10th International Conference on Sustainable Solid Waste Management

Scale-up the production of swine manure hydrochar in a continuous pilot plant

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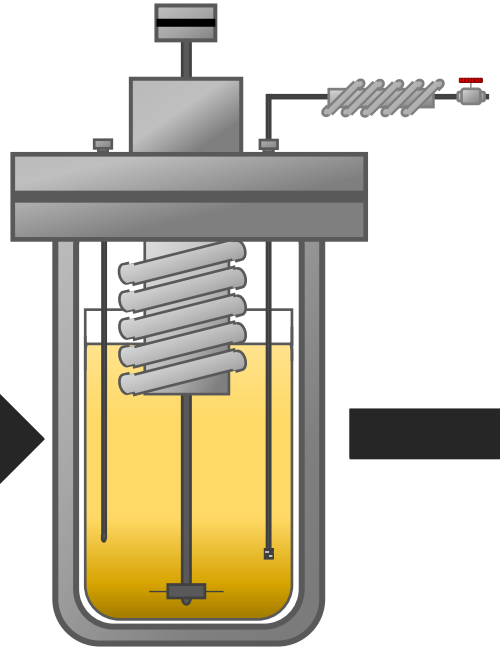
Hydrothermal carbonization (HTC)

Animal manure

Sewage sludge

Food waste

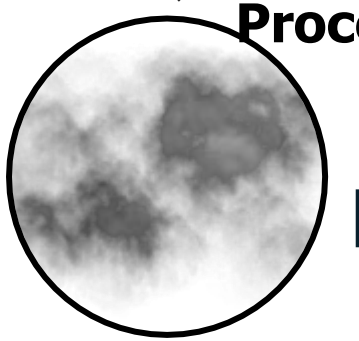


Thermochemical process
T = 180 – 250 °C
t = 5 – 240 min
Autogenous pressure
> 40% moisture content

Hydrochar (HC)

Process water (PW)

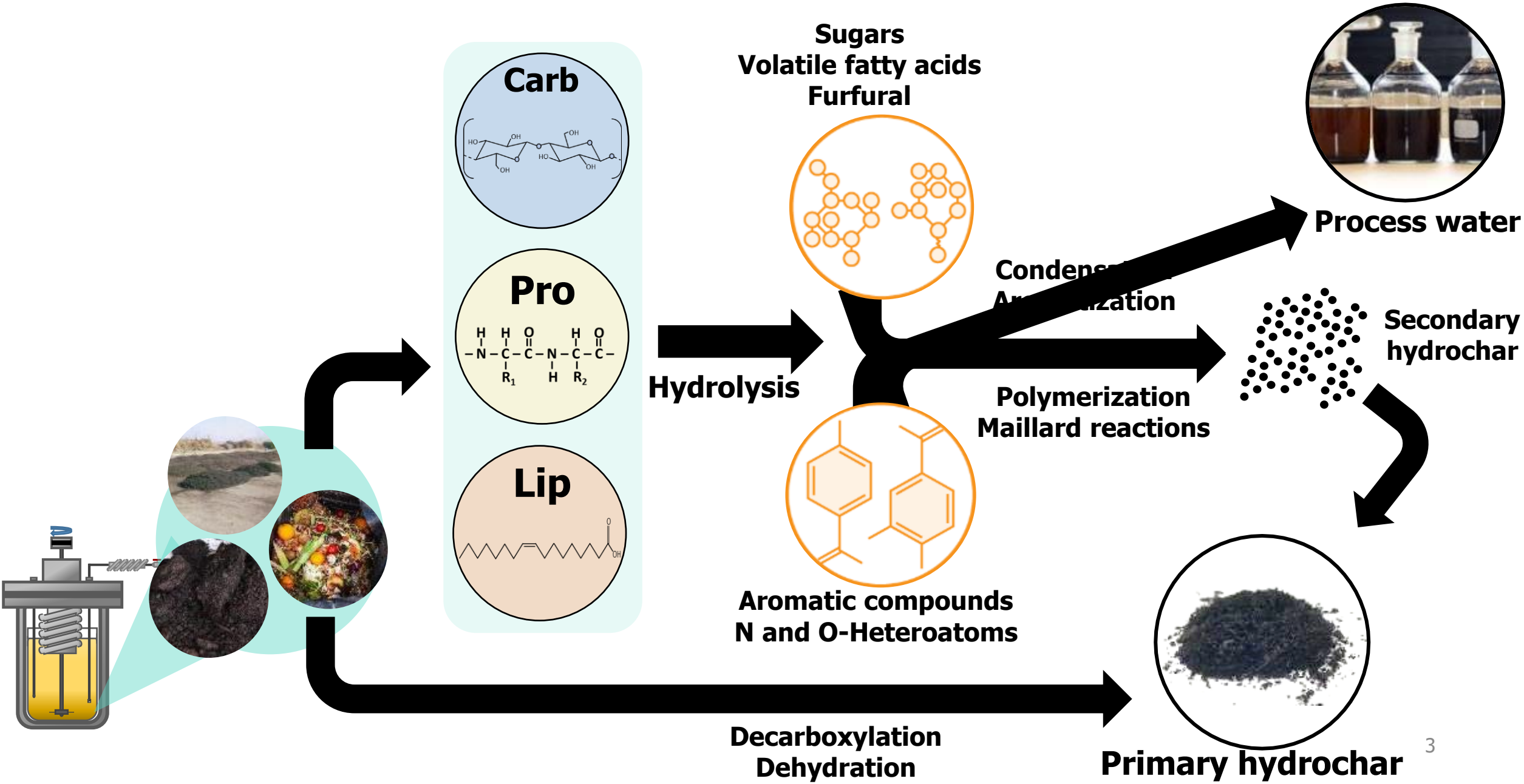
Organic compounds
Nutrients (N, P)



Gas

CO_2
CO
H_2O

HTC reactions



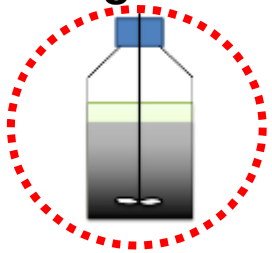
HTC products and applications

Hydrochar

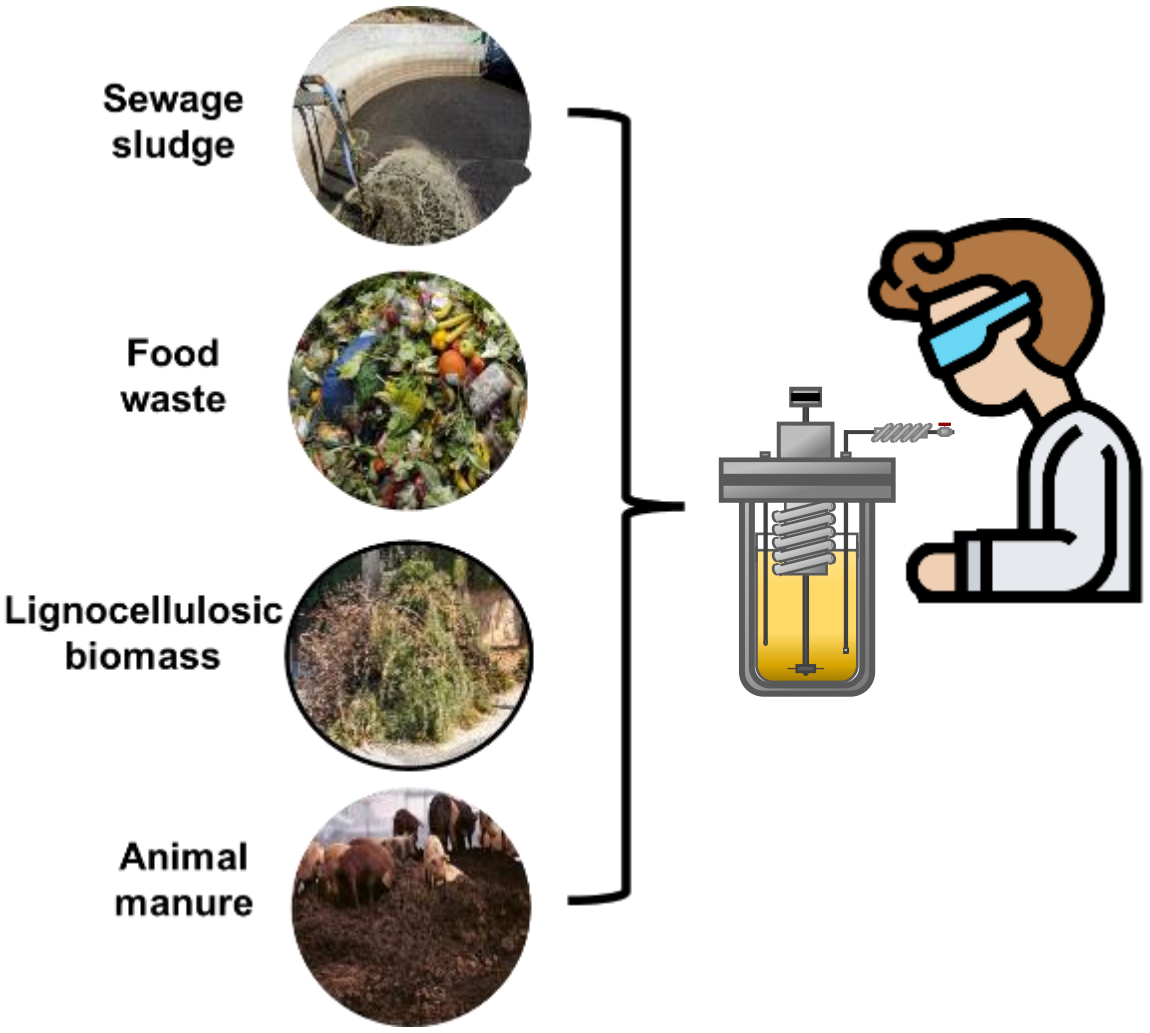
-  Renewable energy
-  Actived carbon
-  Soil amendment
-  Catalytic support

Process water

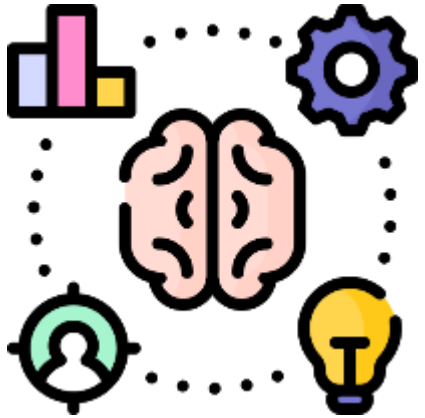
-  Anaerobic digestion
-  Phosphorus fertilizer
- 

