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HHYDROTHERMAL CARBONIZATION AND ANAEROBIC DIGESTION OF AGRICULTURAL AND FORESTRY WASTE: PRACTICAL IMPLEMENTATION IN SENEGAL

LAT GRAND NDIAYE

UASZ. Senegal

B4A Final Conference/BLP 2025.

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This project has recieved funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101000762

Plan

- Context and issues
- Design and certification of the HTC reactor
- Hydrothermal carbonization tests: methods and results
- Installation of an anaerobic digestion bench
- Biochar as additive in anaerobic digestion: methods and results
- Conclusion & perspectives

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Context and issues

- Rich agricultural heritage and biodiversity
- Major challenges in managing wet agricultural and agro-industrial waste
- Poor use of wet biomass

Loss of valuable resources and considerable environmental impact

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Context and issues

- Potential solutions
  - Use of hydrothermal carbonization (HTC)

This process can convert wet biomass into hydrochar - a useful material for a variety of applications.

  - Anaerobic digestion with biochar

Adding biochar to anaerobic digestion can improve biogas production and digestate quality - while reducing greenhouse gas emissions.

Reducing air pollution and protecting health

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Design and certification of the HTC reactor

- HTC reactor was built basis on Robbiani Thesis
- ''Structures Métalliques'' constructor of the reactor
- Certification with Bureau Veritas
- Installation of manometer & thermometer

Characteristics of the HTC reactor

Fluid group: flammable
Category: III
Tubing diameter: DIN200
Capacity: 20 liters
Pressure range : 10-25 bars
Max pressure: 30 bars
Temperature range: 180-220 °C
Max temperature: 300 °C
Max number of charge cycles: 1000

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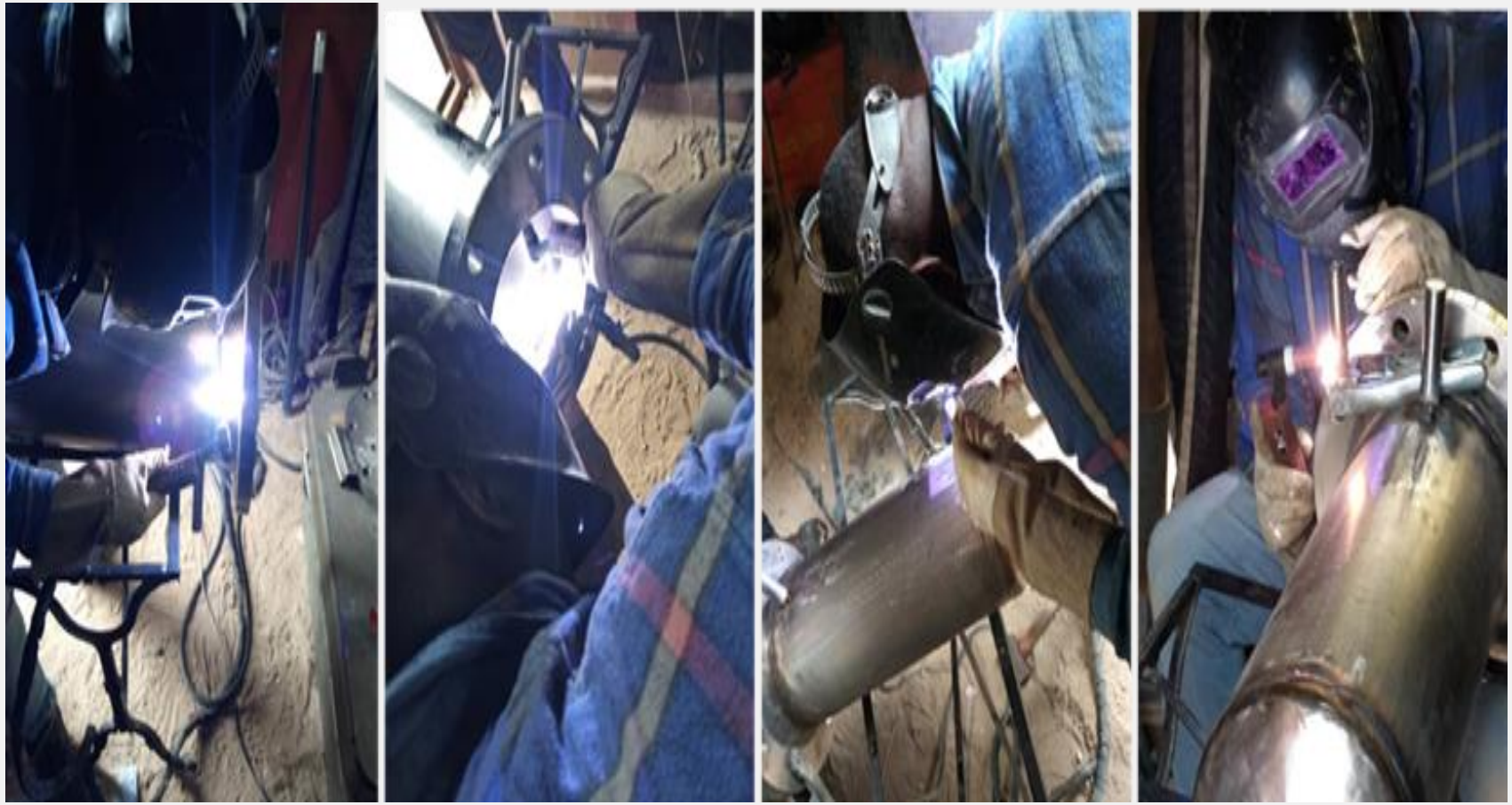
Design and certification of the HTC reactor

