <i>et al.</i> , 2024
Primary Sewage sludge	30,000-130,000	18,000-104,000	-	-	40,000	24,000	741	1202	135	119	-	0.99	1	-	-	Waseem <i>et al.</i> , 2025

Anaerobic digestion



Modelling

ADM1: Anaerobic Digestion Model No 1

Most comprehensive and widely accepted model.

Simulation

SIMBA#, GPS-X, BioWin - softwares

To contribute for an improved understanding of the **AD of mixed sludge** (primary and secondary), **seeking methane production** and energy recovery. It involves the numerical simulation of the AD system of a WWTP, analysing its susceptibility to disturbances in parameters such as temperature, organic load, HRT, etc.

Preliminary tests were carried out to evaluate a model response to **organic load, nitrogen load, temperature, hydraulic retention time**. For each parameter evaluated, the effects on the biogas production and its methane content were quantified.

Anaerobic Digestion

Approximately 100 simulations were carried out in order to evaluate the influence of four parameters.

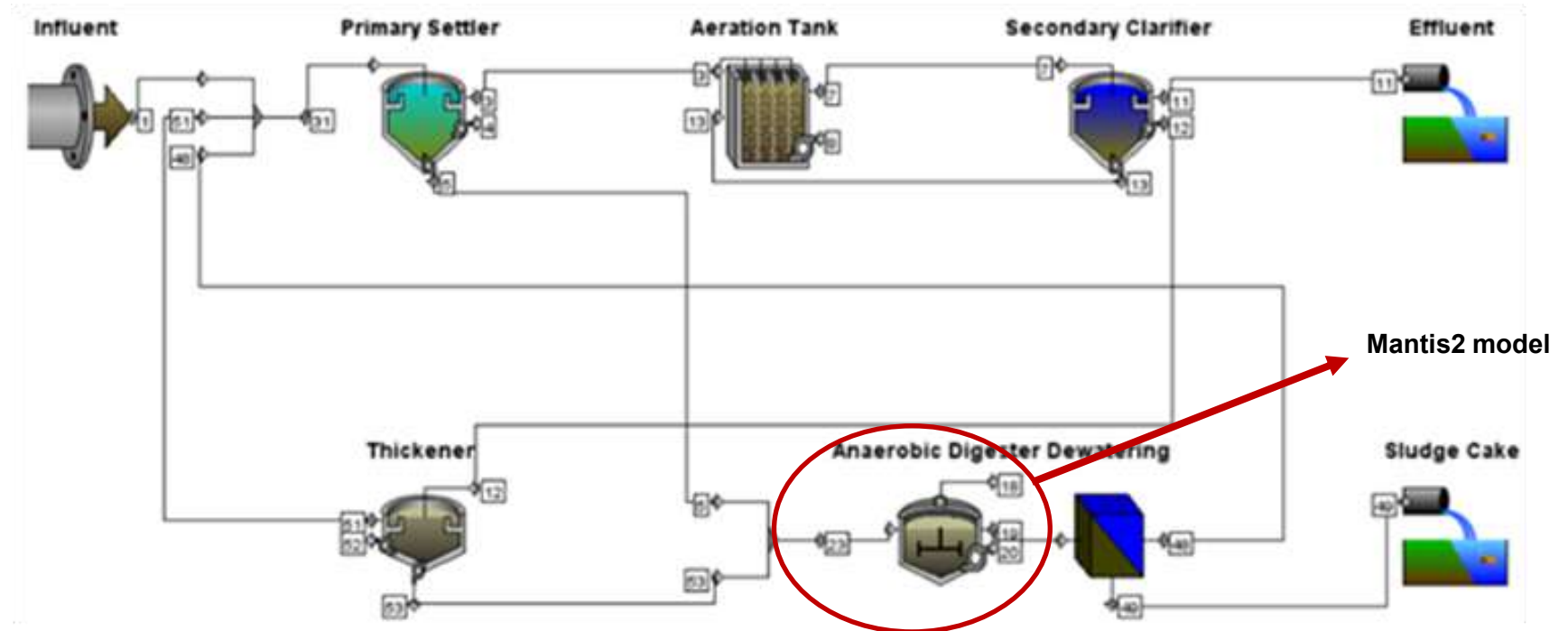
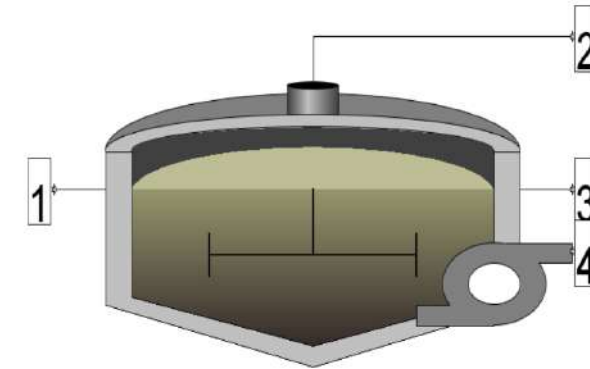