Liquid irrigation fertilizer
-  Dark fermentation

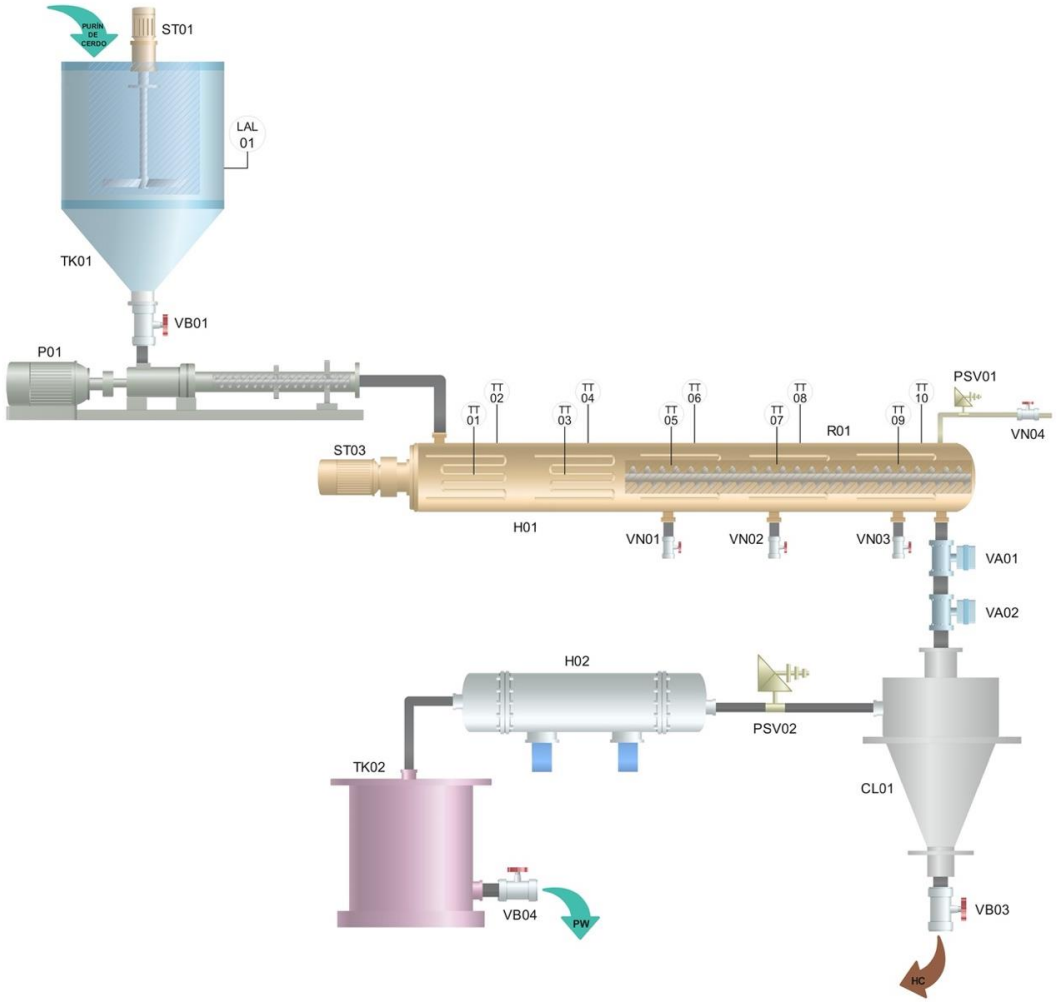
HTC in batch vs continuous scale



The hydrothermal carbonization of biomass wastes using continuous reactors needs to be better understood.



HTC in batch vs continuous scale



Higher energy efficiency

Better process control

Evaluate the potential of the HTC

INDUSTRY 4.0

Evaluate the performance and profitability

Swine manure origin and characteristics

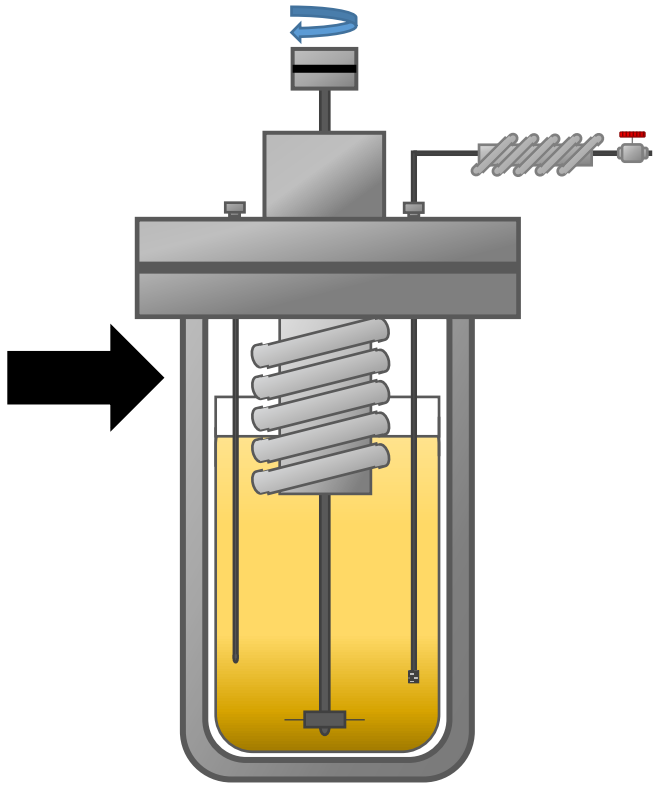
Swine manure (SM)

Avila – Spain

	SM
FC (%)	13.7 (0.2)
VM (%)	75.8 (0.1)
Ash (%)	10.5 (0.1)
C (%)	45.0 (0.4)
N (%)	1.4 (0.0)
S (%)	0.5 (0.0)
HHV (MJ kg^{-1})	18.5 (0.2)

Experimental procedure

Total Solids = 5.0%



T = 180, 210, 230 and 250 ºC

t = 45 min

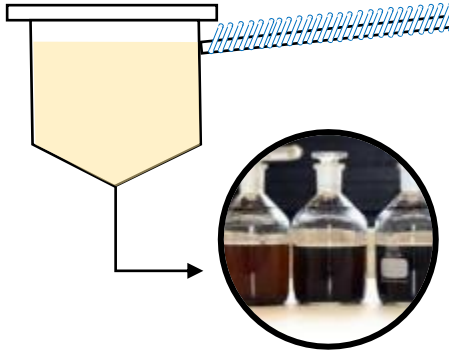
Experimental procedure

Total Solids = 5.0%

T = 180, 210, 230 and 250 ºC

t = 45 min

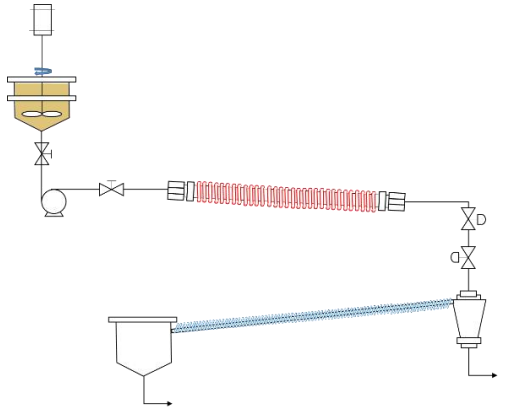
HTC Reactor

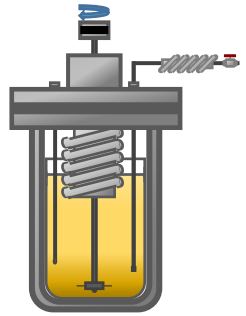


HTC pilot plant

	Name
1	Feed tank
2	Feed tank stirred
3	Feed pump
4	Reactor
5	Decompression valve
6	Cyclone
7	Process water tank
8	Compressor
9	Centrifugal pump
10	IBC agitator
11	Storage IBC
12	Cooler

