9TH International conference on sustainable solid waste management

Improvement of the physicochemical and combustion properties of hydrochars from hydrothermal carbonization of swine manure

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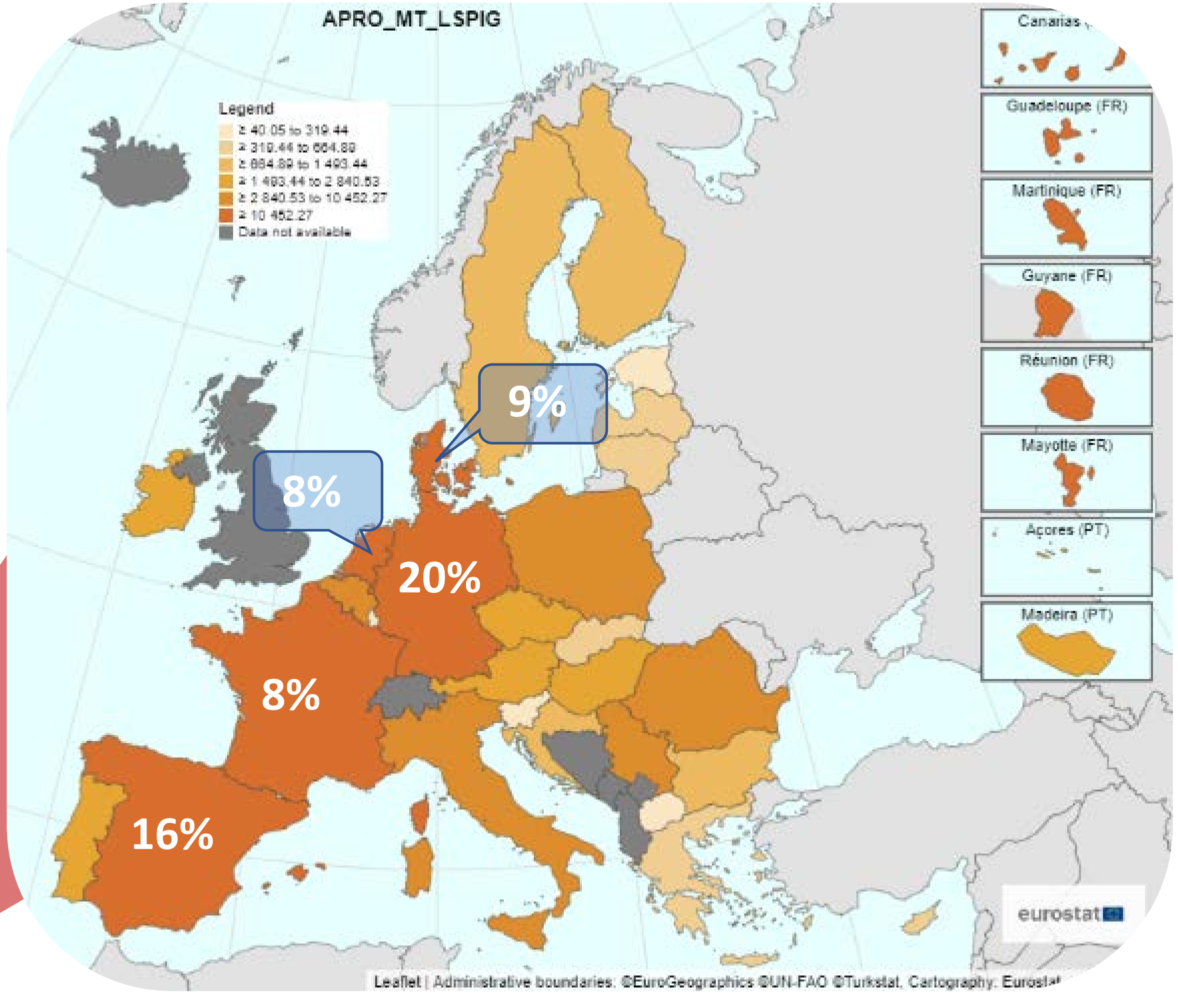
Swine crisis: Swine manure management key to tackling climate change

In the last 10 years the
swine population increase ≈ 3%
$150 \cdot 10^6$ heads in 2020

Swine manure population in EU



Spain, France, Germany, Denmark and Netherlands account for up to 60% of the total swine population

Swine crisis: Swine manure management key to tackling climate change

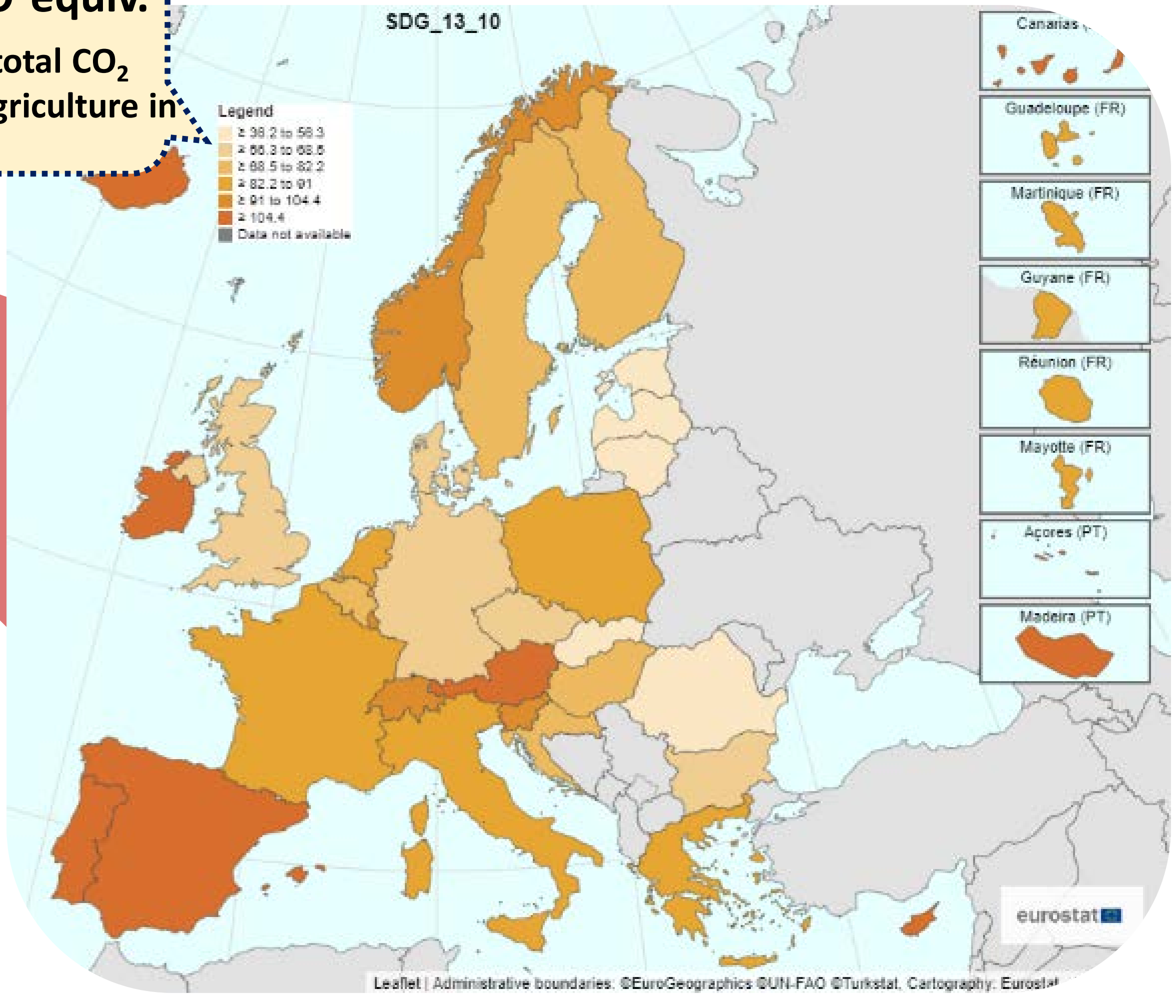
$18 \cdot 10^6$ t swine manure (SM) d.b.