Figure. Scheme used by GPS-X for anaerobic digestion simulation (Hydromantis, 2025)

Test 1 – Temperature Effect

Initial conditions

Parameter	Value
Reactor volume	400 m ³
Volume of the gas phase	20 m ³
Start	Full tank



Steady-state

Other parameters

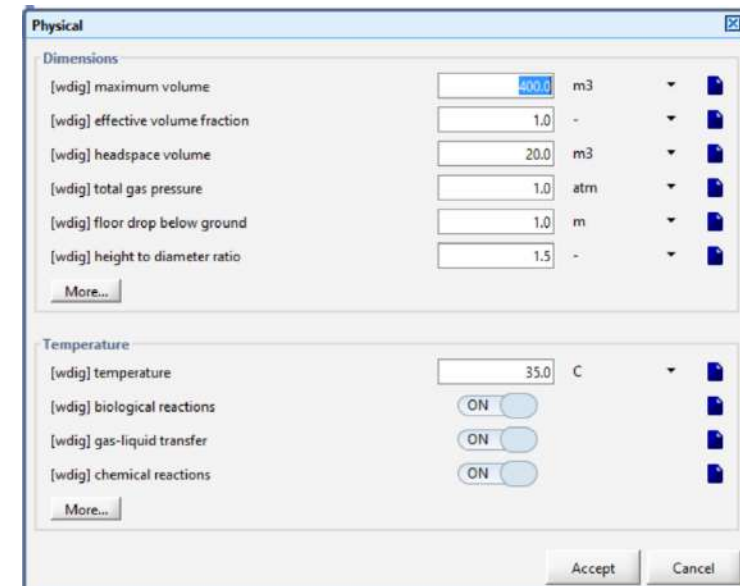
Default values

Temperature 10 to 65 °C

Psychrophilic - 10 to 18°C

Mesophilic – 25 to 40 °C

Thermophilic – 45 to 60 °C



Test 2 – Organic Load Effect

Organic load (COD) – 26,167 to 157,367 g/m³

Test 3 – Nitrogen load Effect

Nitrogen load (N_T) – 4,233 to 12,255 gN/m³

Test 4 – Hydraulic Retention Time (HRT) Effect

HRT – 13 to 66 d (Q_{sludge} – variation)