Experimental procedure





HC180-C **HC180-B**

HC250-C **HC250-B**

PW180-C **PW180-B**

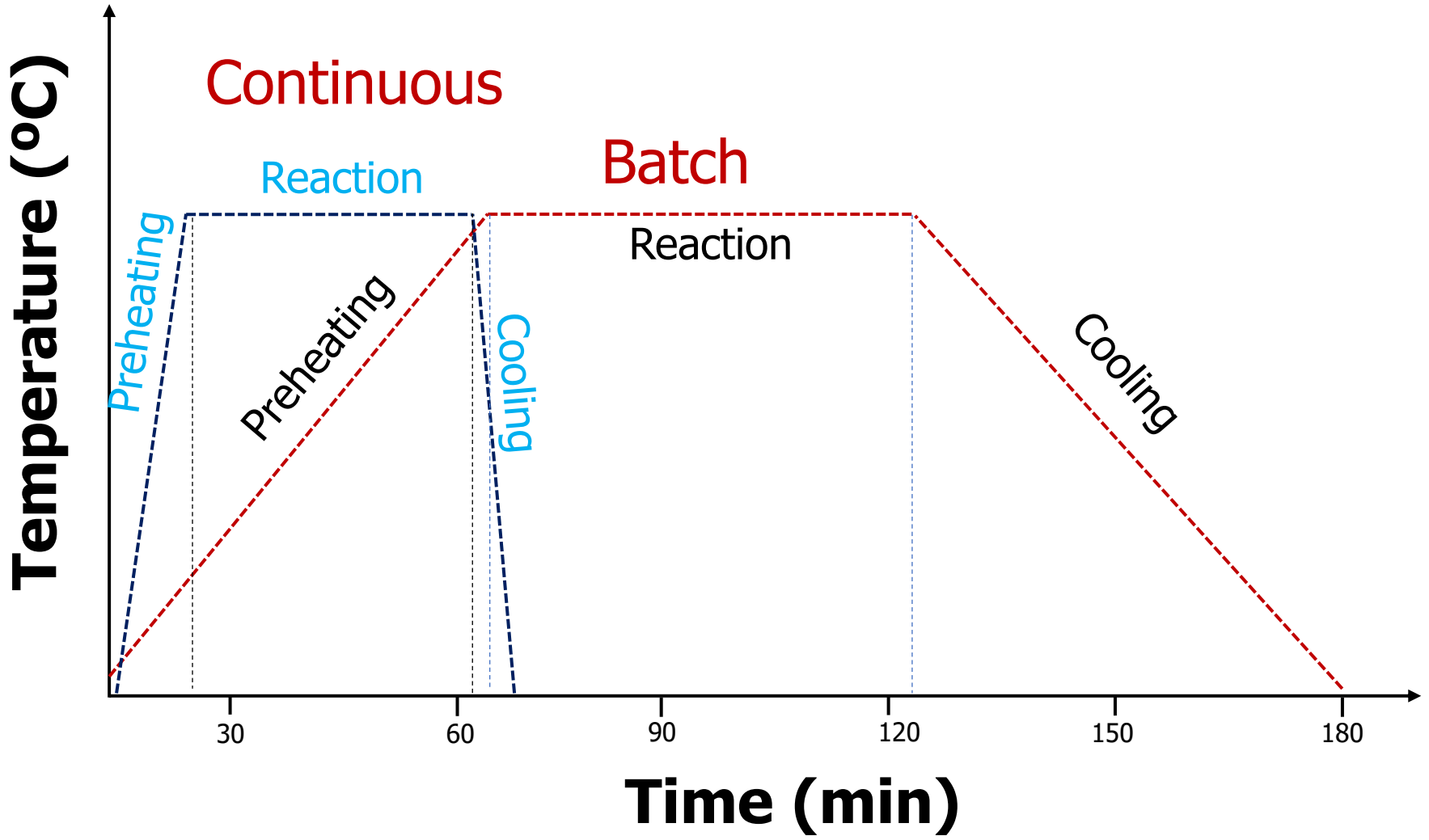
PW250-C **PW250-B**


RESULTS

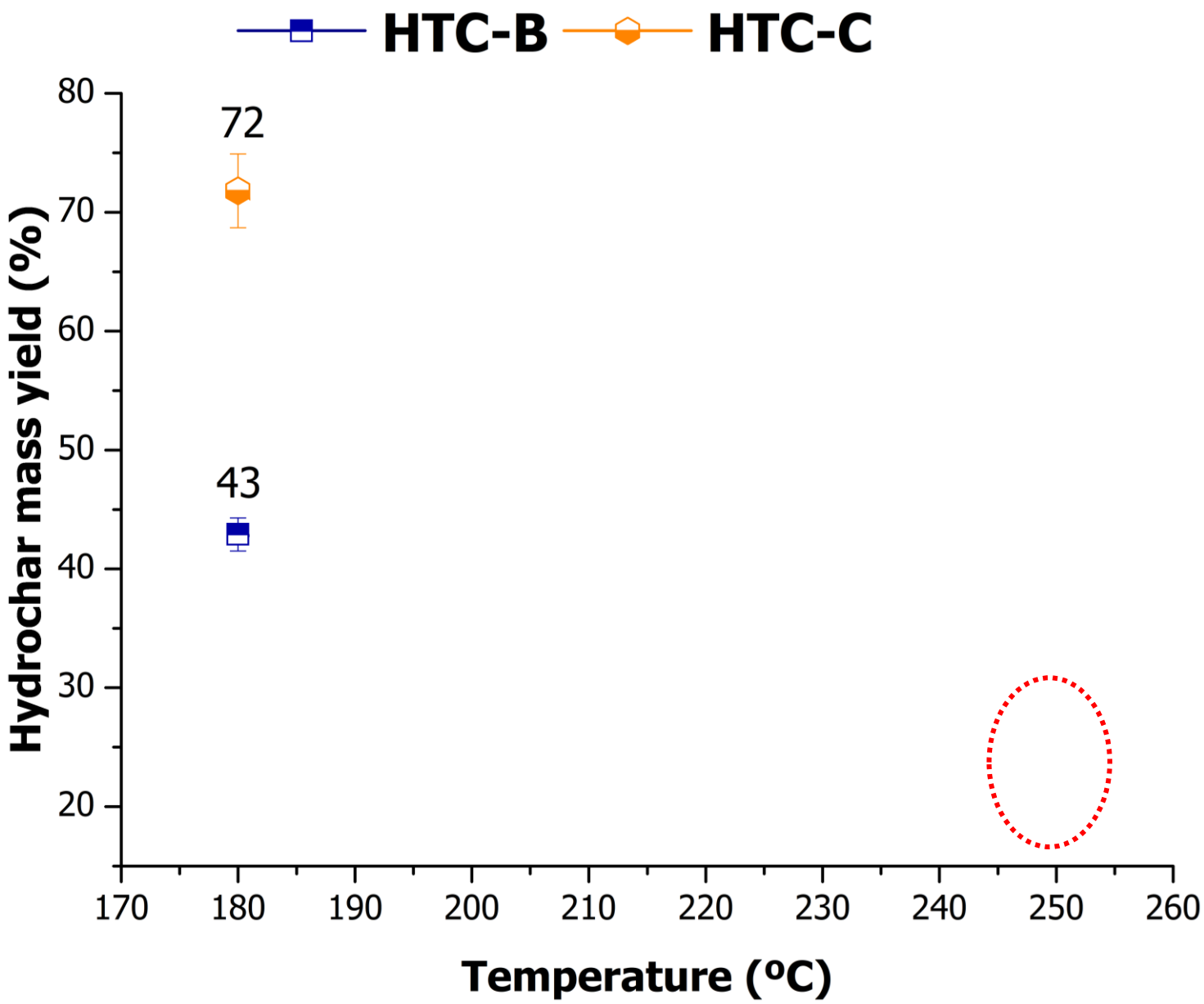

Results


Results

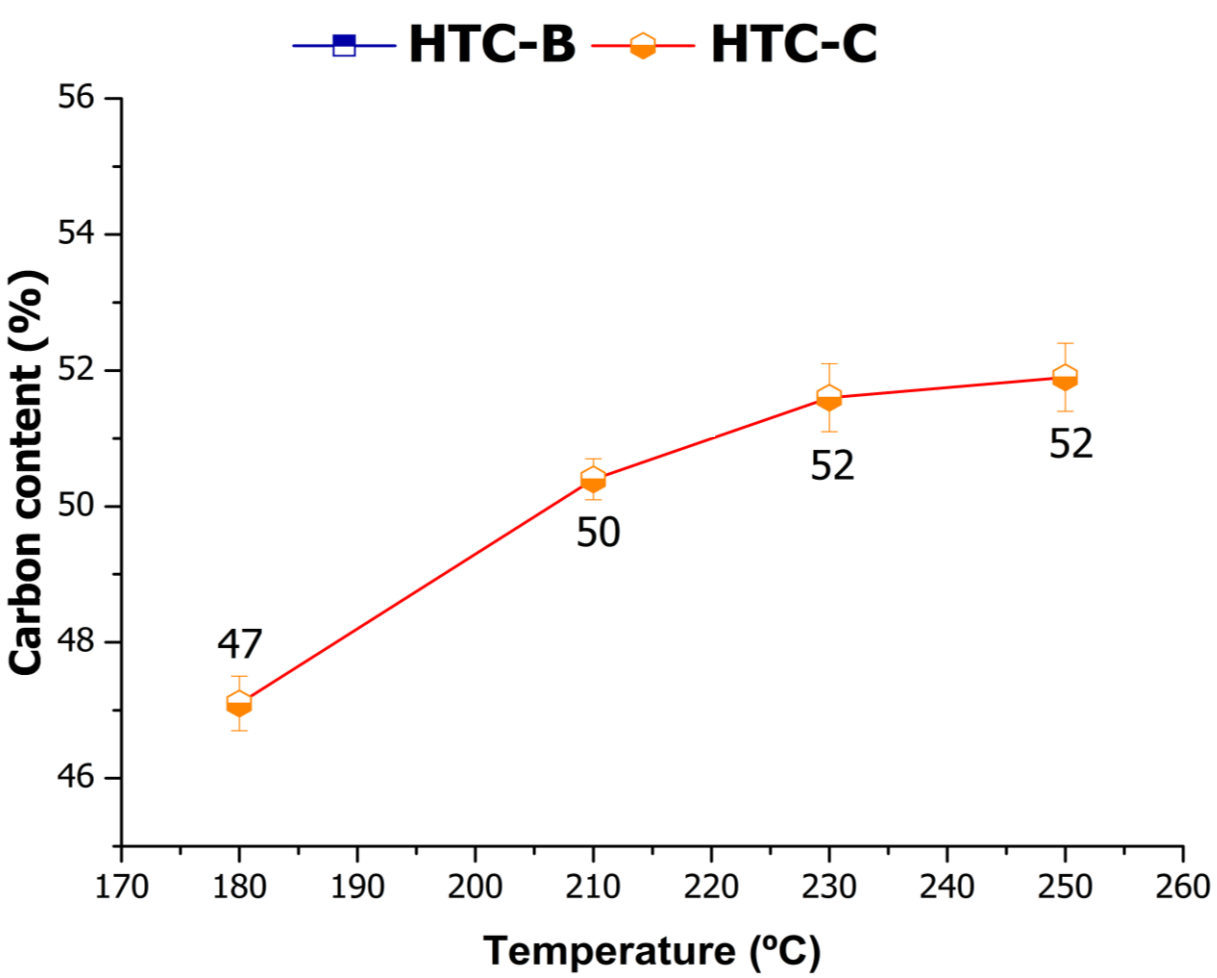
HTC batch vs continuous

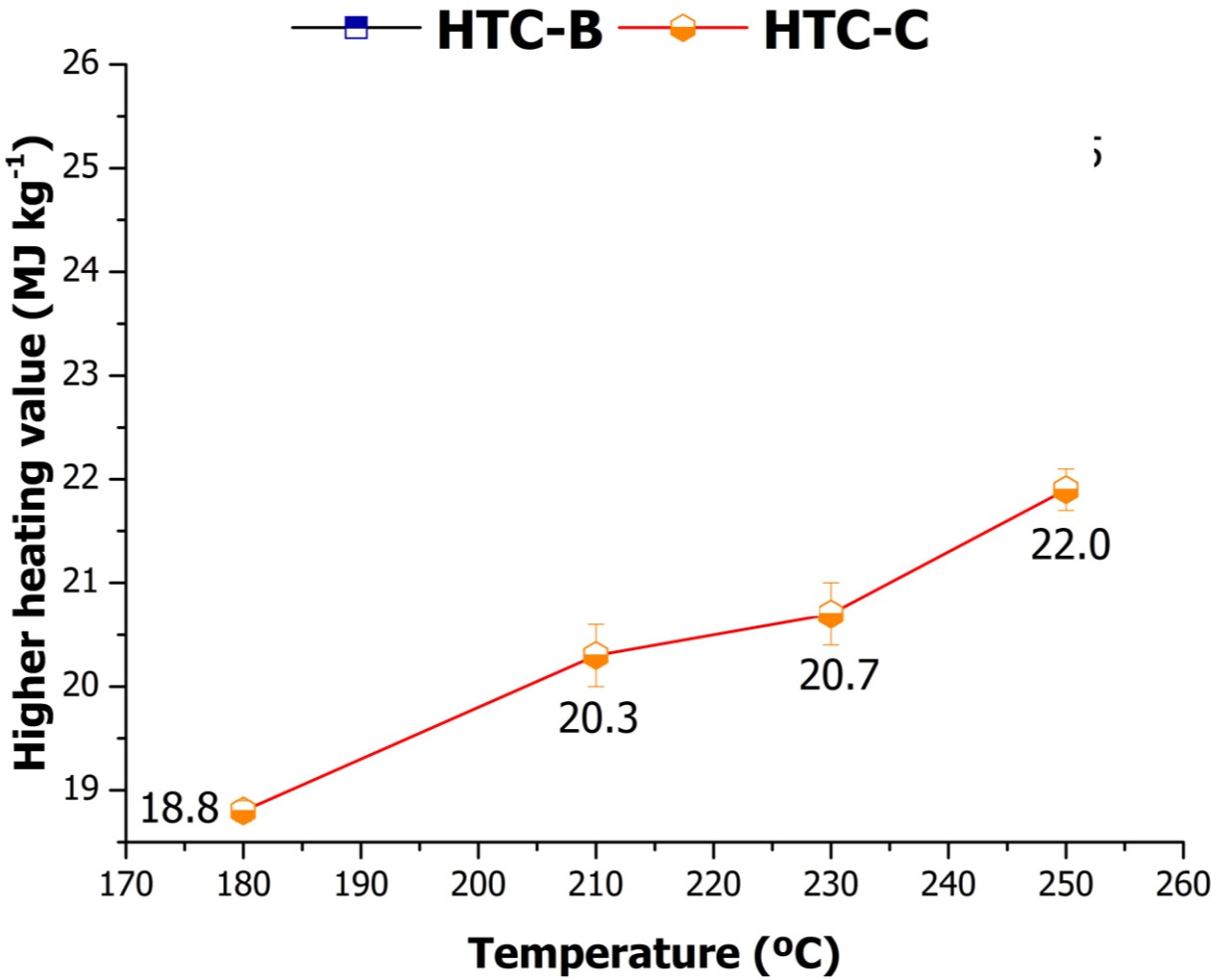


Hydrochar characteristics

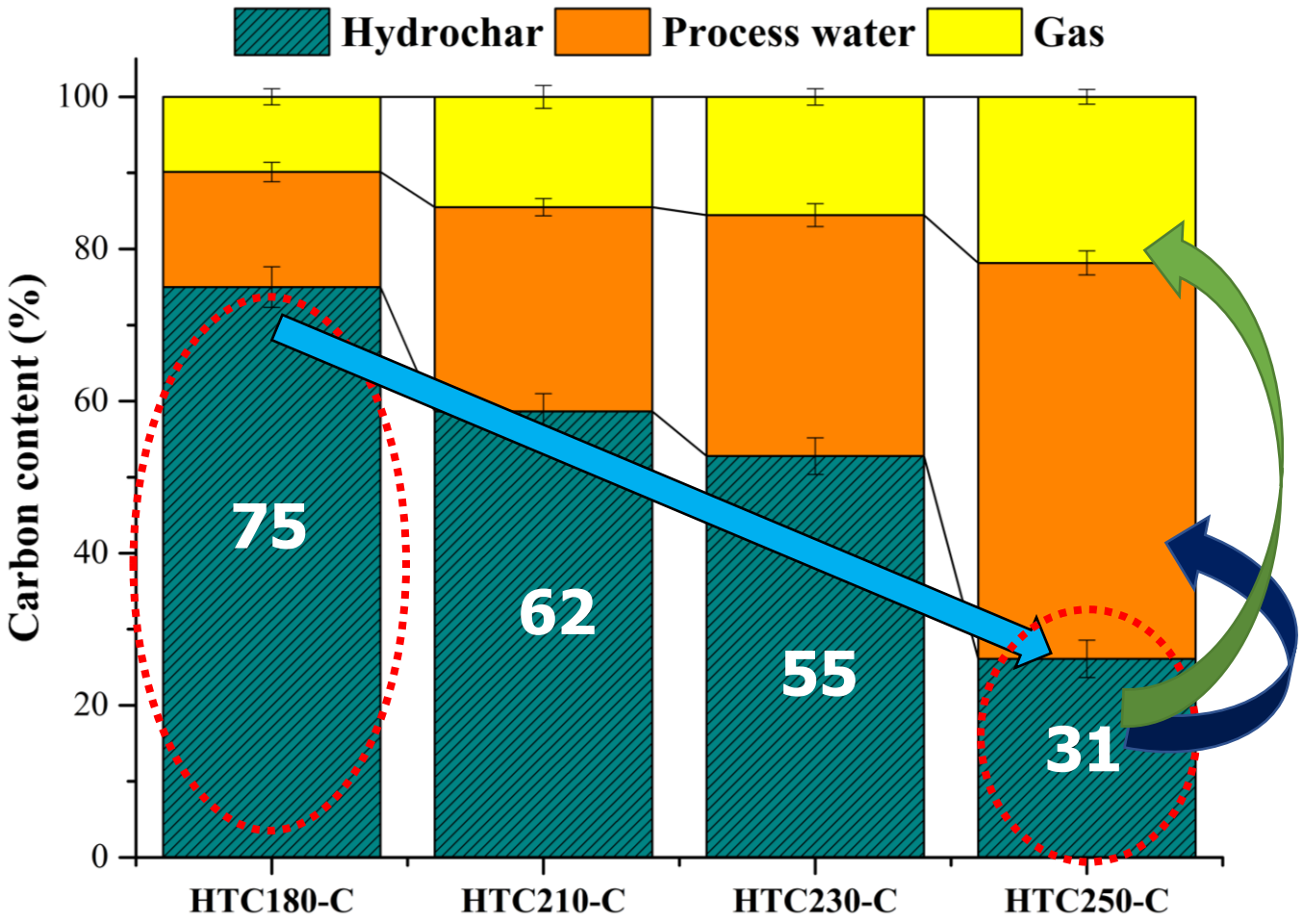


Hydrochar characteristics