In the last 10 years the swine population increase ≈ 3%
$146 \cdot 10^6$ heads in 2019

$25 \cdot 10^6$ t CO^2equiv.

≈ 7% of the total CO_2 generated by agriculture in EU

Greenhouse gases emission in EU



$3.3 \cdot 10^9$ t CO_2equiv. was generated in EU

Useful methods, insufficient for large-scale farms

Aerobic compost

90%

- Stabilization of manure
- Reduce the volume of waste
- Compost rich in organic matter and nutrients

Anaerobic digestion

6%

- Stabilization of manure
- Reduce the volume of waste
- Biogas rich in methane

Useful methods, insufficient for large-scale farms

Aerobic compost

30% Composted

- Runoff of nutrients
- Greenhouse gases emissions
- Long period of time

P N — 70% 55%

CH_4 N_2O NH_3

Anaerobic digestion

High investment

- Poor substrate biodegradability
- Low methane production
- Inhibition of the process

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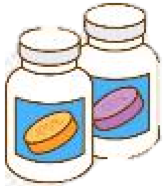

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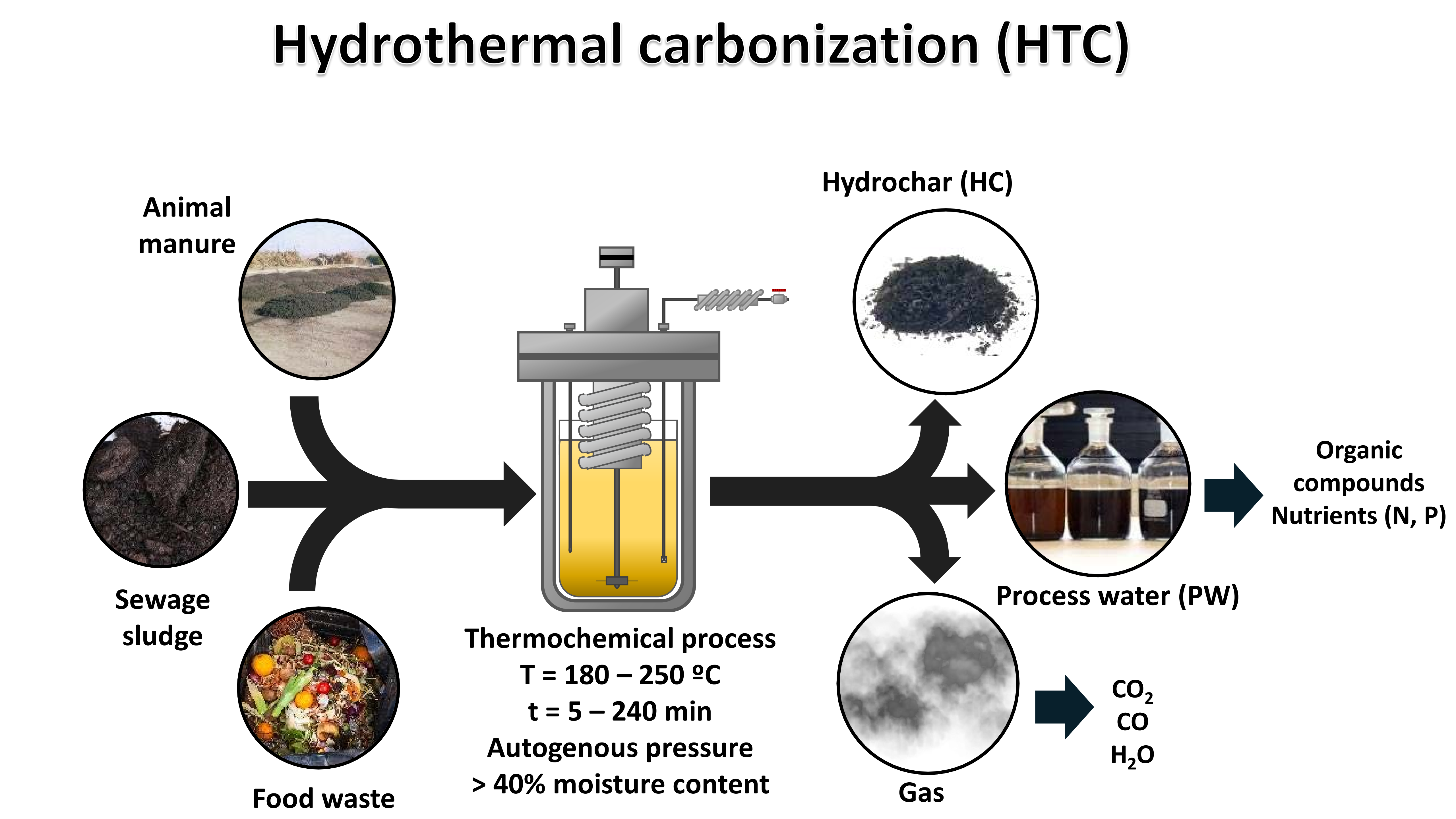
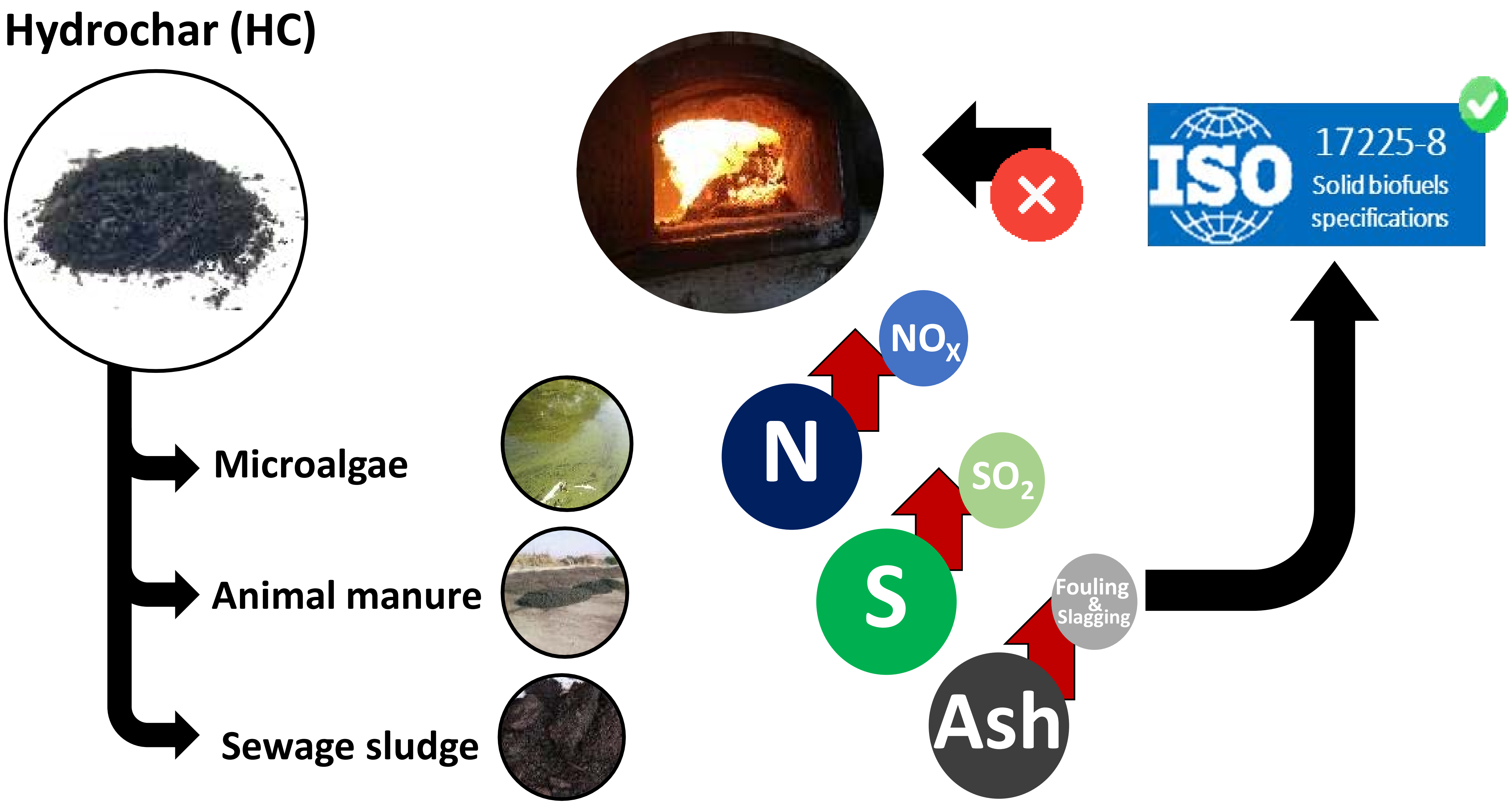
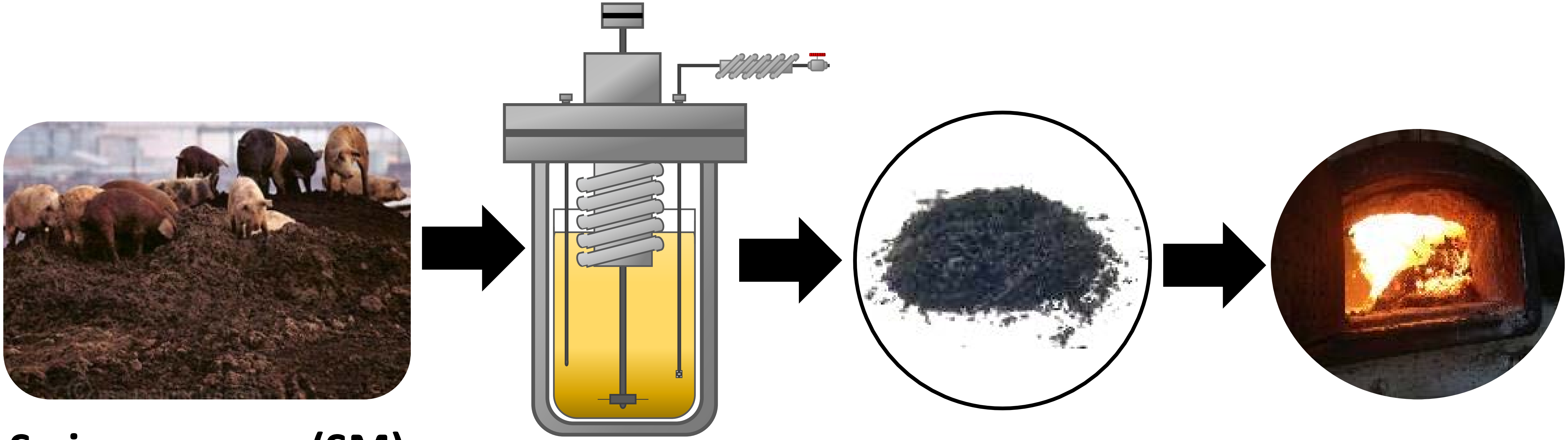