Initial conditions

Psychrophilic – 15 °C

Mesophilic – 35 °C

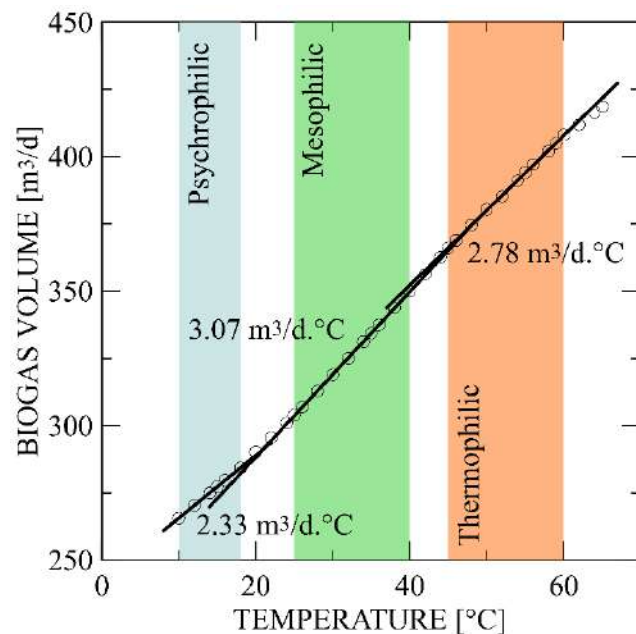
Thermophilic – 55 °C

Parameter	Value
Reactor volume	400 m ³
Volume of the gas phase	20 m ³
Start	Full tank

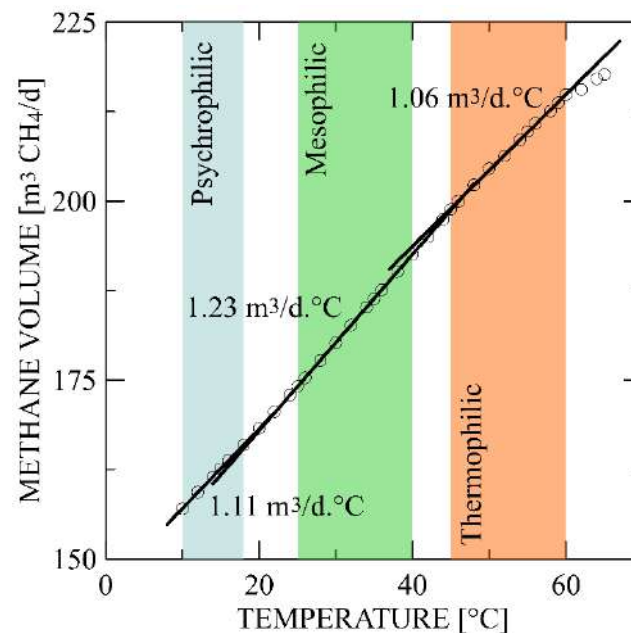
Other parameters

Default values

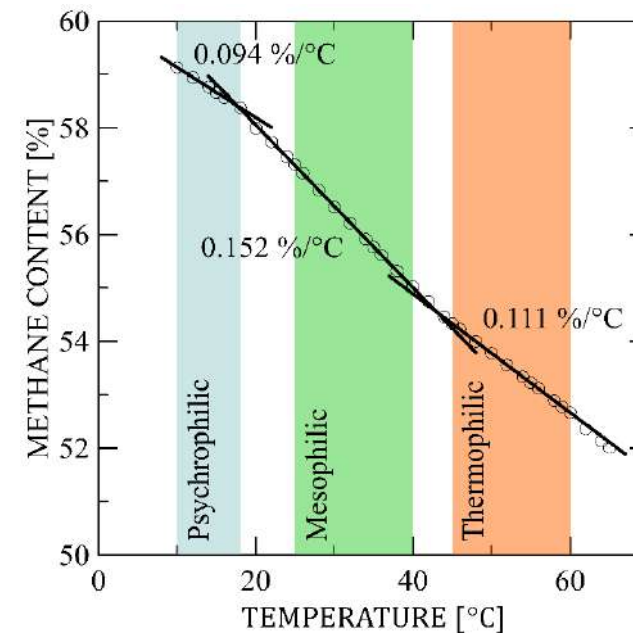
Test 1 – Effect of Three Temperature Ranges