- Welding operation with ‘’Structures Métalliques’’in Dakar



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Design and certification of the HTC reactor

► Training and installation at the reactor laboratory in collaboration with IHE Delft




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Hydrothermal carbonization tests: methods and results

- Hydrochar production

Typha and Cashew apple as sample
Temperature of treatment: 190 °C ;
Reaction time at 190 °C: 3h and 5h
Tests conducted in duplicated
Sample/water ratio of 0.11

Output characterization
Mass yield of hydrochar. liquid and gas determined;
Gas composition analyzed;
Hydrochar characterized

08 hydrochar tests was successfully completed and paper is in preparation with the IHE partner

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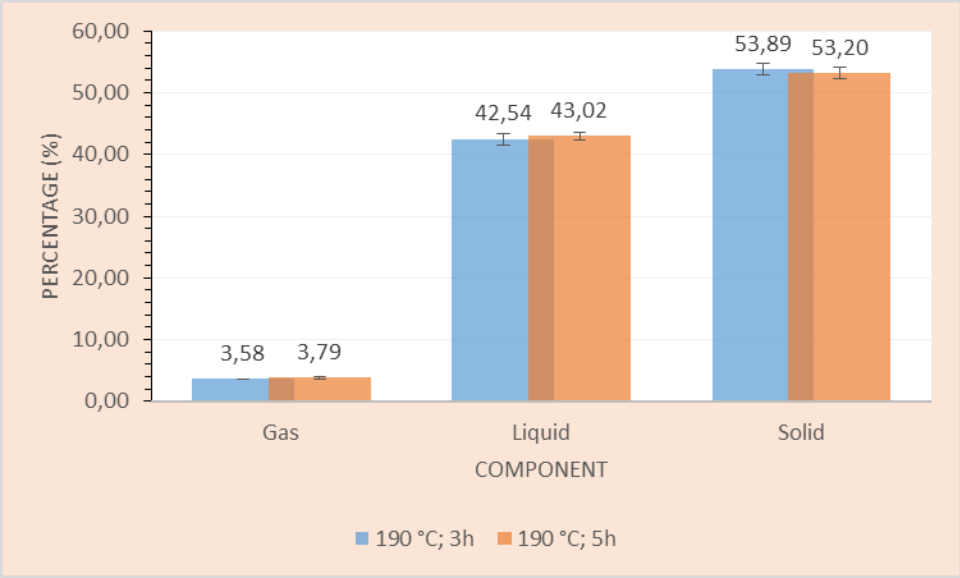
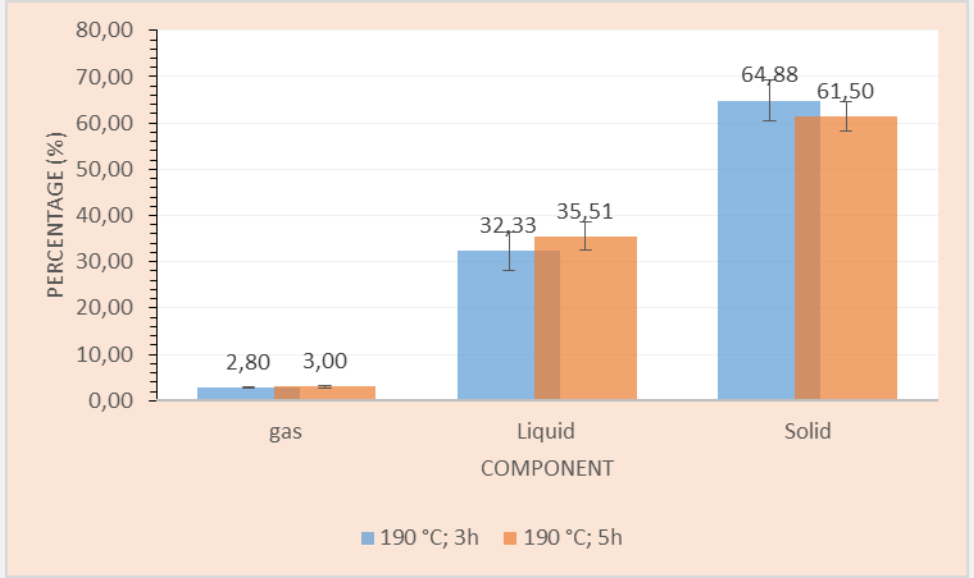
Hydrothermal carbonization tests: methods and results