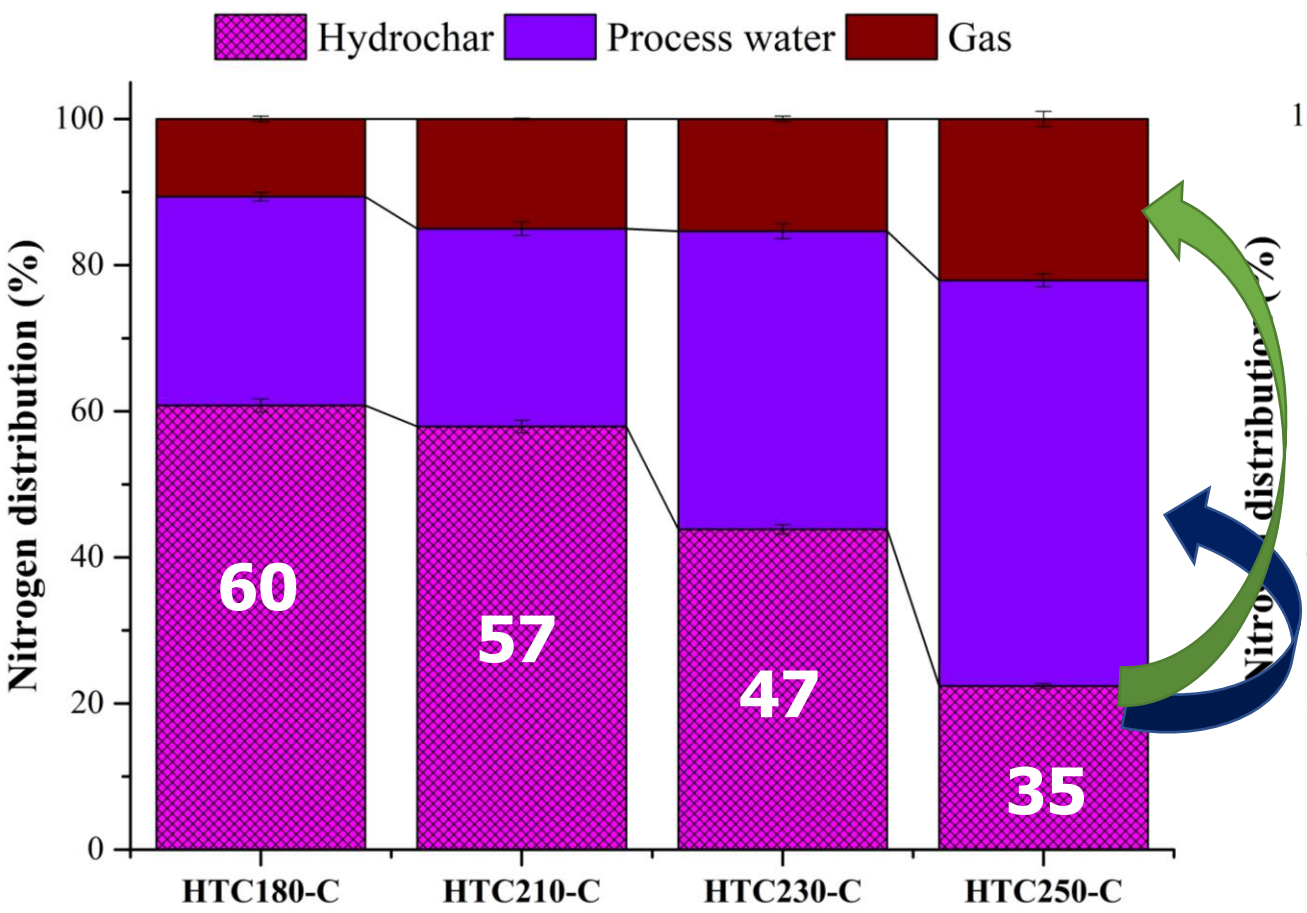
Fate of carbon

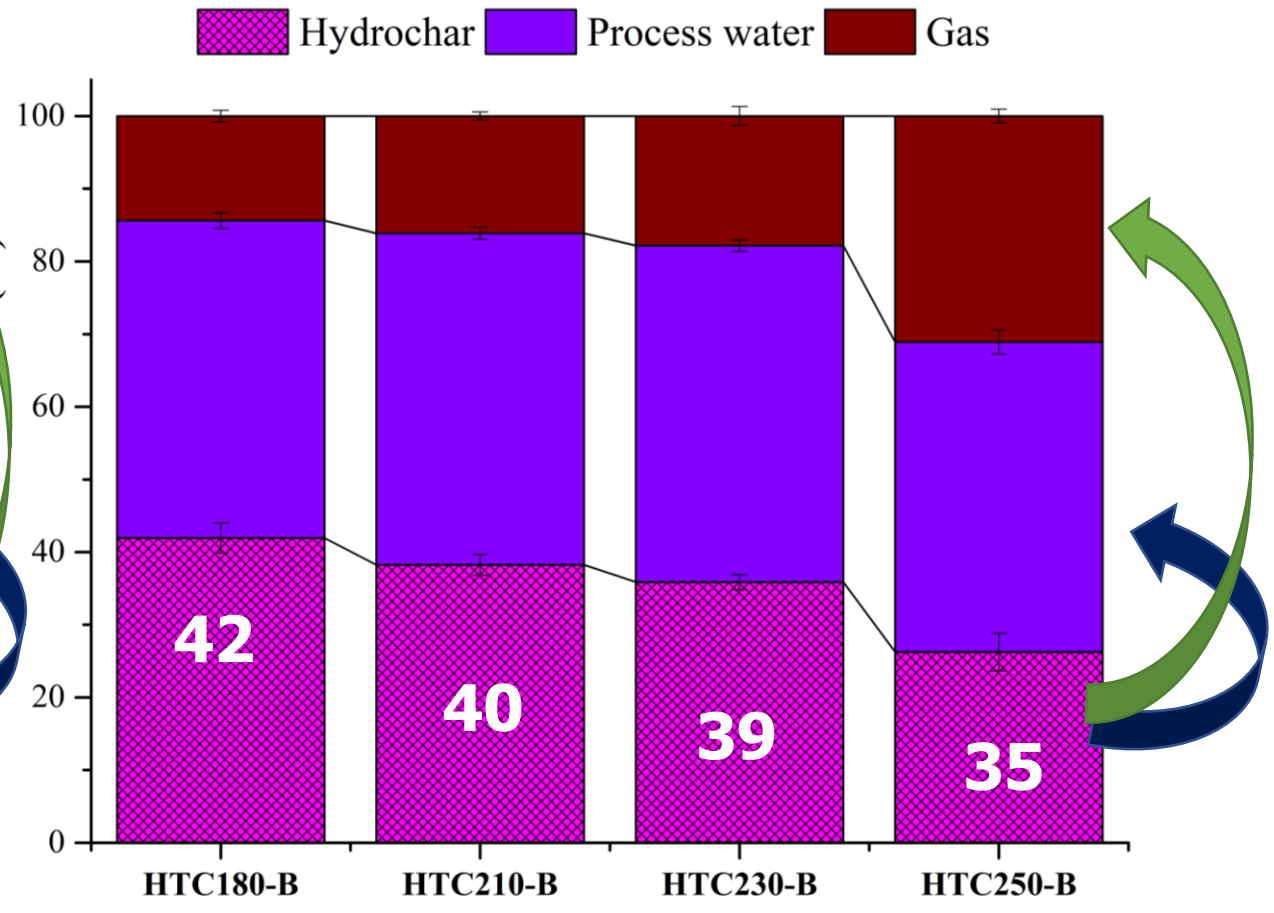


HTC-C

HTC-B

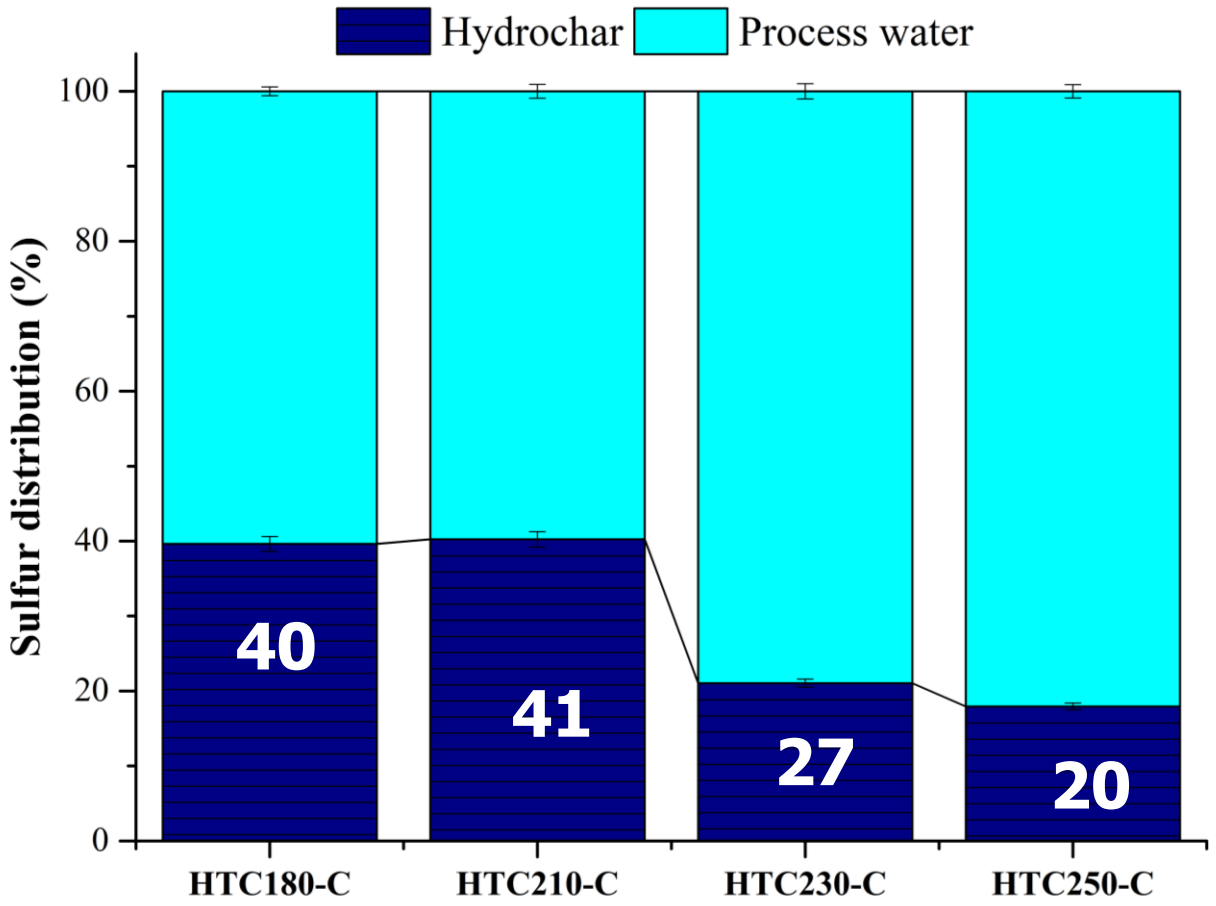
Elements distribution



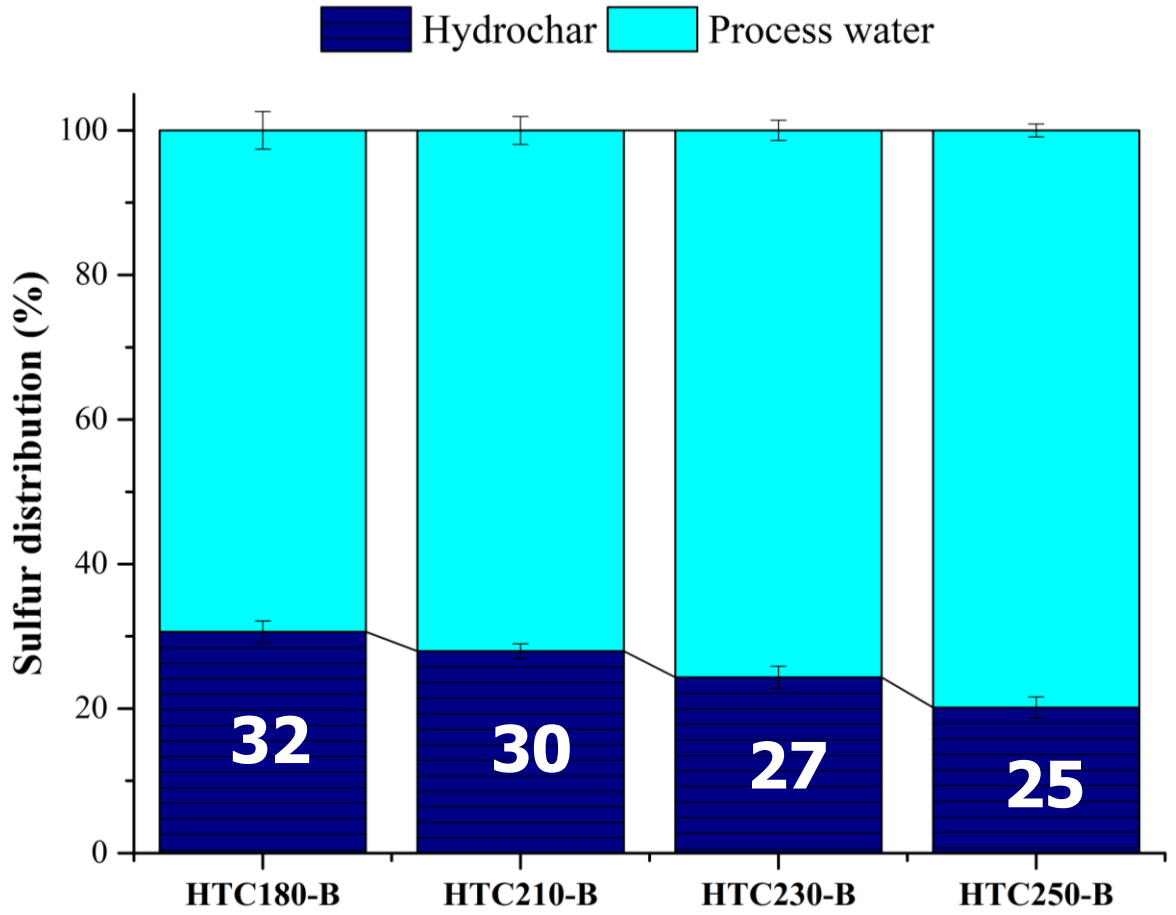


HTC-C **HTC-B**

Elements distribution

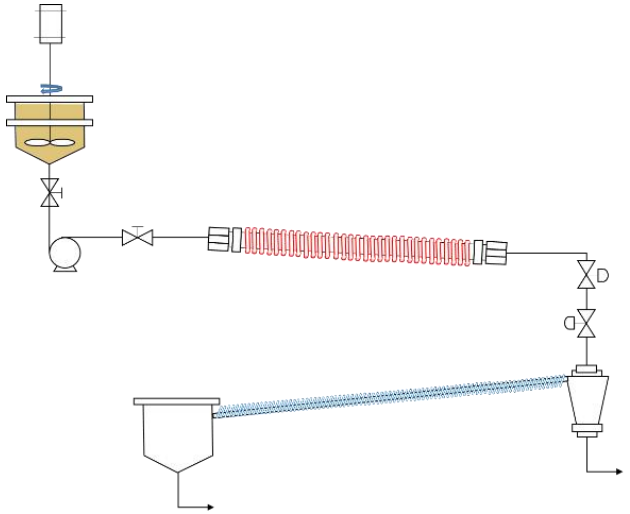


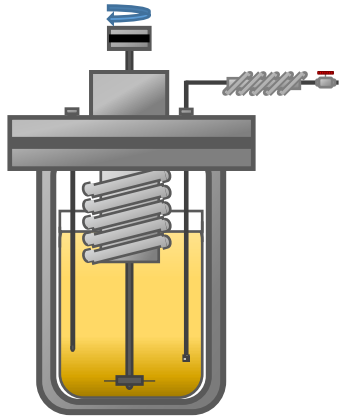
HTC-C



HTC-B

Biofuel





HHV > 17 MJ kg^{-1}

N < 3.0 wt.%