a) biogas volume

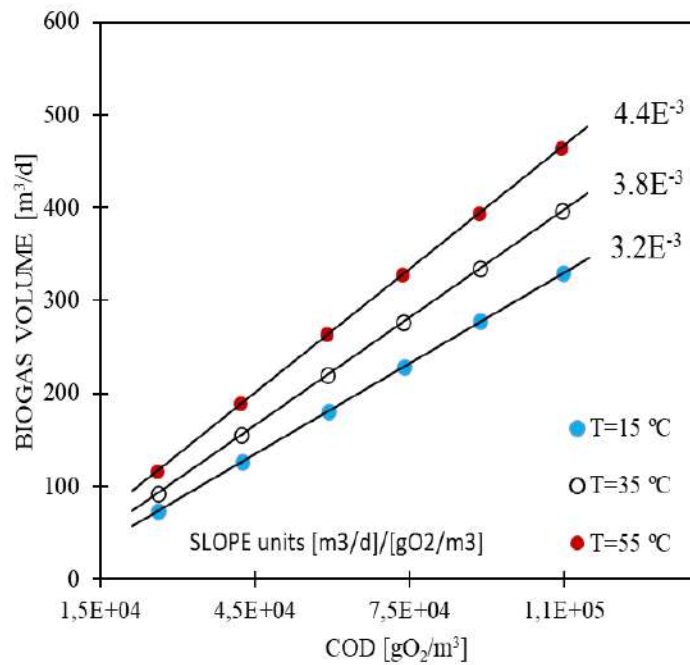


b) methane volume

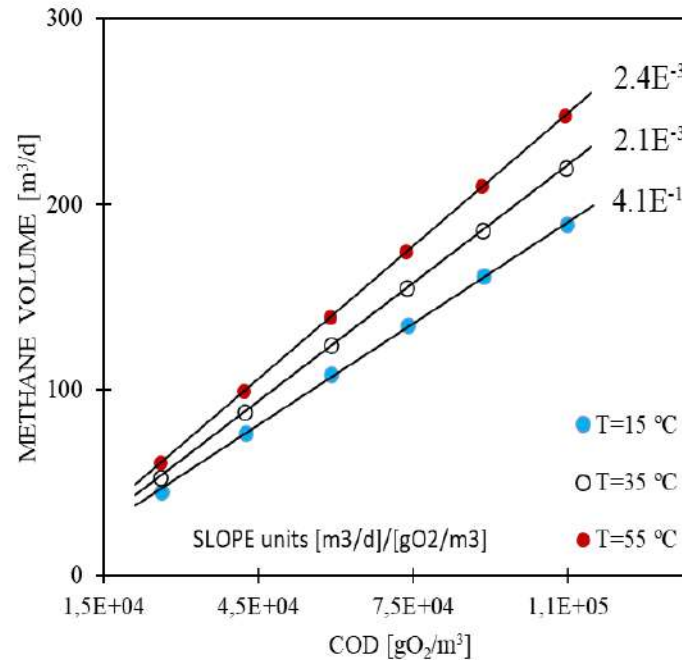


c) methane content

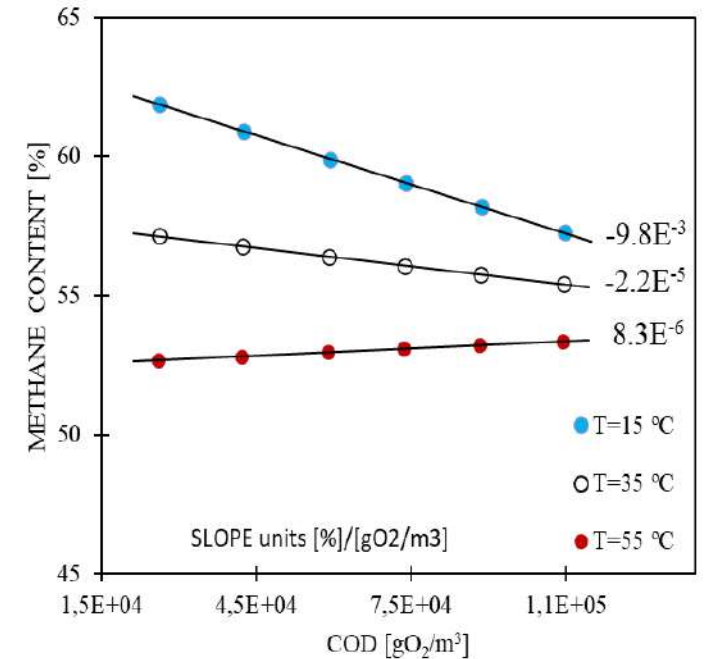
Figure. Effect of three temperature ranges on AD