- Mass balance of hydrothermal tests

Mass balance outputs of Cashew apple tests



Mass balance outputs of Typha tests



High standard deviation between two tests when testing Typha

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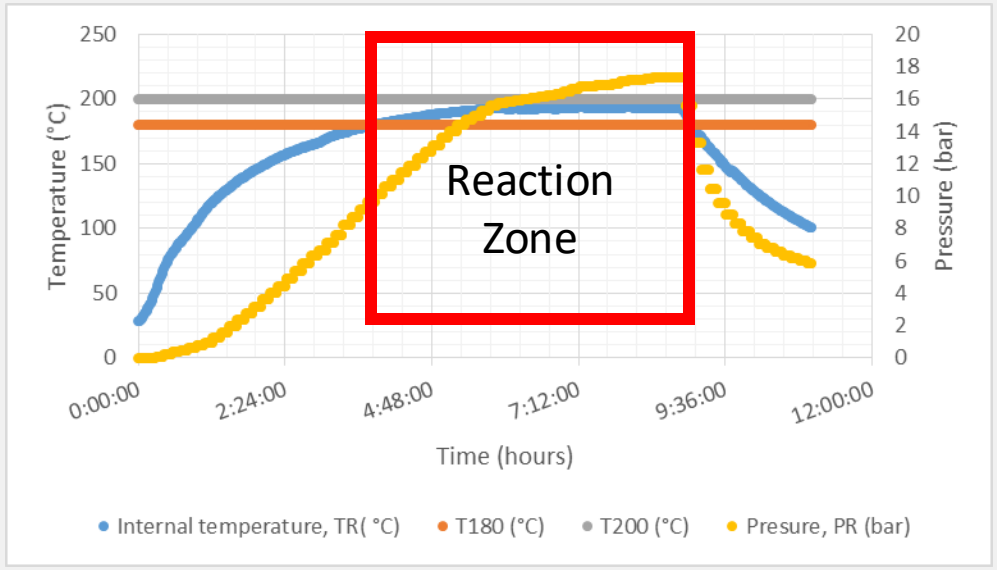
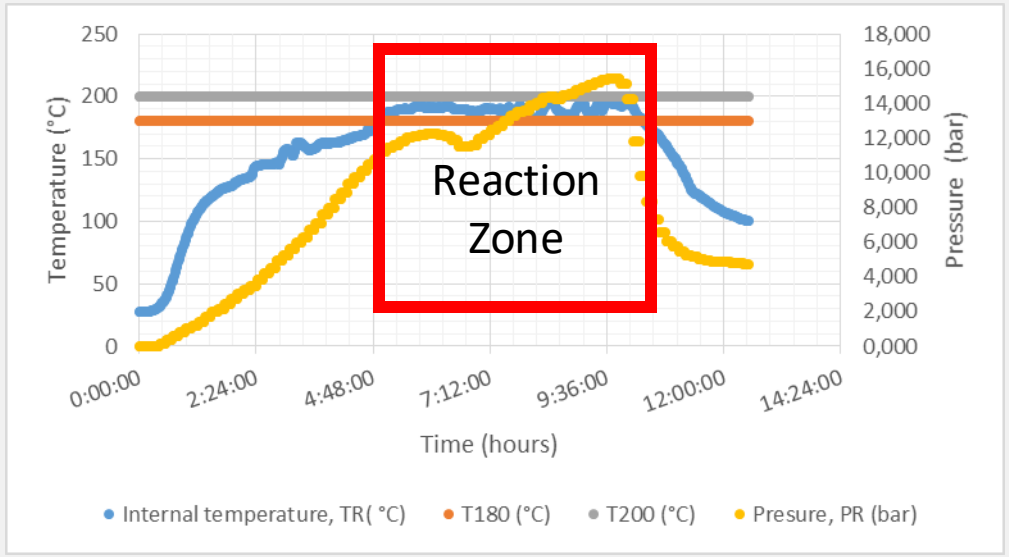
Hydrothermal carbonization tests: methods and results