Hydrothermal carbonization (HTC)
Animal manure
Sewage sludge
Food waste
Thermochemical process
T = 180 – 250 ºC
t = 5 – 240 min
Autogenous pressure
> 40% moisture content
Hydrochar (HC)
Process water (PW)
Organic compounds
Nutrients (N, P)
Gas
CO_2
CO
H_2O

Energy production



Objective



Swine manure (SM)

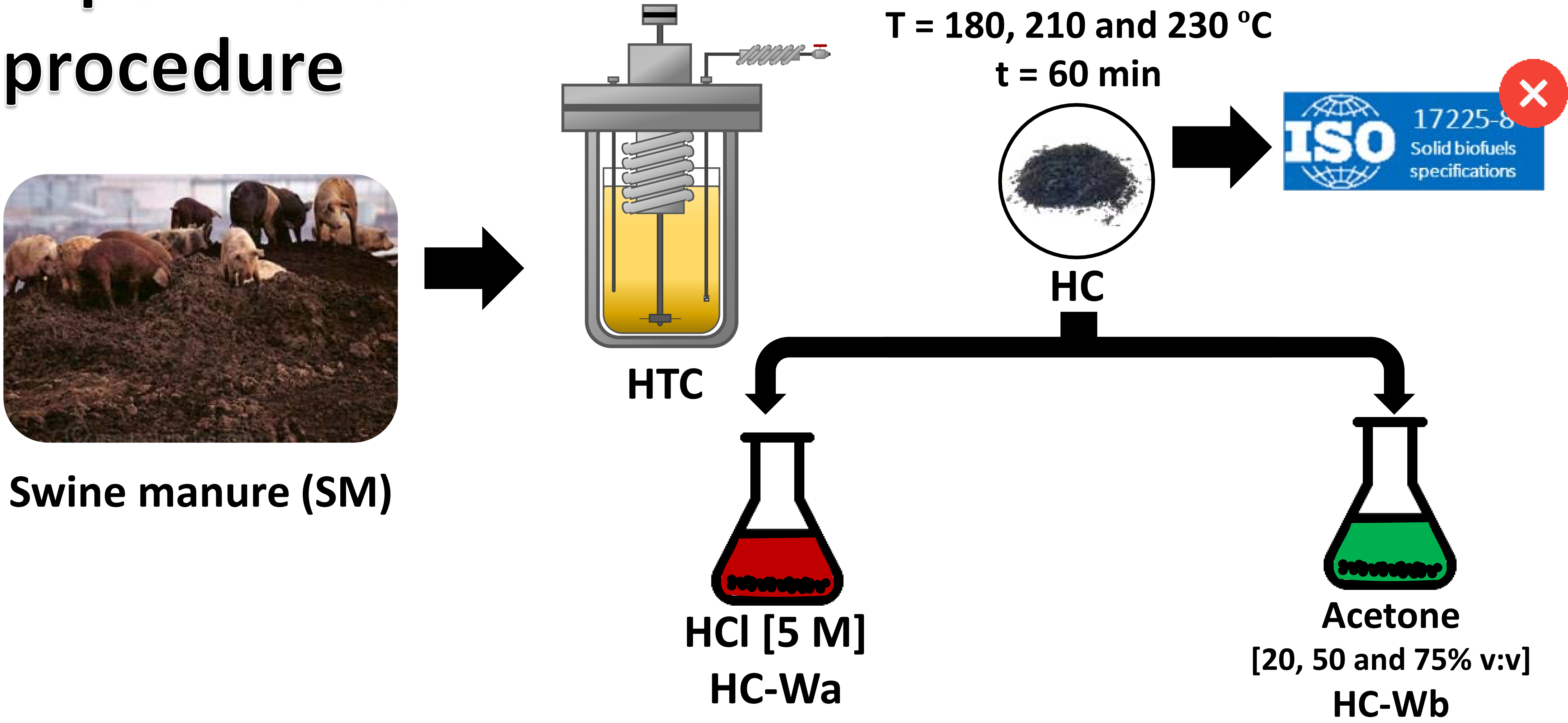
ISO 17225-8 Solid biofuels specifications

N < 3%
S < 0.5%
HHV > 17 MJ kg^{-1}

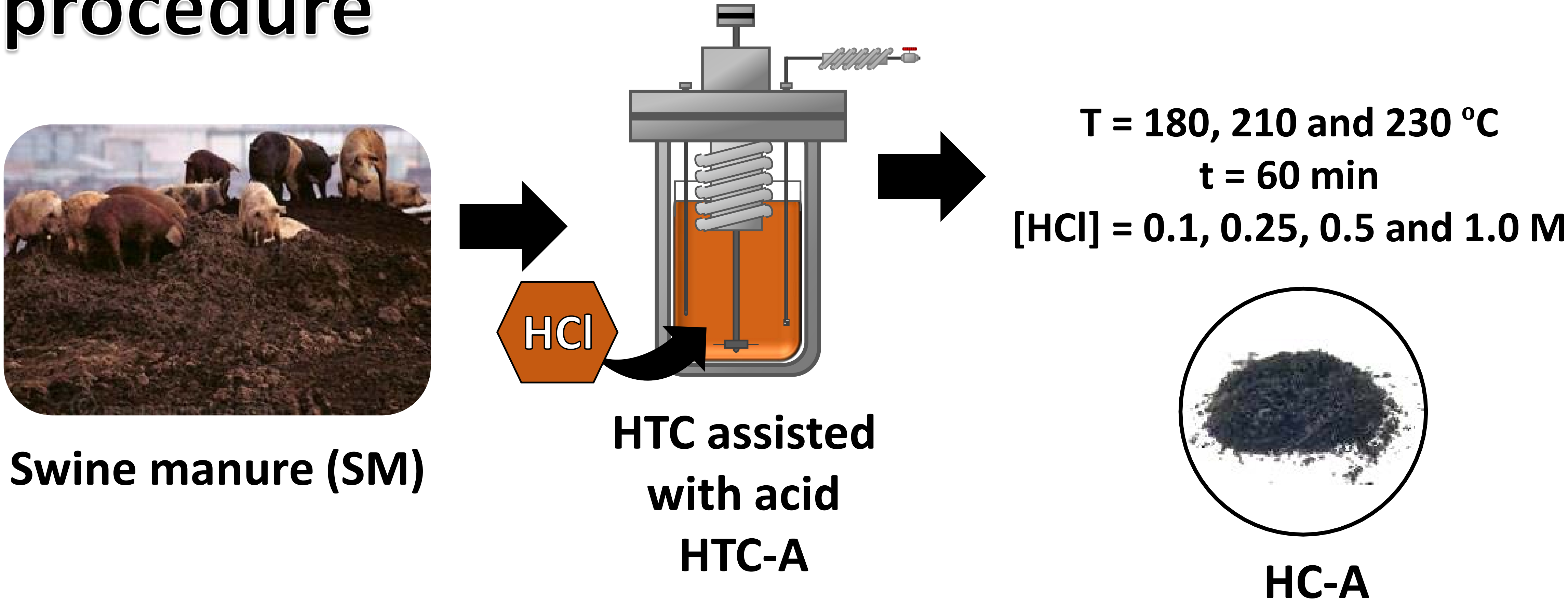
VM < 75%

Ash < 20%

Experimental procedure



Experimental procedure



Swine manure origin and characteristics

Swine manure (SM)