S < 0.5 wt.%

Ash < 10 wt.%

VM < 75 wt.%

ISO 17225-8 Solid biofuels specifications

HHV > 17 MJ kg^{-1}

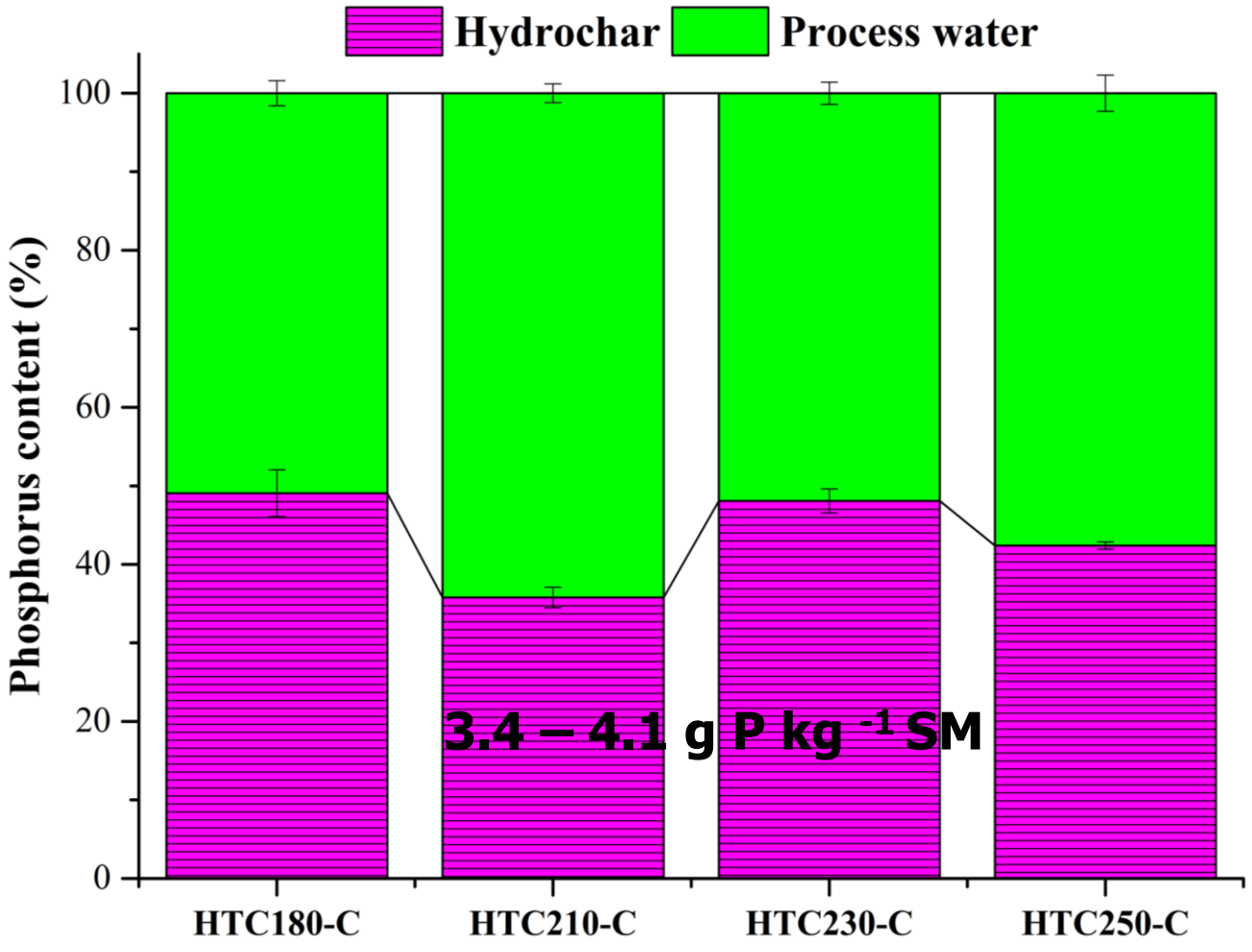
N < 3.0 wt.%

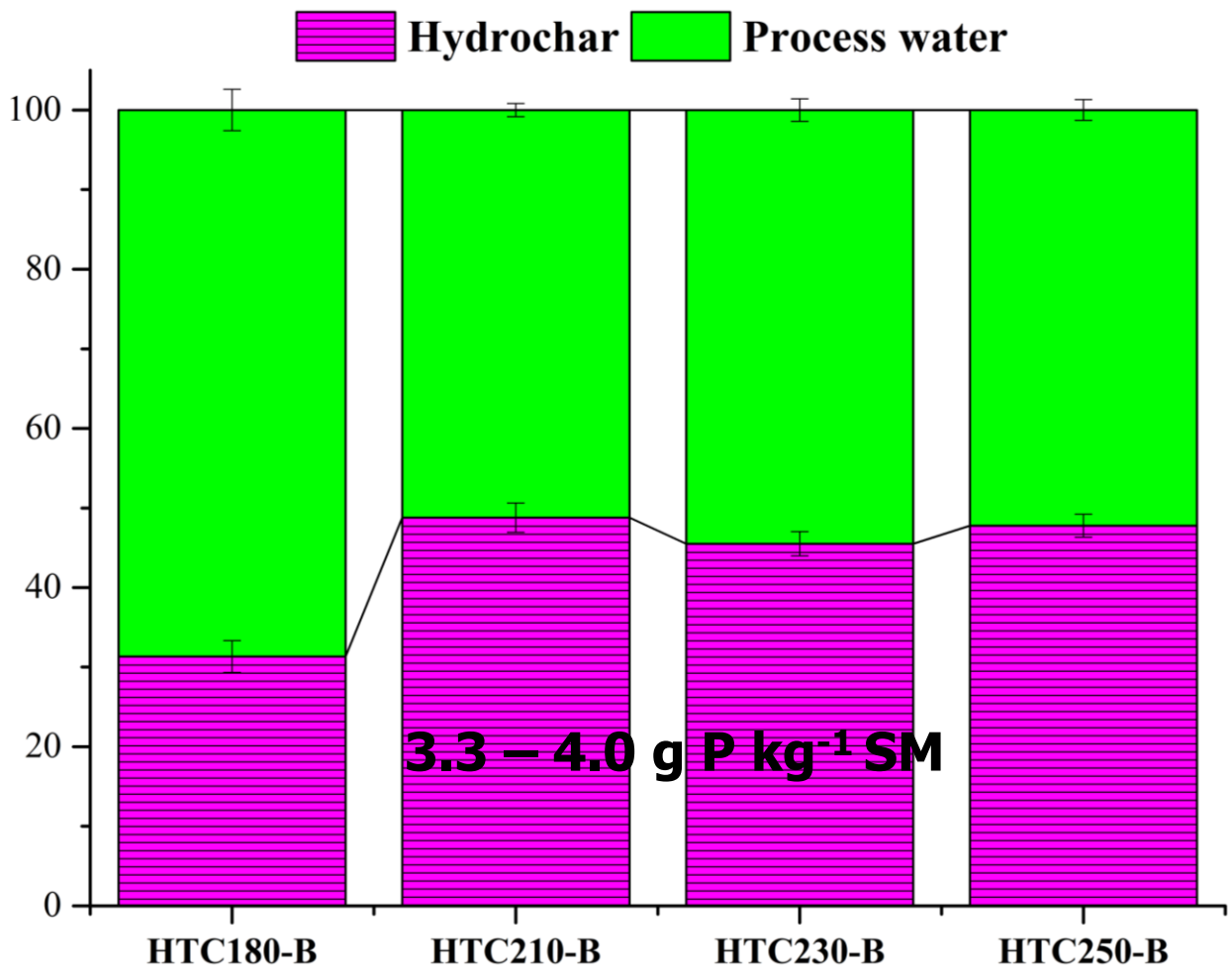
S < 0.5 wt.%

Ash < 10 wt.%

VM < 75 wt.%

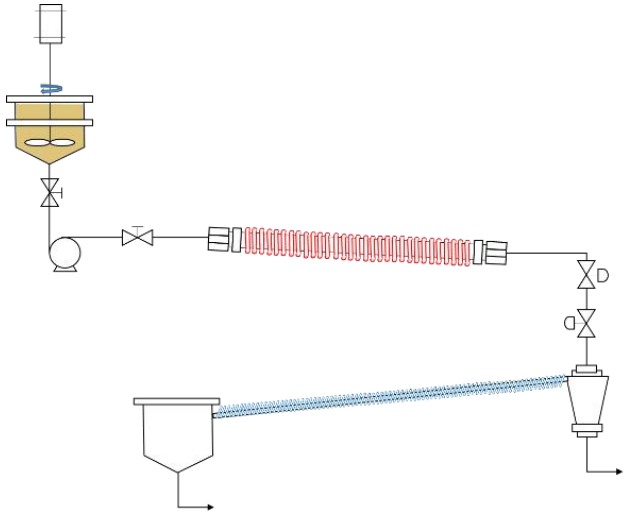
Elements distribution

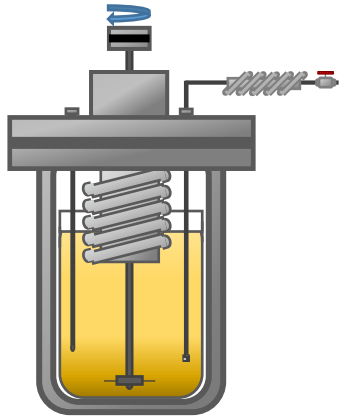




HTC-C **HTC-B**

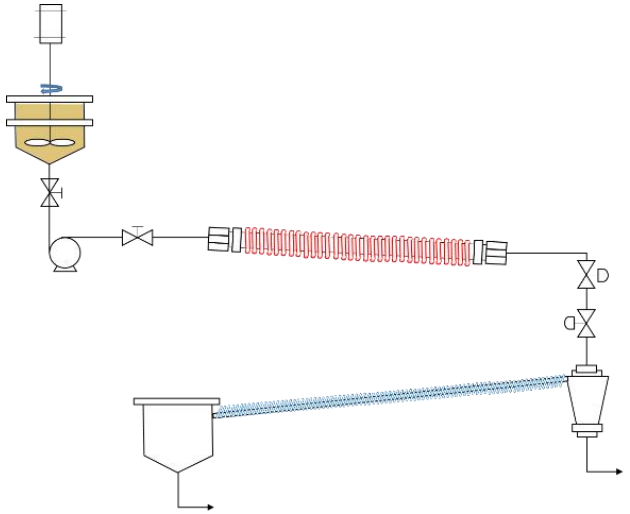
Soil amendment