Pressure & temperature profiles

Example of variation of internal temperature & pressure of the reactor during cashew apple test



Example of variation of internal temperature & pressure of the reactor during Typha test



Maximum pressure was in average 18.108 ± 0.563 bars for cashew apple for the 04 tests while for Typha. it was 15.039 ± 1.719 bars for the 04 tests

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Hydrothermal carbonization tests: methods and results

Gas composition results

Gas composition outputs of Cashew apple tests

Composition gas	HTC-CA-190-3-1	HTC-CA-190-3-2	HTC-CA-190-5-1	HTC-CA-190-5-2
CO_2	n/a	81.02	90.91	84.80
CH_4	n/a	0.12	0.22	0.17
CO	n/a	2.51	2.76	2.66
O_2	n/a	4.08	3.3	0.42
NO	n/a	0.06	0.07	0.07
H_2S	n/a	0.00	0.00	0.00
N_2	n/a	12.21	2.74	11.88

Gas composition outputs of Typha tests

Composition gas	HTC-T-190-3-1	HTC-T-190-3-2	HTC-T-190-5-1	HTC-T-190-5-2
CO_2	n/a	n/a	78.23	61.40
CH_4	n/a	n/a	0.24	0.21
CO	n/a	n/a	2.03	1.19
O_2	n/a	n/a	0.85	1.02
NO	n/a	n/a	0.11	0.06
H_2S	n/a	n/a	0.00	0.00
N_2	n/a	n/a	18.54	36.12

CO_2 the main component of the gas

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Hydrothermal carbonization tests: methods and results

- Proximate & elemental analyses of the hydrochars

Samples	Moisture (%)^{wb}	Ashes (%)^{db}	VM (%)^{db}	FC (%)^{s}	C (%)^{db}	H (%)^{db}	N (%)^{db}	O (%)^{db}
CA_190°C_3_1	2.35	2.84	58.09	39.06	58.29	5.53	1.95	31.39
CA_190°C_3_2	2.95	2.51	58.74	38.75	58.55	5.39	1.89	31.66
CA_190°C_5_1	3.15	2.95	57.36	39.69	59.95	5.43	2.04	29.63
CA_190°C_5_2	3.30	1.92	58.34	39.74	60.27	5.57	1.92	30.32
T_190°C_3_1	3.70	14.24	56.05	29.71	45.52	5.25	0.96	34.03
T_190°C_3_2	4.40	16.45	56.89	26.65	48.69	5.57	1.16	28.13
T_190°C_5_1	2.30	10.81	62.98	26.21	49.83	5.7	0.88	32.78
T_190°C_5_2	4.20	12.99	57.29	29.72	46.13	5.29	0.99	34.60