Test 2 – Organic Load Effect (COD low range)

a) biogas volume

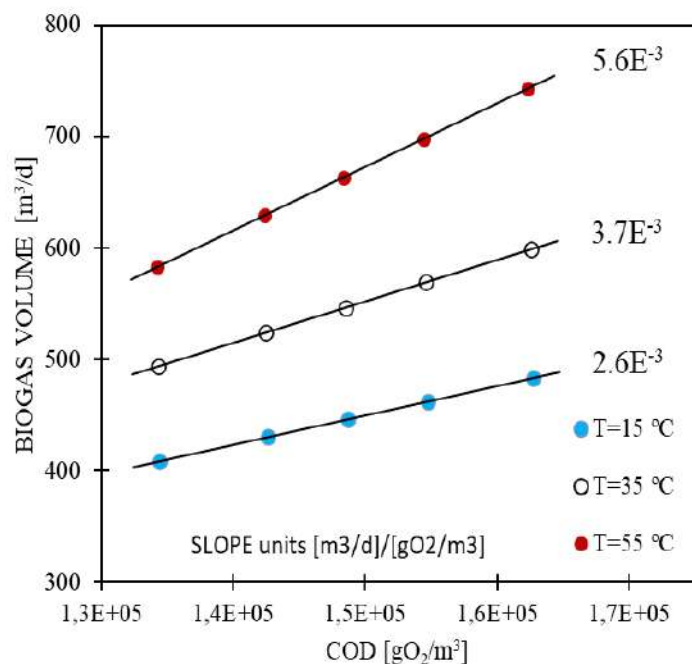


b) methane volume

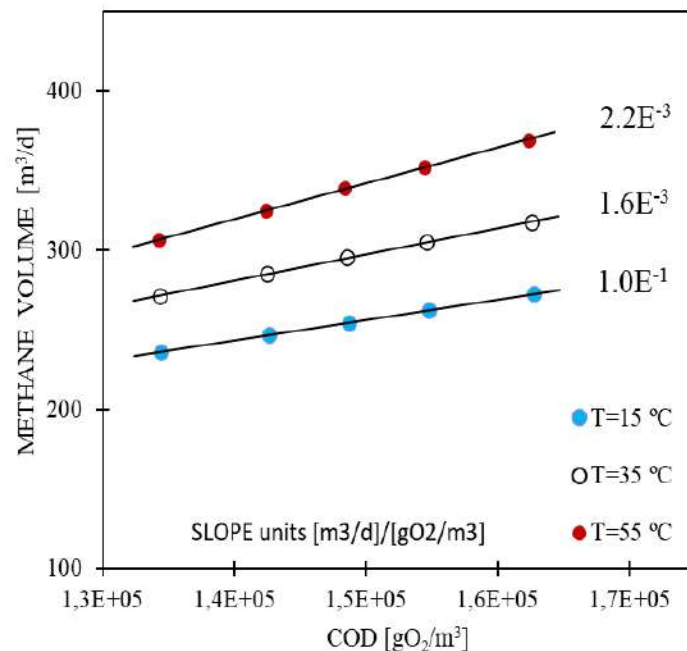


c) methane content

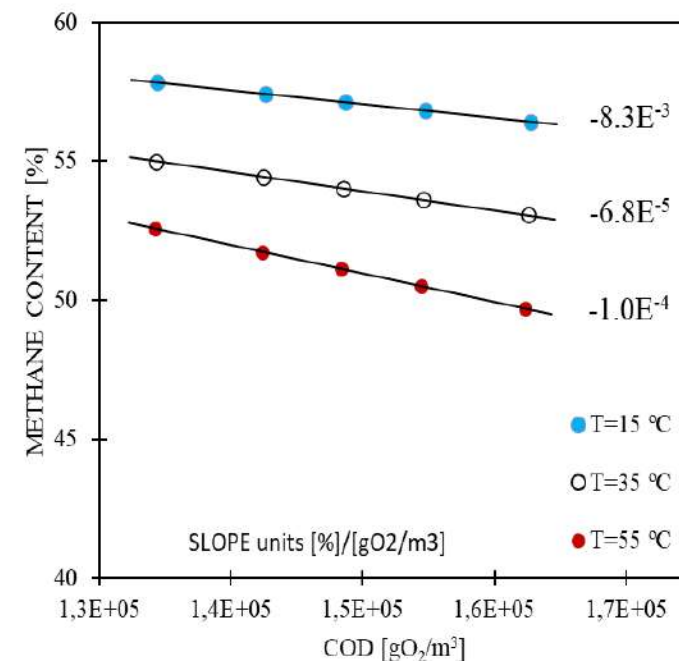
Figure. Effect of organic load (COD - 26,167 to 104,450 g/m^3) in the three temperature ranges

Test 2 – Organic Load Effect (COD high range)