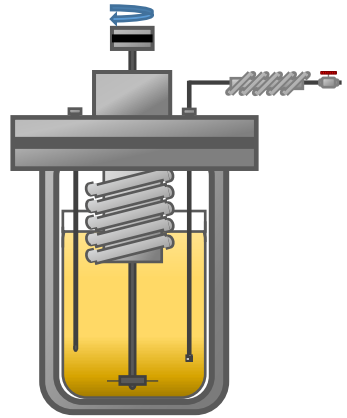




CE 1009/2019

Soil amendment





CE 1009/2019

C > 50 wt.%

H/C < 0.7

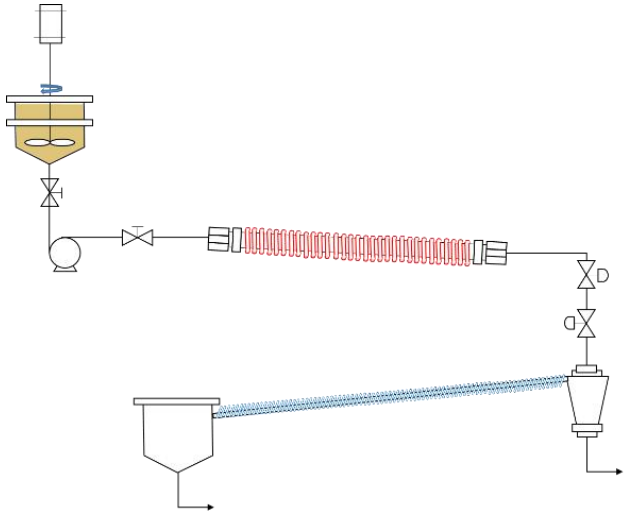
O/C < 0.4

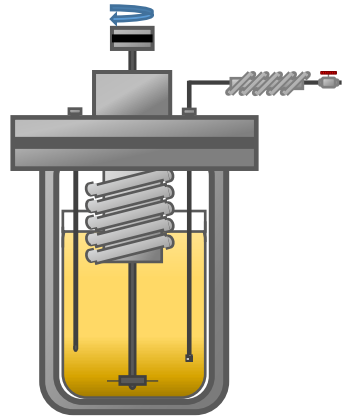
C > 50 wt.%

H/C < 0.7

O/C < 0.4

Soil amendment



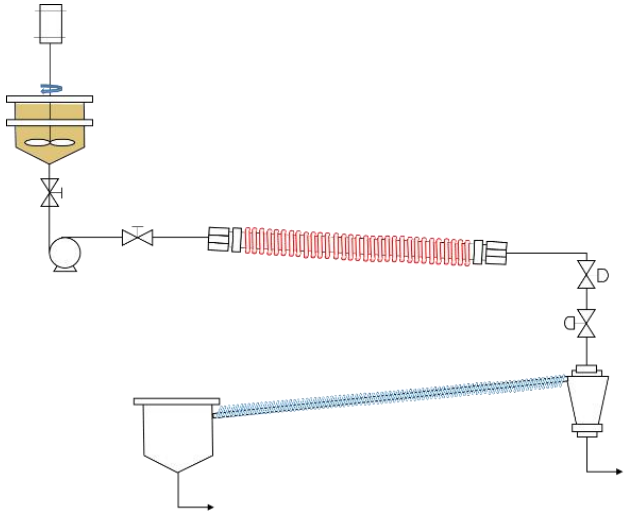


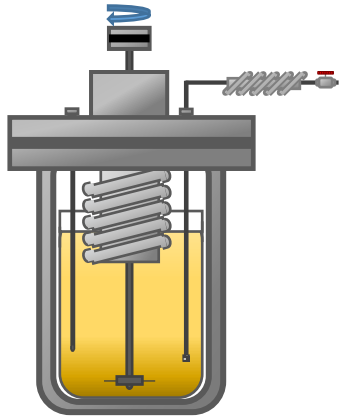
(mg kg^{-1})	HC-C
Cd	< 3
Cr	< 150
Cu	> 100
Ni	< 90
Pb	< 150
Zn	< 800