- Good repeatability between two tests with cashew apple
- High standard deviation between two tests with Typha
- Carbon and Nitrogen contents more important in hydrochar of Cashew apple than hydrochar of typha

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Installation of an anaerobic digestion bench

► Biogas system setup

Equipment to setup the system

Tubing

Bottles of 1 L

Bain Marie

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Characterization of substrate and additives

Characterization results

Proximate analysis

Samples	M (%)	TS (%)	VS (%)^{S}	Ash (%)^{S}	FC (%)^{S}
CWM	95.70	4.30	63.14	22.46	14.39
INOC	94.26	5.74	43.80	42.67	13.52
PNS_550_2h	2.16	97.84	3.42	61.45	35.13
HTyp_500_2h	2.01	97.99	8.96	21.85	69.18
Hydrochar	3.75	96.25	58.1	2.11	39.79

Elemental analysis by empirical formula

Samples	Ash (%)^{S}	C (%)^{S}	H (%)^{S}	O (%)^{S}	N (%)^{S}	C/N
CWM	22.46	39.01	4.63	32.36	1.53	25.43
INOC	42.67	29.53	3.12	22.22	2.45	12.03
PNS_550_2h	61.45	33.22	0.62	1.43	3.28	10.12
HTyp_500_2h	21.85	69.81	2.00	4.90	1.44	48.47
Hydrochar	2.11	62.21	4.96	30.14	0.58	107.83

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Biochemical methane potential tests

- BMP processing

- ❑ Substrate of cow manure (CWM);
- ❑ Inoculum of digestated cow manure
- ❑ Biochar PNS_550_2h
- ❑ upgraded hydrochar Htyp_500_2h
- ❑ hydrochar from HTC (190 °C; 3h)

Applied biochar dose:

- 0.12 and 0.36 g biochar/g substrate in dried total solid
- Digesters were filled at 75 % of the volume capacity
- Tests were performed in duplicate

- Caw manure substrate was prepared using cow dung to water ratio of 1:3
- Inoculum was collected from a digester working on cow manure as substrate
- Ratio cow manure to inoculum was 1:2 in dried volatile solid

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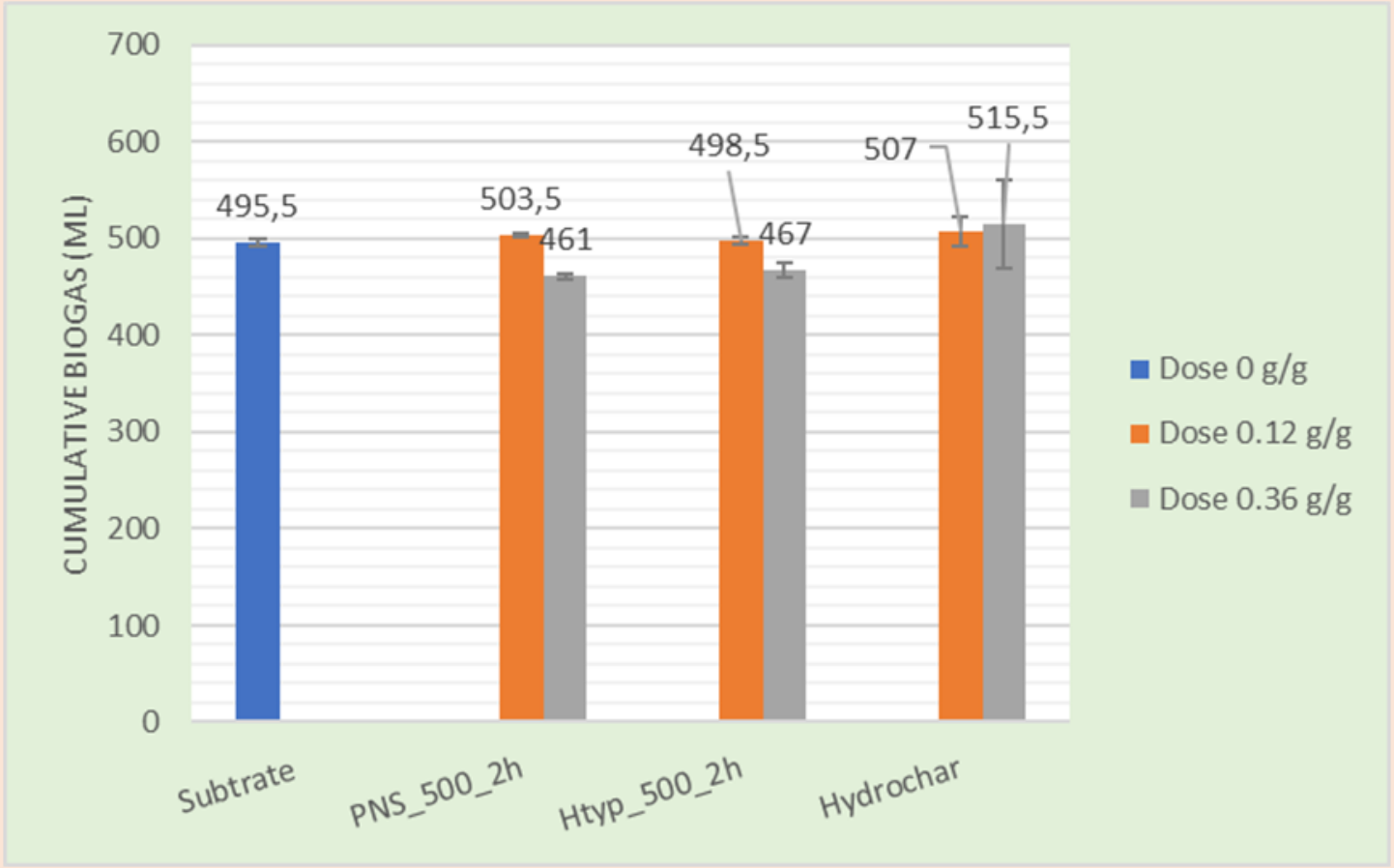
Biochemical methane potential tests