a) biogas volume

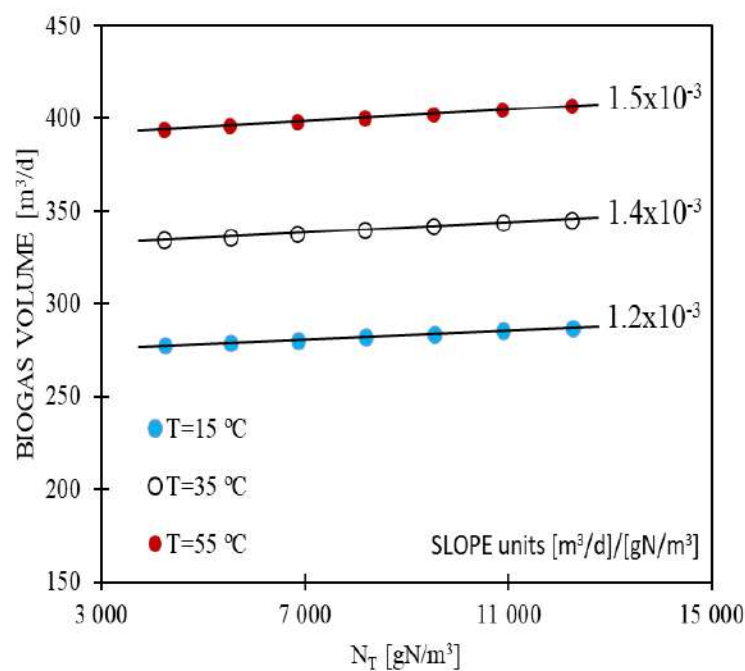


b) methane volume

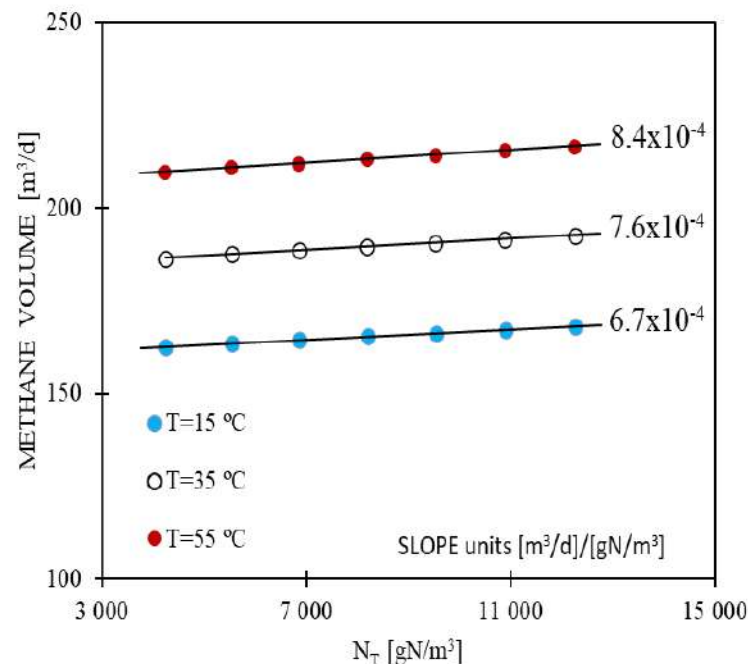


c) methane content

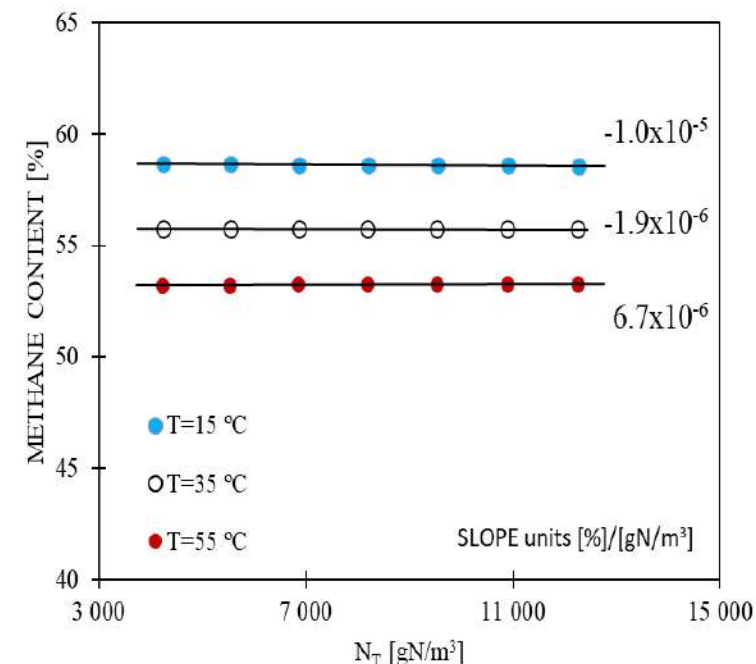
Figure. Effect of organic load (COD - 129,250 to 157,367 g/m^3) in the three temperature ranges.

Test 3 – Nitrogen Load Effect (NKT)