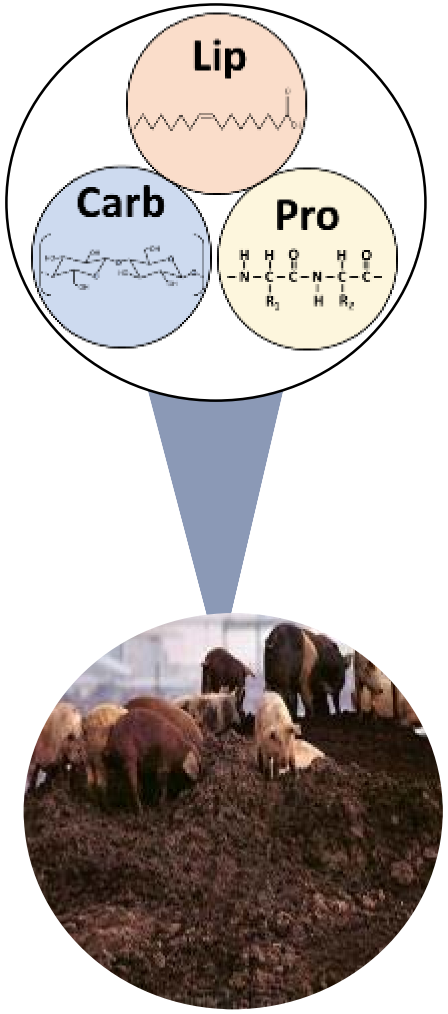
Avila – Spain

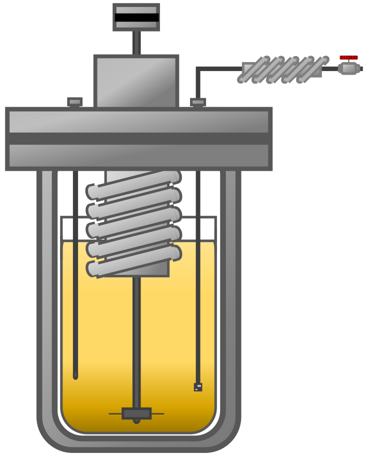
Swine manure (SM)	
C (%)	35.3 ± 0.6
N (%)	2.4 ± 0.1
S (%)	0.7 ± 0.0
HHV (MJ kg^{-1})	14.1 ± 0.3
Volatile matter (%)	60.0 ± 1.2
Fixed carbon (%)	15.7 ± 0.5
Ash (%)	24.3 ± 0.4

Metals composition (g kg^{-1})	
Ca	31.2 ± 0.2
Mg	13.5 ± 0.3
K	35.4 ± 0.2
Na	10.2 ± 0.1