CE 1009/2019

(mg kg^{-1})	HC-B
Cd	< 3
Cr	< 150
Cu	> 100
Ni	< 90
Pb	< 150
Zn	< 800

Process water characteristics





TCOD (g L^{-1}) = 6.5 – 12.6

TOC (g L^{-1}) = 3.5 – 11.0

NH_4-N (mg L^{-1}) = 98 – 186

PO_4-P (mg L^{-1}) = 60 – 95

TCOD (g L^{-1}) = 16.3 – 21.2

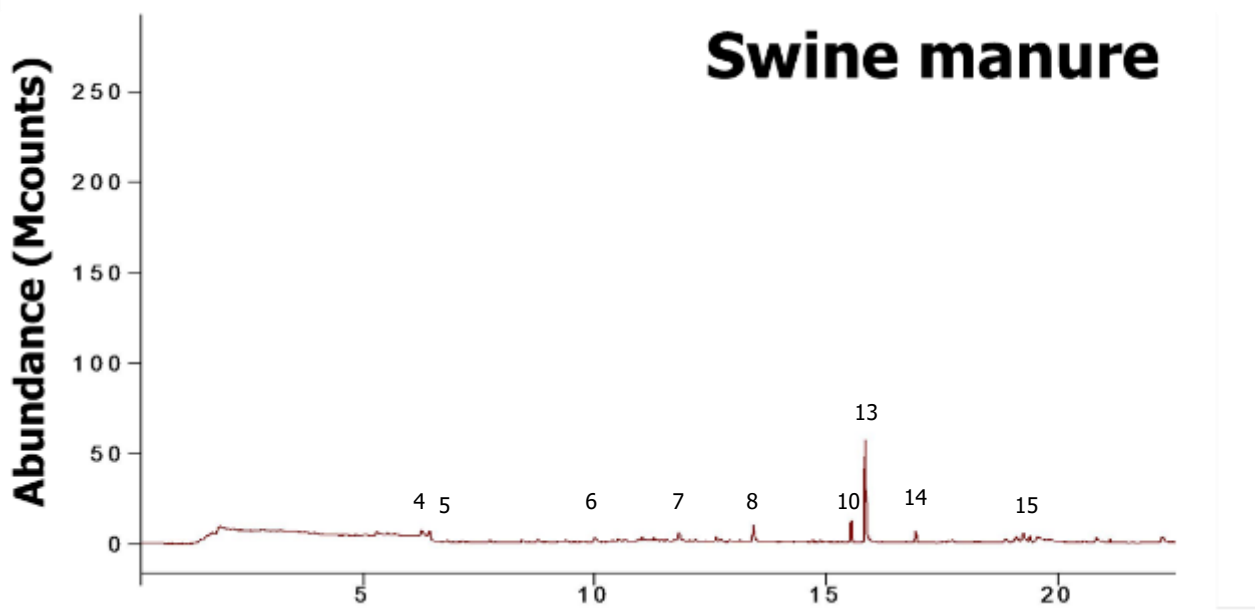
TOC (g L^{-1}) = 8.1 – 9.7

NH_4-N (mg L^{-1}) = 392 – 496

PO_4-P (mg L^{-1}) = 38 – 64

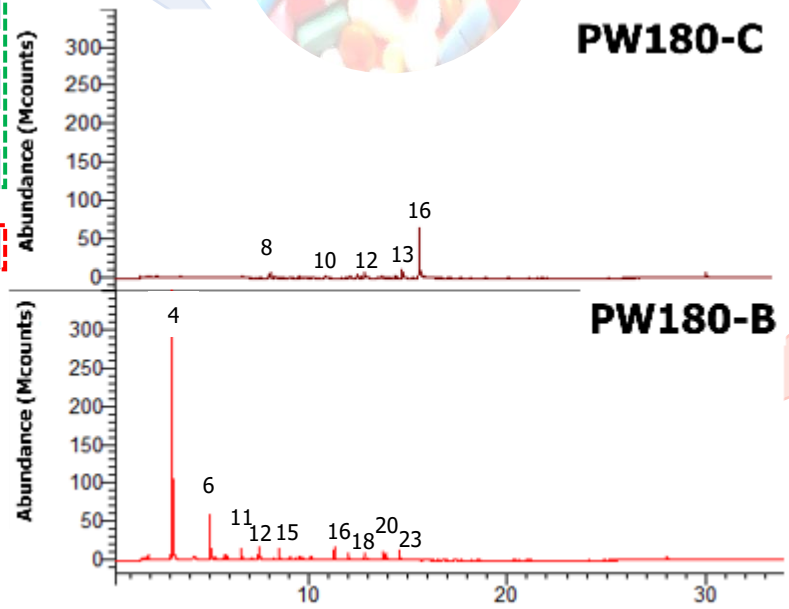
GC/MS: Swine manure

Number	Name	Area
1	Penicillamine	1,42E+07
2	Methylene Chloride	2,48E+08
3	Threonine	8,33E+07
4	2-chloro-2-nitro-Propane	8,90E+08
5	Prednisolone Acetate	1,72E+07
6	dimethyl-Disulfide	2,42E+08
7	3,4-bis(4-hydroxyphenyl)-3,4-Hexanediol	3,43E+08
8	2,4,6-Trihydroxybenzoic acid	5,57E+08
9	Hydroxy-lactone-Undecanoic acid	6,80E+07
10	cis-9-Tetradecen-1-ol	6,49E+07
11	dimethyl-Tetrasulfide	1,06E+08
12	2-ethoxy-Propane	1,29E+08
13	3-methyl-1H-Indole	2,47E+08
14	1,3-Dioxolane	1,16E+08
15	Ethyl Chloride	2,12E+09



GC/MS: Process water

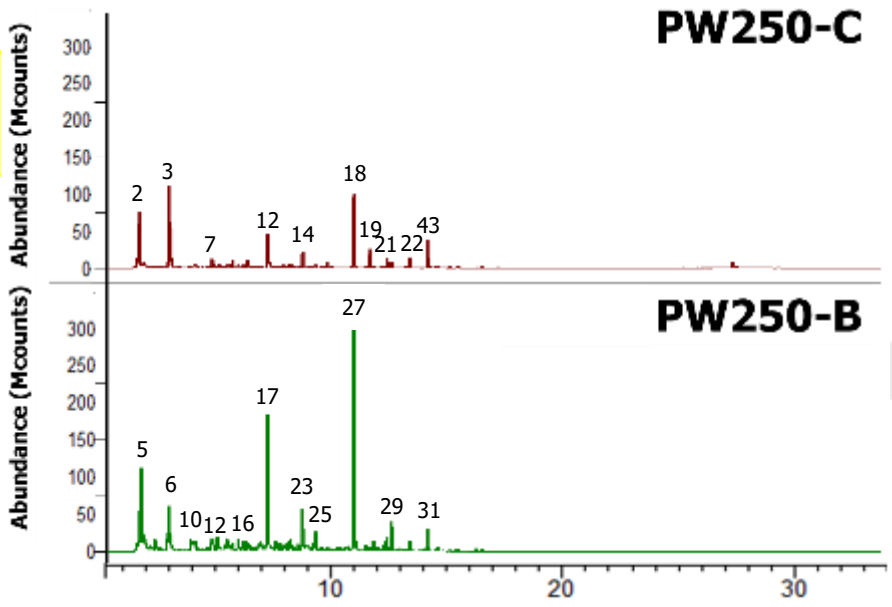
PW180-C		
Number	Compound	Area
1	Methyl formate	1,04E+07
2	dichloro Methylene	7,07E+06
3	Cholomethyl cyanide	4,47E+06
4	3-methyl-1-butanol	1,12E+07
5	2-furanmethanol	5,59E+06
6	2-ethyl-1-Hexanol	3,75E+06
7	2-methoxy-phenol	4,02E+06
8	2-nonanone	2,15E+07
9	1-undecanol	4,77E+06
10	2-decanone	4,98E+06
11	Phthalan	8,00E+06
12	2,4-Dimethoxytoluene	7,78E+06
13	2-undecanone	1,32E+07
14	p-tert-butyl-phenol	1,95E+07
15	eugenol	4,58E+06
16	3-methyl-1H-Indole	7,37E+06
17	2-methoxy-4-phenol	2,62E+07
18	2-methoxy-4-(E) -phenol	1,94E+08
19	1-Tetradecanol	4,42E+06
21	Bis-ester-Hexanedioic acid	2,46E+07



PW180-B		
Number	Compound	Area
1	Methyl formate	1,13E+07
2	1,3-Propanediol	1,84E+07
3	4-methyl-Pyrimidine	1,35E+07
4	Furfural	1,02E+09
5	1,4-Benzenediamine	1,79E+07
6	1,3,5-trimethyl-1H-Pyrazole	1,52E+08
7	Benzaldehyde	3,51E+07
8	phenyl ester-Carbamic acid	1,25E+07
9	2-ethyl-3-methyl-Pyrazine	1,99E+07
10	2(1H)-Pyridinone	1,70E+07
11	3-methyl-1,2-Benzenediol	5,47E+07
12	2-methoxy-Phenol	4,64E+07
13	3,5-dimethyl-Cyclohexanone	1,26E+07
14	2-methoxy-4-methyl-Phenol	4,17E+07
15	3,4-dimethyl-Phenol	1,45E+07
16	1-methyl-2-Benzene	1,31E+07
17	3,7,7-trimethyl-Bicyclohept-2-ene	9,72E+06
18	1-methyl-2-nitro-Benzene	1,50E+07
19	2,4-Dimethoxytoluene	4,06E+07
21	p-tert-butyl-Phenol	1,82E+07
22	Eugenol	2,27E+07
23	2-methoxy-4-Phenol	2,74E+07
24	Acetyl bromide	1,80E+07
25	2-methoxy-4-Phenol	3,51E+07
26	Bis-ester-Hexanedioic acid	1,75E+07

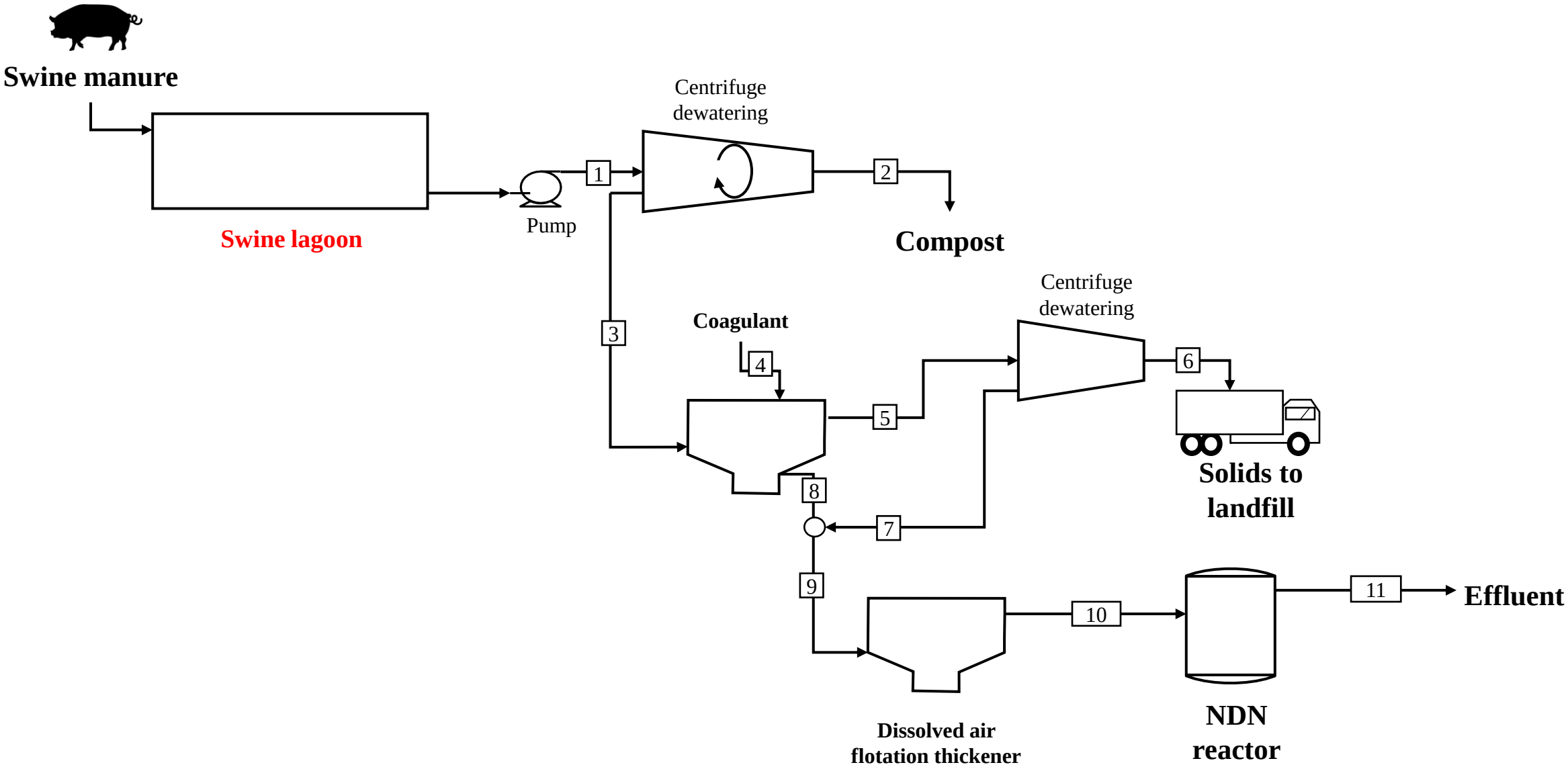
GC/MS: Process water

Number	PW250-C	Area
1	Urea	1,66E+08
2	dl-Alanine	1,05E+07
3	Furfural	2,46E+08
4	2,3-dimethyl-Pyrazine	1,11E+07
5	Hydroquinone	2,30E+07
6	Benzaldehyde	1,47E+07
7	Phenol	2,19E+07
8	2-methyl-1,3-Cyclopentanedione	1,34E+07
9	3-Methylpyridazine	2,39E+07
10	3-methyl-1,2-Cyclopentanedione	1,14E+07
11	3-methyl-1,2-Benzenediol	1,84E+07
12	2-methoxy-Phenol	9,06E+07
13	3,5-dimethyl-Cyclohexanone	2,30E+07
14	2,4,6-Trihydroxybenzoic acid	1,18E+07
15	2-methoxy-4-methyl-Phenol	1,10E+07
16	4-ethyl-Phenol	5,32E+07
17	2-Methoxy-5-methylphenol	1,13E+07
18	2-methoxy-4-propyl-Phenol	1,61E+08
19	p-tert-butyl-Phenol	5,15E+07
20	Eugenol	2,74E+07
21	2-methoxy-4-propyl-Phenol	1,36E+07
22	2-methoxy-4-Phenol	2,61E+07
23	2-methoxy-4-(E)-Phenol	6,73E+07
24	Diisooctyl adipate	2,15E+07