a) biogas volume

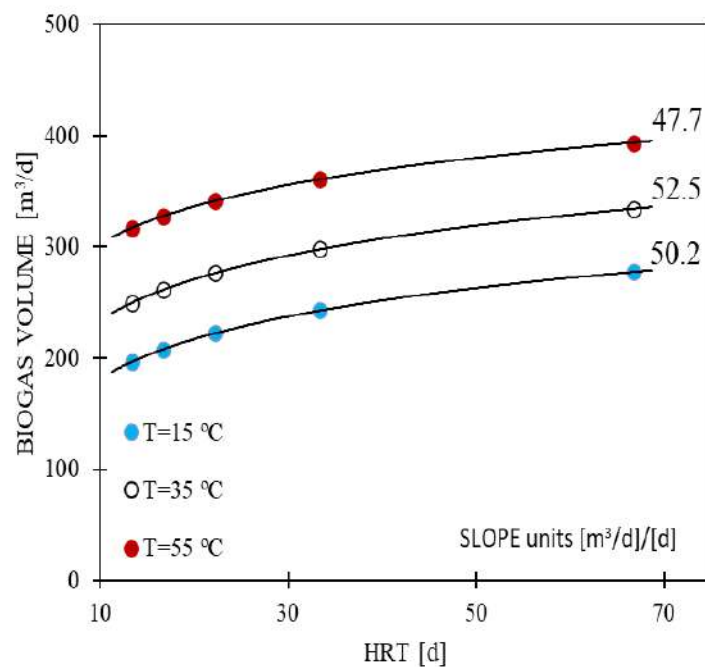


b) methane volume

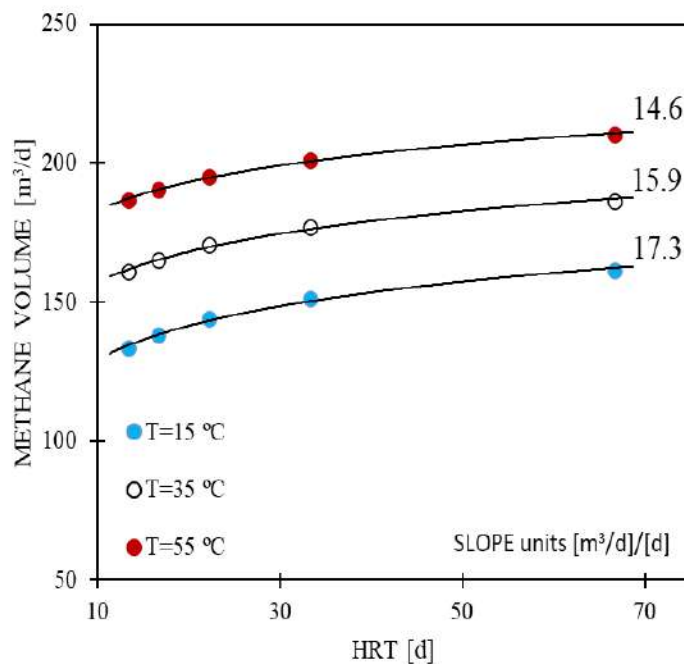


c) methane content

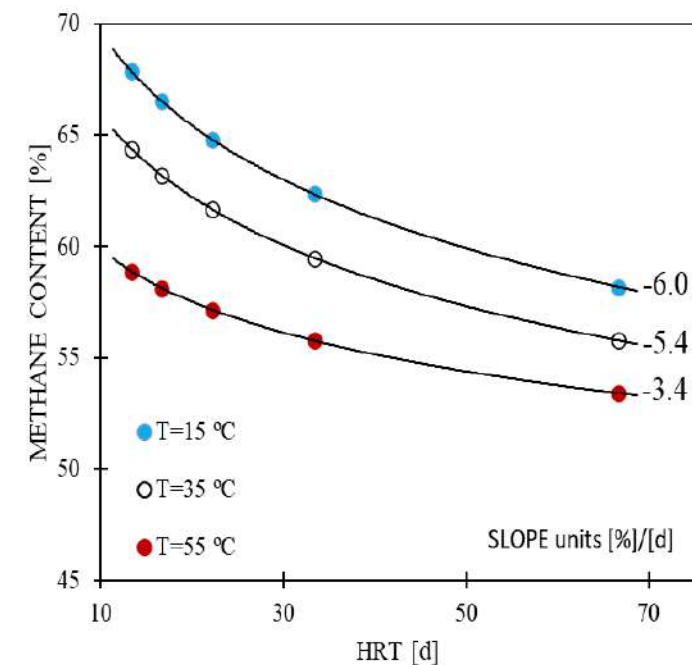
Figure. Effect of nitrogen load (N_T – 4,223 to 12,247 g/m³) in the three temperature ranges.

Test 4 – Effect of hydraulic retention time (HRT)

a) biogas volume



b) methane volume



c) methane content

Figure. Effect of HRT (13 to 66 d) in the three temperature ranges.

- **The temperature variation is an important parameter in biogas production.**
 - ✓ Higher temperature higher methane production, methane production rate depends on the temperature range, methane purity decreases with increasing temperature.
- **The organic load variation has a slight effect on biogas and methane production.**
 - ✓ high range – biogas and methane productions increased more with temperature.
- **The nitrogen load has a lower effect when compare with organic load.**
- **The HRT is also an important parameter in biogas production.**
 - ✓ It was the parameter with with the greatest effect on methane production.
- **The present work is still in an initial phase and is under development (real data for model validation).**

ACKNOWLEDGMENTS

Hydromantis

Thank you for your attention.

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