Results

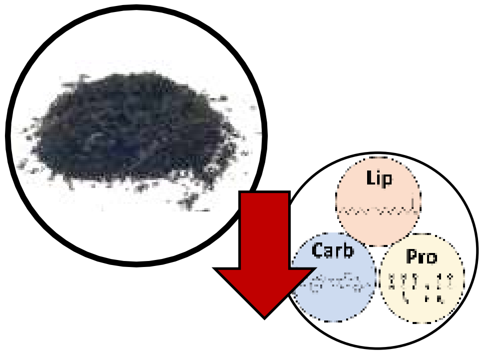
Hydrochar characteristics; Mass yield

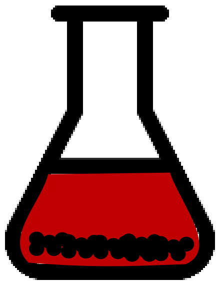




Plain HTC

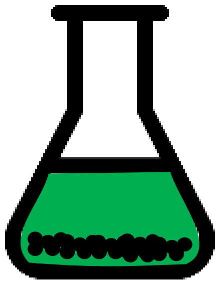
Y_{HC} = 51 – 56%





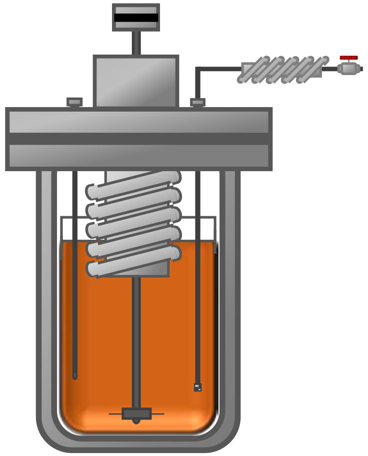
Acid washed

Y_{HC} = 28 – 39%



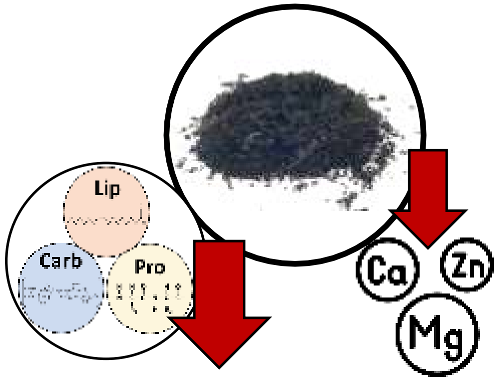
Acetone washed

Y_{HC} = ≈ 44%



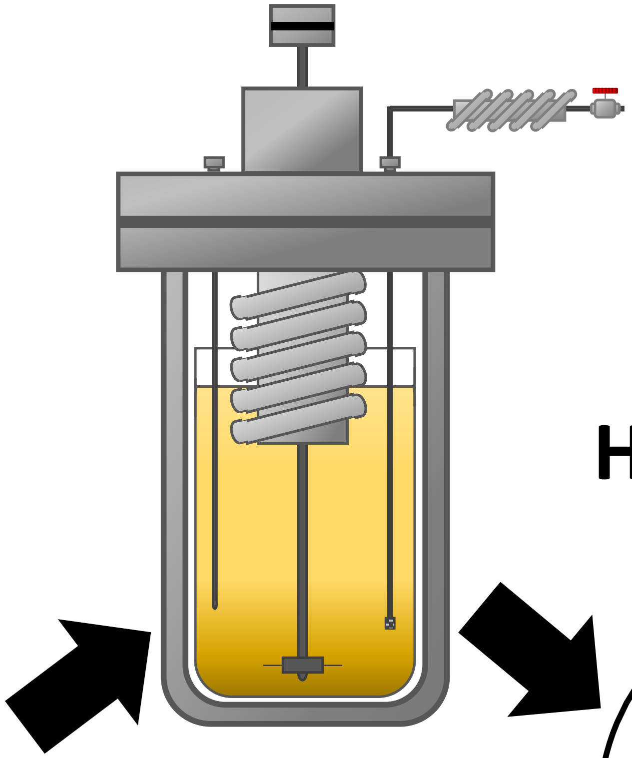
Acid-HTC

Y_{HC} = 26 – 43%



Results

<u>Hydrochar characteristics; Plain Hydrochar</u>



T = 180, 210 , 230 ^{o}C

C = 6 – 10%

HHV = 9 – 13%

ISO 17225-8 Solid biofuels specifications

N = 1.8 – 2.1%

VM ≈ 55%

HHV = 15 – 16 MJ kg^{-1}

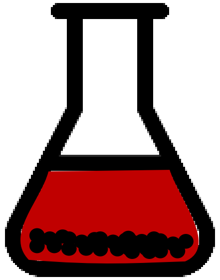
S = 0.5 – 0.7

Ash ≈ 32%

Results

Hydrochar characteristics; Washed hydrochars

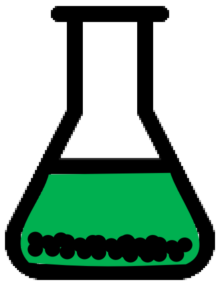
Acid washed
HC-Wa



Ash = 60 – 70%
C = 50 – 60%

Ash ≈ 50%
C ≈ 35%

Acetone washed
HC-Wb



HHV = 22 – 25 MJ kg^{-1}
N < 3%
Ash < 10%
VM < 75%

ISO 17225-8 Solid biofuels specifications

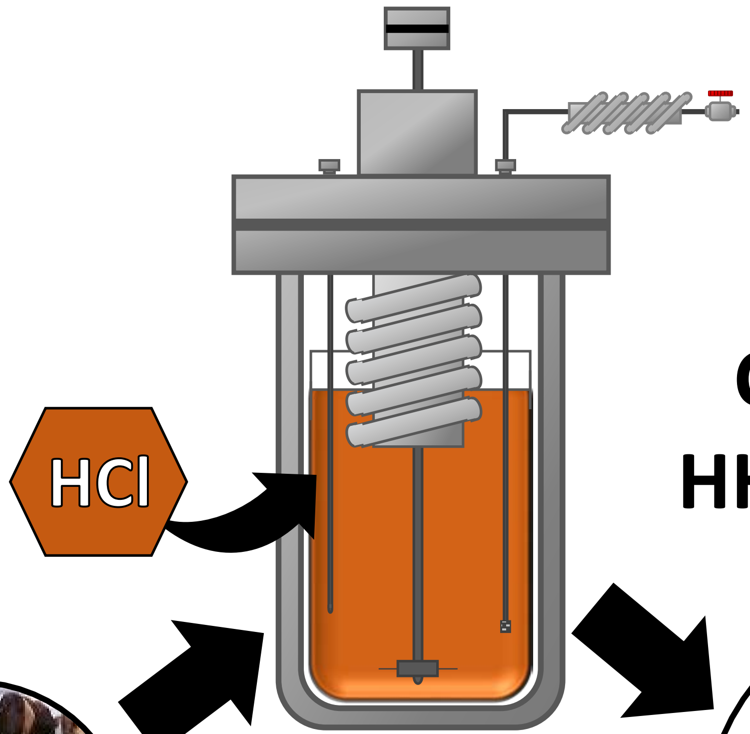
HHV ≈ 19 MJ kg^{-1}
N < 2%
Ash < 12%
VM < 75%

S = 0.5 – 0.7%

S < 0.2%

Results

Hydrochar characteristics; Acid-Hydrochars



T = 180, 210, 230 ºC

C = 10 – 60%

HHV = 20 – 70%

ISO 17225-8 Solid biofuels specifications

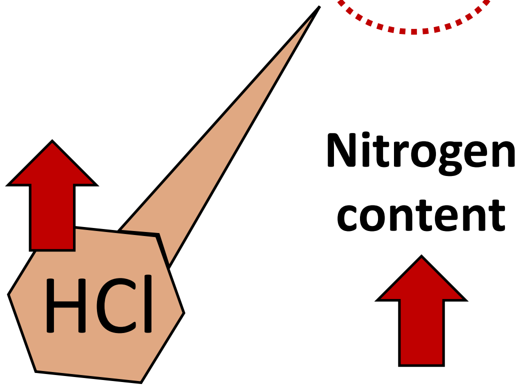
HHV = 17 – 24 MJ kg^{-1}

Ash = 8 – 15%

VM ≈ 70 %

S ≈ 0.7%

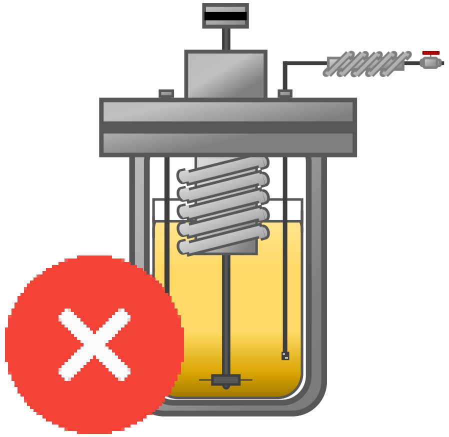
N = 2.8 – 4.0%



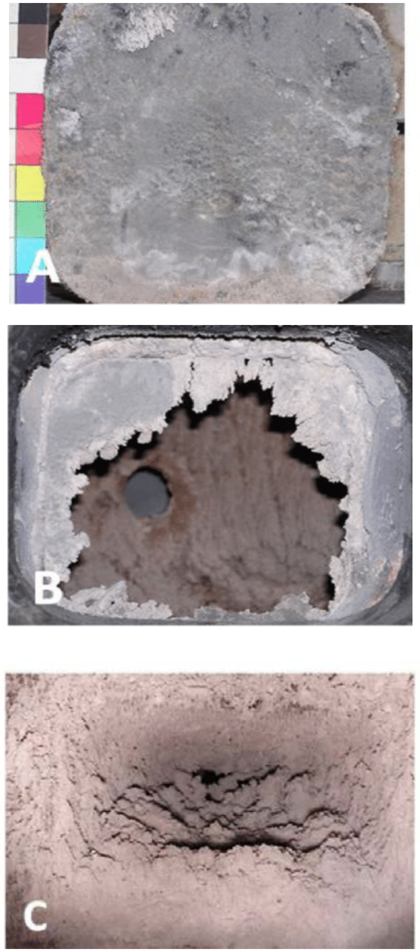
Results

Ash agglomeration; Slagging and fouling indexes

Swine manure (SM)