Number	PW250-B	Area
1	Urea	2,19E+08
2	1,3-Propanediol	1,10E+08
3	Propanoic acid	3,69E+07
4	Pyridine	3,80E+07
5	Furfural	2,62E+08
6	2,5-dimethyl-Furan	3,22E+07
7	2,3-dimethyl-Pyrazine	4,02E+07
8	Hydroquinone	3,58E+07
9	Benzaldehyde	5,59E+07
10	Phenol	8,90E+07
11	2-ethyl-3-methyl-Pyrazine	6,67E+07
12	3-Methylpyridazine	3,13E+07
13	3-methyl-1,2-Cyclopentanedione	3,48E+07
14	1,3,5-trimethyl-1H-Pyrazole	4,13E+07
15	3-methyl-1,2-Benzenediol	5,88E+07
16	3-methyl-Phenol	6,08E+07
17	2-methoxy-Phenol	3,80E+08
18	3,5-dimethyl-Cyclohexanone	4,61E+07
19	4,4-dimethyl-2-Cyclohexen-1-one	3,63E+07
20	Nonanal	3,10E+07
21	2,2-Dimethyl-3-heptene trans	3,82E+07
22	2-methoxy-4-methyl-Phenol	5,65E+07
23	4-ethyl-Phenol	1,37E+08
24	1-methyl-4-Benzene	4,46E+07
25	2-methoxy-4-methyl-Phenol	6,72E+07
26	Quinoline	3,14E+07
27	2-methoxy-4-propyl-Phenol	5,20E+08
28	1,3-dihydro-2H-Inden-2-one	4,04E+07
29	Benzenethiol	4,82E+07
30	Eugenol	4,20E+07
31	2-methoxy-4-propyl-Phenol	7,99E+07

Typical swine manure management



Typical swine manure management

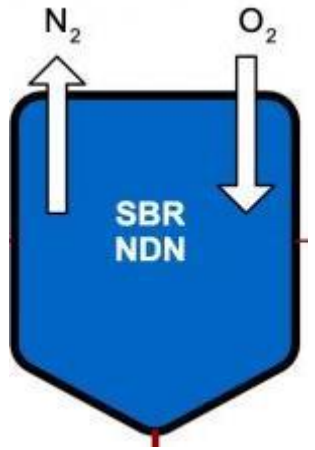
Swine manure compost

40 – 60 € ton^{-1}

Sludge management

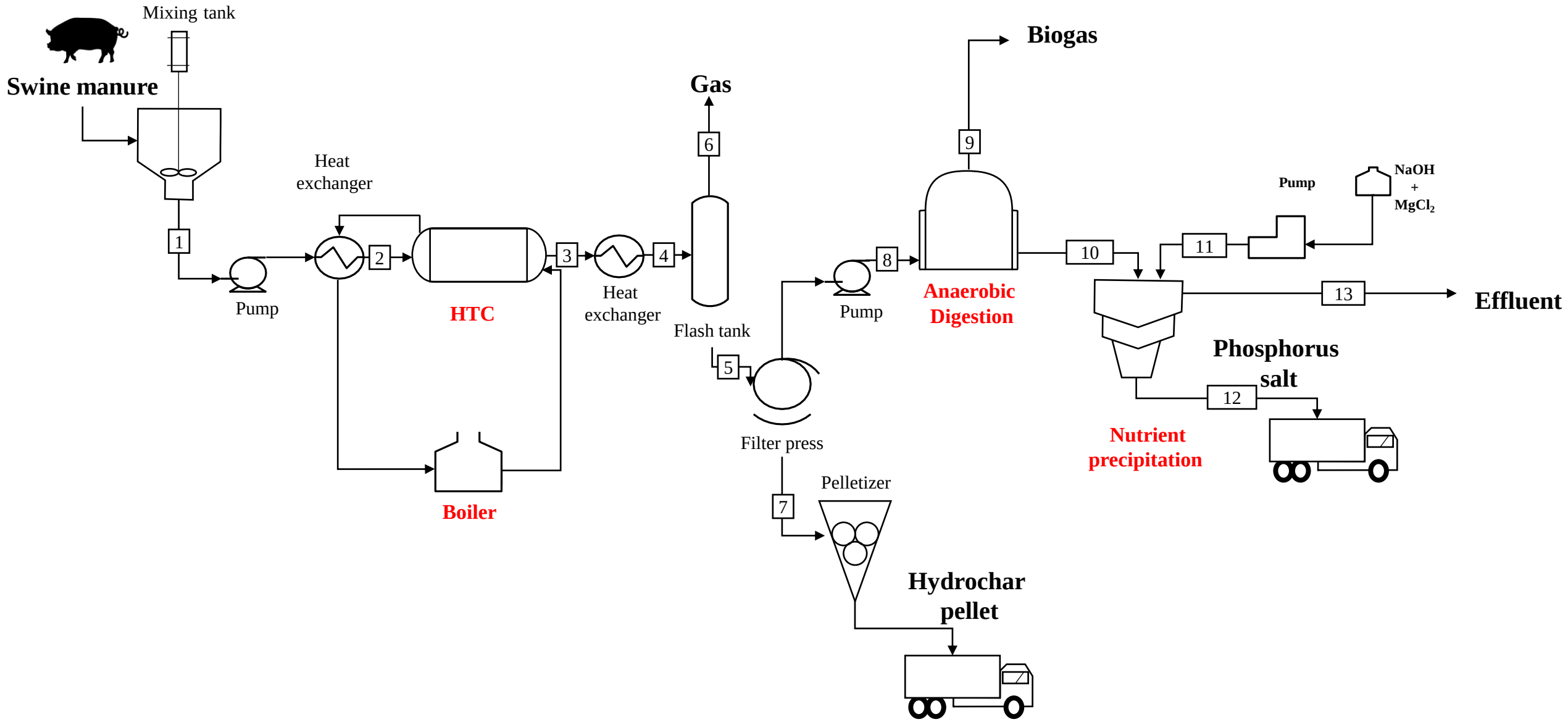
20 – 40 € ton^{-1} SM

Liquid fraction management



50 – 150 € ton^{-1} SM

New strategy for swine manure valorization



New strategy for swine manure valorization

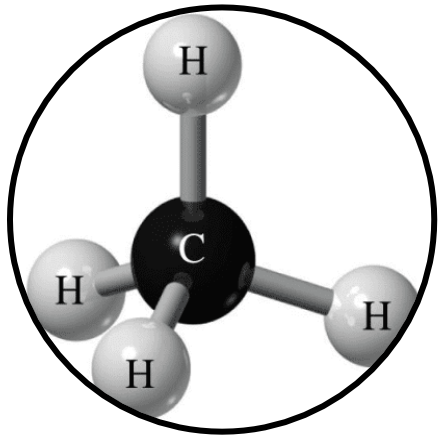
Hydrochar

200 – 300 € ton^{-1} HC

Struvite

400 – 600 € ton^{-1} struvite

Methane



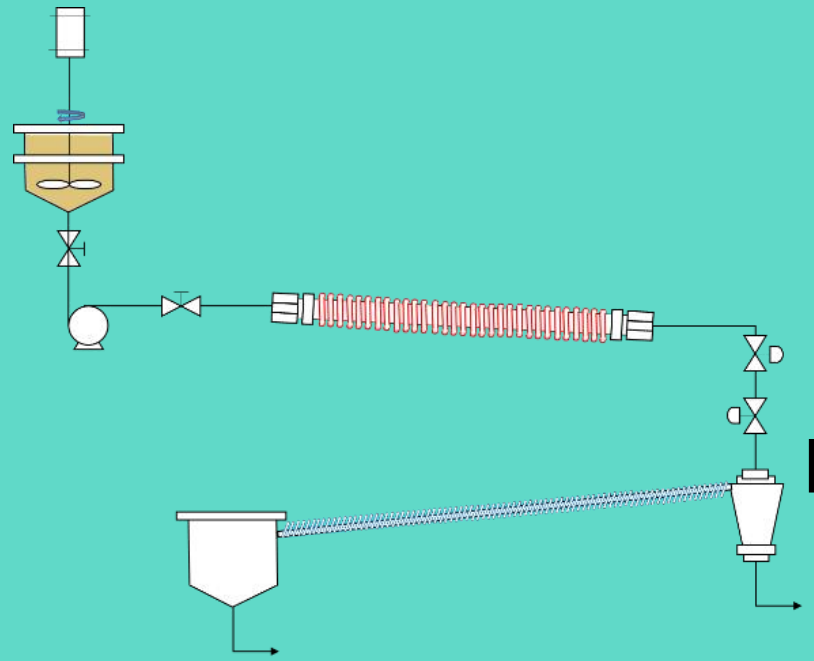
≈ 2 € GJ^{-1}

Potential application of HTC in a swine farm

	Hydrochar (kg t^{-1} SM)
HTC180	36
HTC210	26
HTC230	23
HTC250	12

Solid biofuel

Summary



The continuous HTC reactor showed a high performance to valorization of swine manure into a carbonaceous solid.

The characteristics of the products obtained differ slightly from those obtained in a batch reactor.

The hydrochar obtained shows suitable characteristics to be considered a solid biofuel at an industrial level

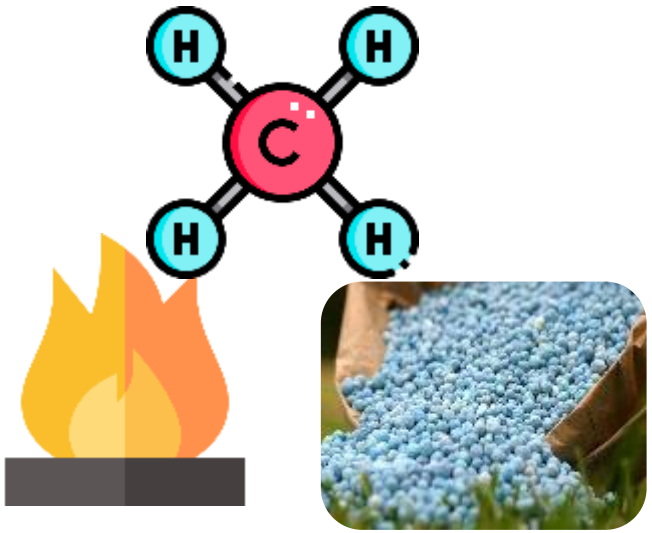
ISO 17225-8 Solid biofuels specifications

The hydrochar does not meet previous the requirements to be used as soil amendment

CERTIFIED BIOCHAR EBC EUROPEAN BIOCHAR CERTIFICATE (EBC)

European Commission

CE 1009/2019



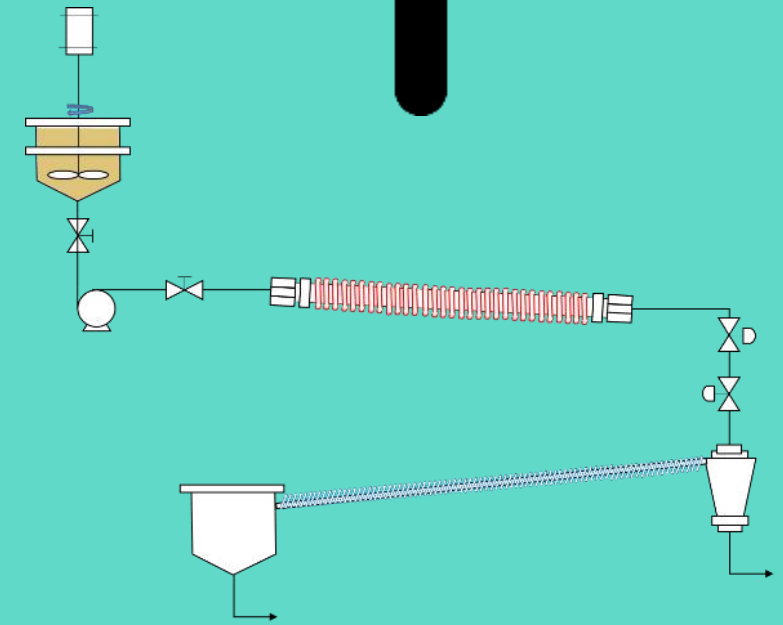
Hydrochar

Methane

Fertilizer

VS

Compost



If you want to know more about our work, please contact us.

R. P. IPIALES

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Scale-up the production of swine manure hydrochar in a continuous pilot plant

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