Conversion of Wastewaters and Organic Waste into Valuable Chemicals, Energy and Organic Fertiliser

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INTRODUCTION

Wastewater requires adequate treatment to prevent water pollution and human health risks, before being discharged in the main water bodies. Biological wastewater treatment is an environmentally friendly process. Anaerobic digestion processes do not need oxygen and are able to produce and recover high valuable chemicals (hydrogen, methane, short chain organic acids SCOAs) from WW treatments [1,2].

This research project focuses on the anaerobic digestion and conversion of municipal wastewaters into valuable chemicals (short chain organic acids SCOAs and hydrogen), energy (hydrogen and methane) and biofertilizer, using open mixed microbial cultures. An in-depth literature review investigated the effect of operating parameters on hydrogen yields, using anaerobic digestion (AD) [3].

METHODS

Statistical Analysis:

- 55 literature studies (339 experiments)
- The effect of operating parameters on hydrogen yield HY (% COD/COD) from organic waste

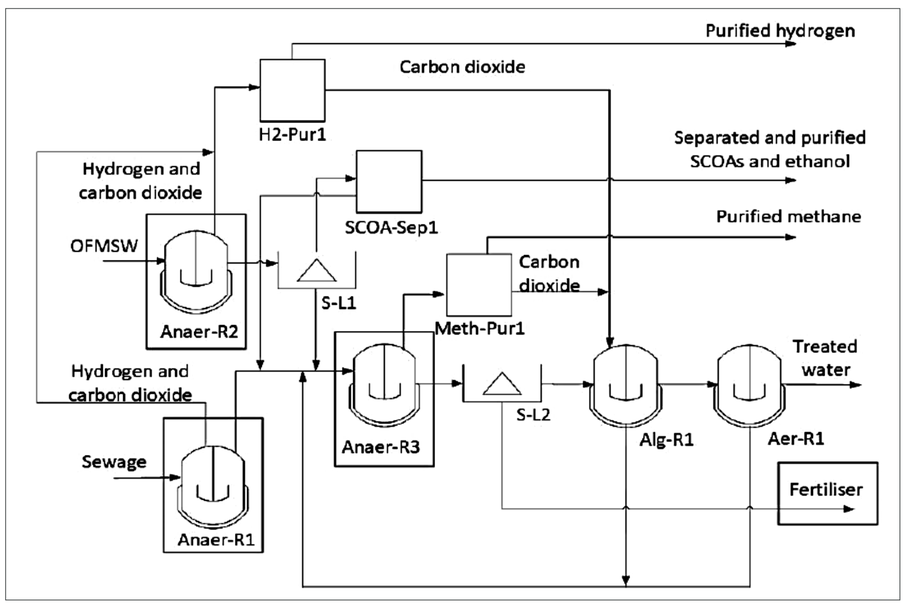

Figure 1: Scheme of the proposed process for the combined treatment of municipal WW and organic fraction of municipal waste (OFMSW).
- Anaerobic digestion processes (Anaer-R1 and Anaer-R2).
- Methanogenic digester (Anaer-R3)
- Algal process (Alg-R1), Aerobic process (Aer-R1)

RESULTS

- The effect of total chemical oxygen demand (TCOD) and pH on HY.

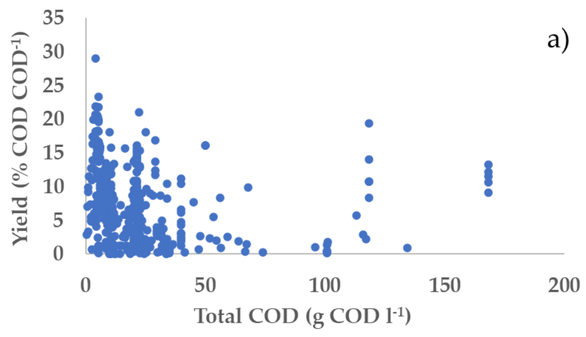

Figure 2: The effect of TCOD on HY.

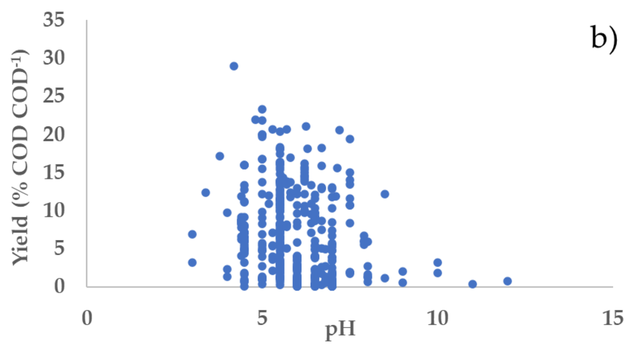

Figure 3: The effect of pH on HY.