Plain HTC



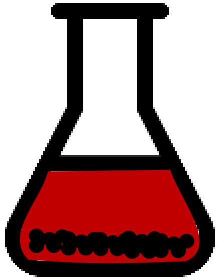
Not recommended for combustion

	Swine manure (SM)	Plain HTC
FI =	> 2000	≈ 800
SI =	> 26	≈ 14
AI =	> 4	1.2 – 1.8
	Extremely high	High

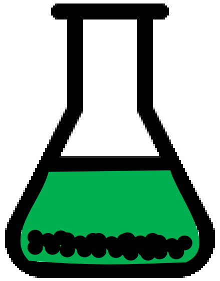
Ash deposits forming during the combustion

Results

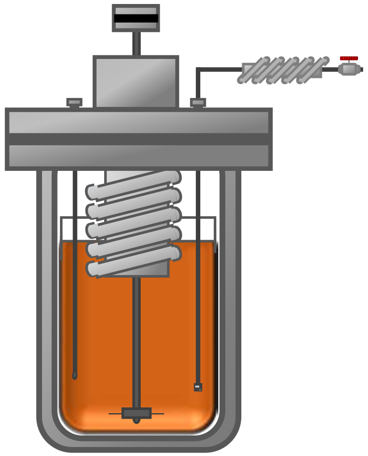
<u>Ash agglomeration; Slagging and fouling indexes</u>



Acid washed



Acetone washed



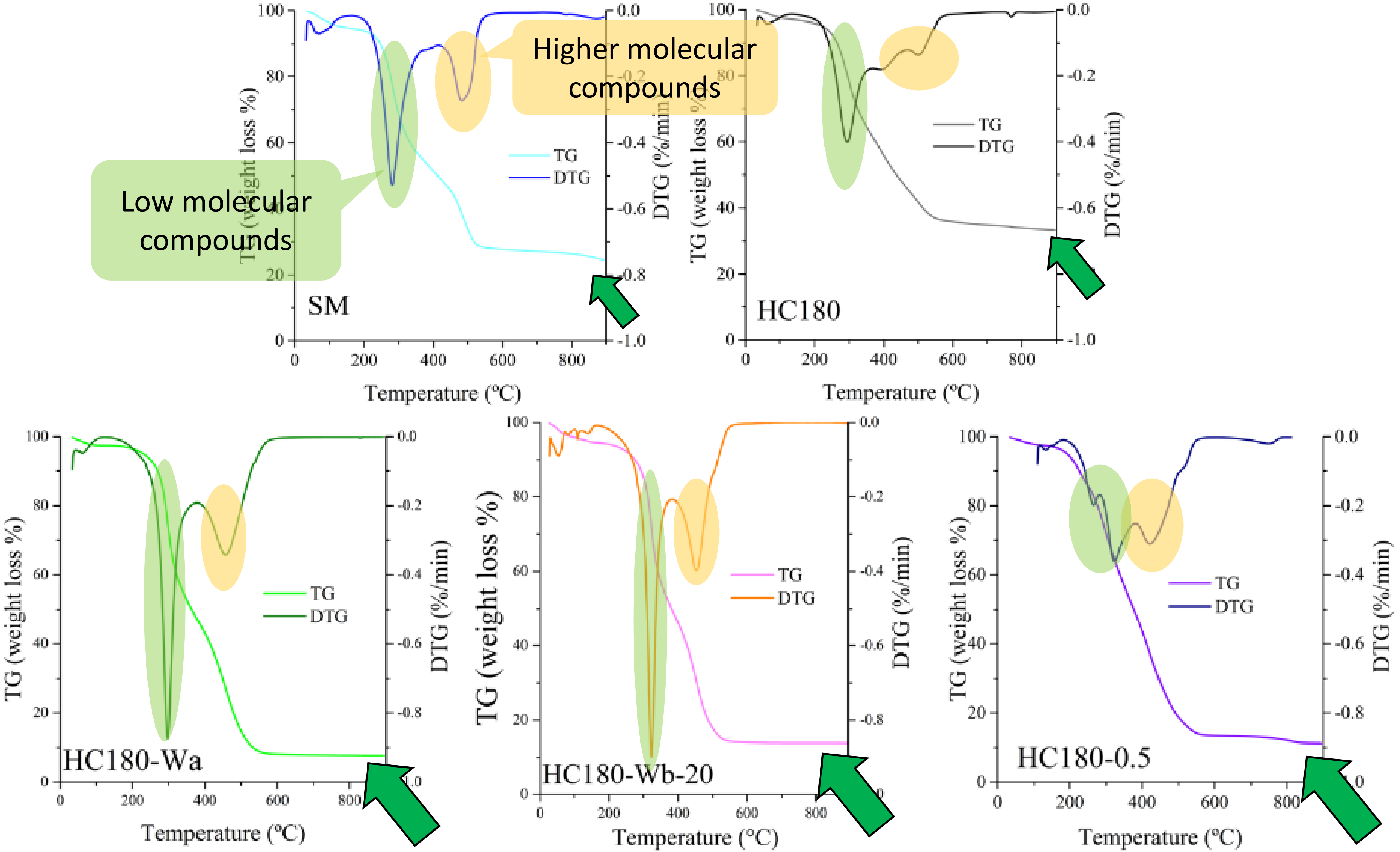
HTC-Acid

Suitable for combustion

	Acid washed	Acetone washed	HTC-Acid
FI =	1.4 – 2.3	2.5 – 5.5	31 – 45
SI =	0.9 – 1.8	0.1 – 0.3	2.5 – 5.0
AI =	0.2	0.1	0.5 – 0.8
	Low	Low	Low-medium