► Cumulative biogas tests

Slight increase of the biogas production with a dose of 0.12 g biochar/g substrate in dry basis when biochar of peanut shells (PNS_500_2h) and upgraded hydrochar of typha are used as additives.

Slight increase of the biogas production with a dose of 0.12 and 0.36 g biochar/g substrate in dry basis when biochar of peanut shells (PNS_500_2h) and upgraded hydrochar of typha are used as additives.



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Biochemical methane potential tests

- Normalized cumulative biogas

Normalized in Nm^3/kg TS CWM

Digester with	0 g/g		0.12 g/g		0.36 g/g	
	Average	STDEVA	Average	STDEVA	Average	STDEVA
CWM+INOC	51.2134	0.3659				
CWM+A+INOC			52.0402	0.2191	47.6476	0.2915
CWM+B+INOC			51.5234	0.3659	48.2677	0.7307
CWM+C+INOC			52.402	1.6082	53.2805	4.7303

Normalized in Nm^3/kg VS CWM

Digester with	0 g/g		0.12 g/g		0.36 g/g	
	Average	STDEVA	Average	STDEVA	Average	STDEVA
CWM+INOC	81.1047	0.5794				
CWM+A+INOC			82.4141	0.347	75.4576	0.4619
CWM+B+INOC			81.5957	0.5794	76.4397	1.1572
CWM+C+INOC			82.987	2.5469	84.3783	7.5228

A: PNS_-550_2h
B: HTyp_550_2h
C: Hydrochar

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Conclusions

- HTC was installed in UASZ and tested successfully;
- Hydrochar Yields above 50% (for cashew apple) and above 60% (for Typha) were obtained;
- Carbon and nitrogen contents were high in hydrochar of cashew apple than hydrochar of Typha;
- Biogas BMP tests show that hydrochar of Typha can slightly increased the biogas production by applying 0.36 g/ g of dried cow manure.

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Perspectives

- HTC Hydrochar production with cow manure for KRC and in collaboration with IHE, finalize the replication of the technology for KRC;
- Use other wet biomasses on the HTC (Water hyacinth, Banana peelings, etc.);
- Automate the BMP bench and scale up to a 10L and 10 m^3 digester;
- Biogas H_2S removal (using biochar) results and paper in preparation.

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