- General multi-linear fitting model:

(Eq.1) **Yield** = 6.93 + 1.4 × pHa – 1.05 × pHn - 1.39 × pHb + 1.2 × SS – 1.19 × SNS

(Eq.2) **Productivity** = 96.72 + 64.13 × pHa + 1.7 × tCOD + 46.38 × Tm + 107.34 × SS – 21.09 × SNS + 53.9 × IY + 29.87 × SN + 174.52 × CN + 111.81 × RT1

(Eq.3) **Hydrogen content** = 52.49 – 0.93 × pHn – 0.06 × tCOD – 2.08 × Tt – 3.08 × SY – 1.55 × IY – 1.07 × BA – 1.1 × RT2

DISCUSSION

- Highest yields obtained for low pH and short residence time.

Table 1: Correlation between hydrogen yields and operating parameters (RStudio 4.1.2). Operation mode (batch BA, continuous CN), substrate composition (soluble substrate SS, non-soluble substrate SNS), total chemical demand tCOD, residence time (RT), temperature (mesophilic Tm, thermophilic Tt), pH (acidic pHa, neutral pHn, alkaline pHb), methanogens inhibition (yes IY, no IN), substrate pre-treatment (yes SY, no SN).

Parameters	Estimate	± SE	t-value	p-value
Intercept	6.93	0.36	19.48	$< 2\ e^{-16}$ ***
pH_a	1.4	0.53	2.65	0.008 **
pH_n	- 1.05	0.26	- 4.01	$6.20\ e^{-05}$ ***
pH_b	- 1.93	0.67	- 2.09	0.04 *
tCOD	- 0.02	0.01	- 1.93	0.05 •
SS	1.2	0.51	2.34	0.02 *
SNS	- 1.19	0.27	- 4.45	$9.03\ e^{-06}$ ***
Tm	- 0.32	0.46	- 0.67	0.49 •
Tt	- 0.74	0.45	- 1.66	0.98 •
CN	0.12	0.6	0.2	0.85
BA	- 0.36	0.24	- 1.47	0.14
RT_1	- 0.16	0.53	- 0.3	0.76
RT_2	- 0.45	0.28	- 1.61	0.11
RT_3	- 0.007	0.3	- 0.025	0.98
IY	- 0.64	0.48	- 1.34	0.18
IN	0.05	0.32	0.16	0.87
SY	- 0.81	0.6	- 1.34	0.18
SN	- 0.25	0.26	- 0.95	0.34

The most favorable conditions for hydrogen production identified in this analysis:

- high substrate concentration,
- acidic pH,
- and short residence time

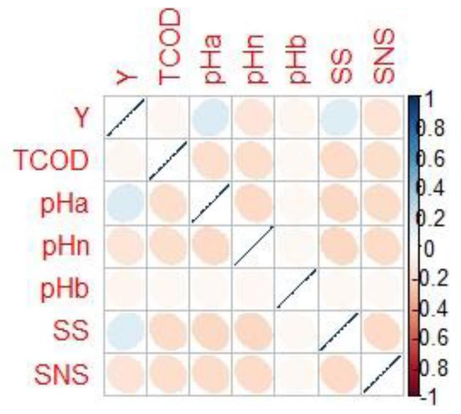

Figure 4: R plot correlation between operational parameters and process performance parameter (hydrogen yield, Y). Blue (light blue to dark blue): positive correlation. Red (light red to dark red): negative correlation.

For more details:

CONCLUSIONS

The future studies involve studying:

- the effect of temperature and pH on gas production and short chain organic acid from synthetic wastewaters,
- the effect of different substrates (carbohydrates, lipids, proteins)
- the microorganisms involved in the fermentation by microbial genomic analysis
- the toxicity of heavy metals (copper, zinc) on AD in the presence of microbial biosensors.

"It's time to change our Relationship with water"
Pr Bob Ferrier, CREW, 2021

Circular Economy → "DISPOSAL" to "REUSE" and "Resource recovery"

References: [1] L. De Bere, 2000 Anaerobic digestion of solid waste: state-of-the-art. *Wst,* **41** (3), 283-290.
[2] DIONISI, D., BOLAJI, I., NABBANDA, D. and SILVA, I.M.O., 2018. Calculation of the potential production of methane and chemicals using anaerobic digestion. *Biofuels, Bioproducts and Biorefining,* **12** (5), 788-801.
[3] Moussa RN, Moussa N, Dionisi D. Hydrogen Production from Biomass and Organic Waste Using Dark Fermentation: An Analysis of Literature Data on the Effect of Operating Parameters on Process Performance. Processes. 2022; **10**(1):156.

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