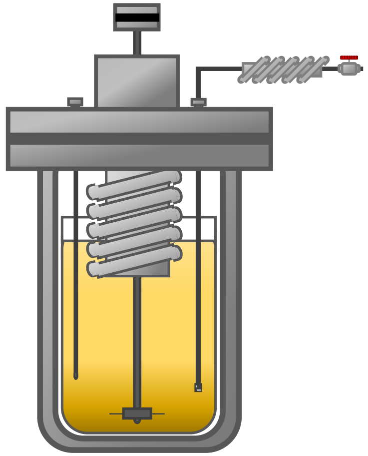
Results

Thermogravimetric analysis; Kinetic and combustion properties



Results

Thermogravimetric analysis; Kinetic and combustion properties



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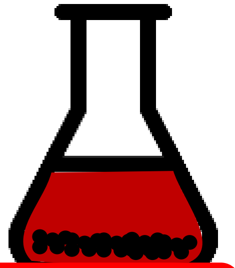
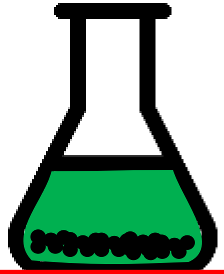


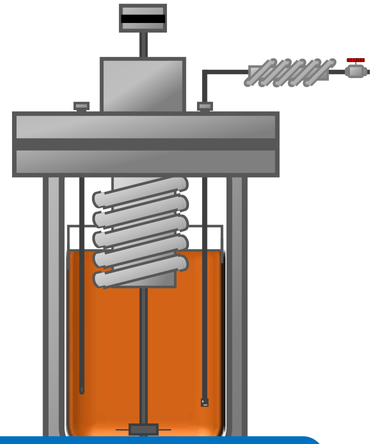
Higher content of fixed carbon

d



Higher content of fixed carbon

ed



Higher content of volatile matter

Ea =	55 – 68	104 – 184	110 – 118	44 – 49
CCI $\cdot 10^7$=	5.6 – 6.2	6.3 – 8.9	≈ 10.6	7.5 – 9.9

Higher and properly combustion stability

In summary

- Plain HTC slight improved the hydrochar energy characteristics

ISO 17225-8 Solid biofuels specifications

- Hydrochar washing using hydrochloric acid

Energy densification
and
Combustion performance

S > 0.5%

ISO 17225-8 Solid biofuels specifications

In summary

- **Hydrochar washing using acetone**

ISO 17225-8 Solid biofuels specifications

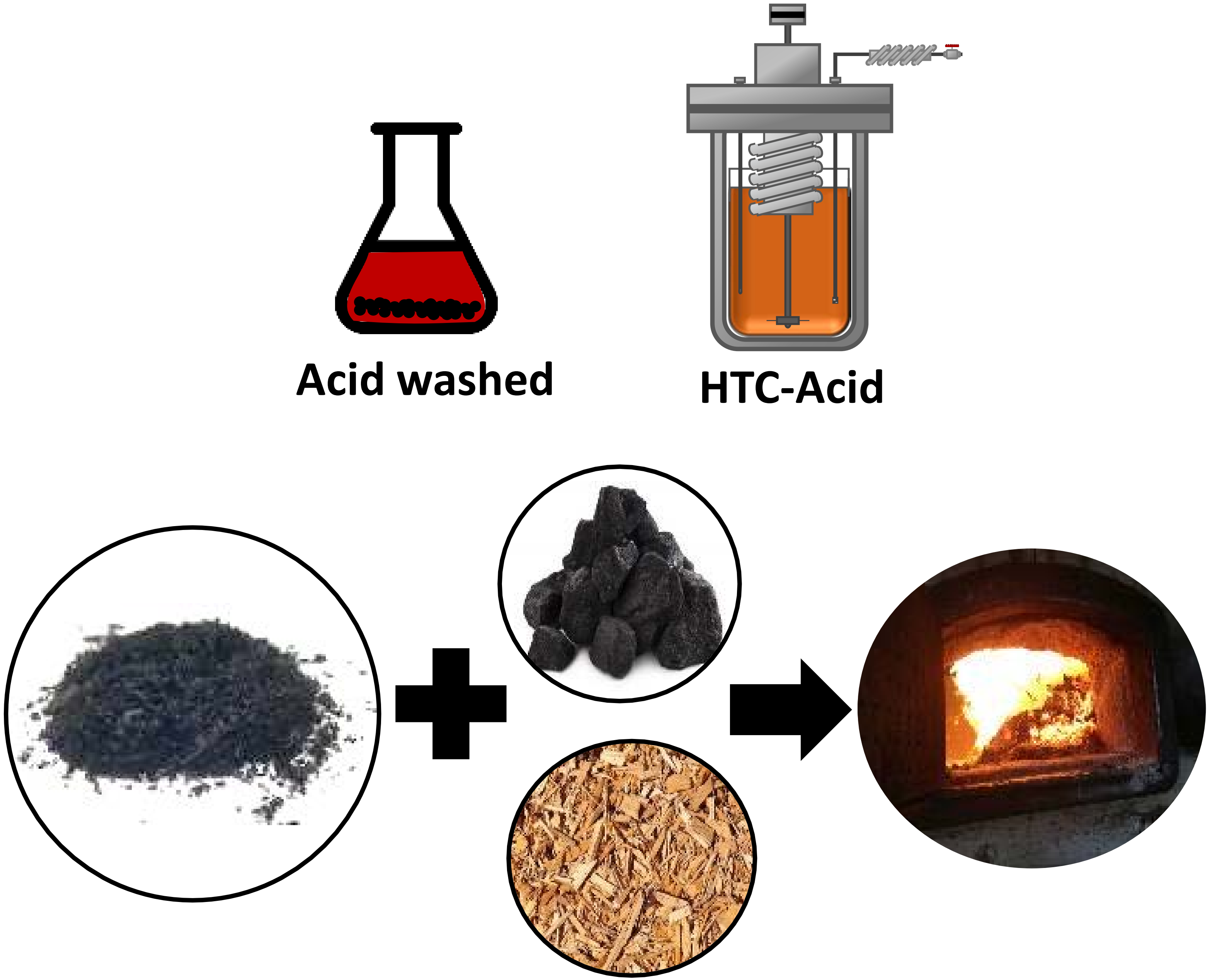
- **Acid-assisted HTC**

Acid concentration and temperature

N > 3%
S > 0.5%

In summary

- Blending is necessary



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THANK YOU

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