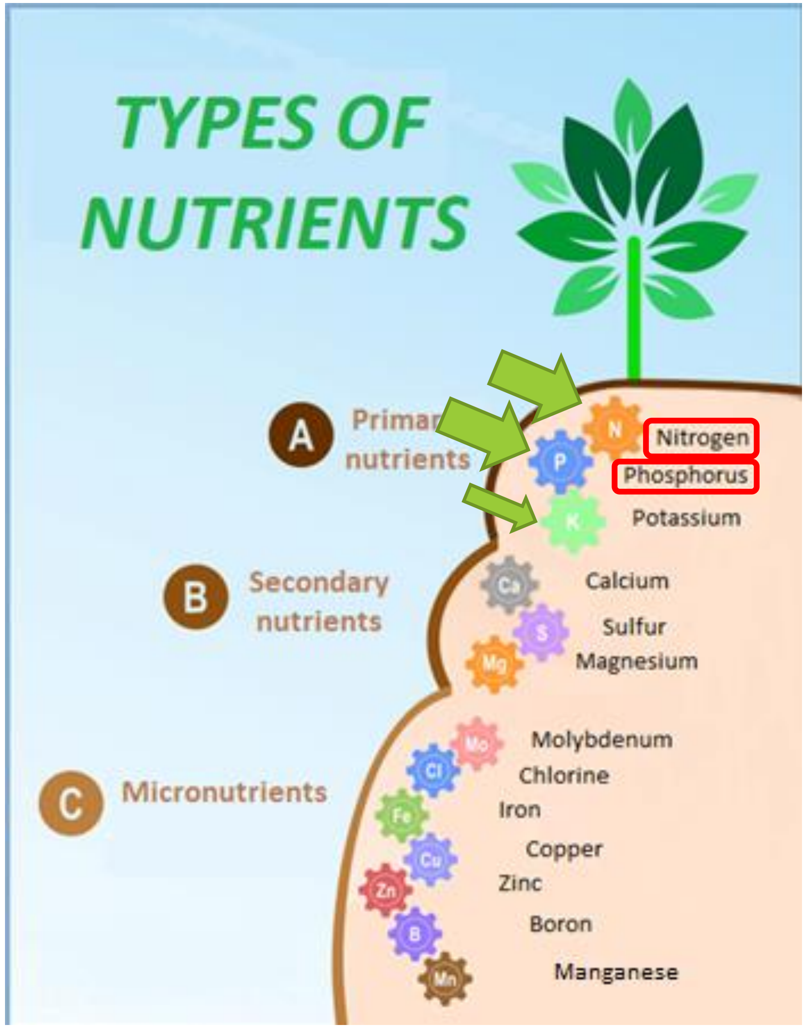
9th International Conference on Sustainable Solid Waste Management
CORFU 2022

Nutrient and energy recovery from chicken meat & bones meal by hydrothermal treatment and anaerobic digestion

Andres Sarrion, Ricardo P. Ipiales, M. Angeles de la Rubia, Angel F. Mohedano, Elena Diaz

UAM Universidad Autónoma de Madrid

IQUAM
Departamento de Ingeniería Química
Universidad Autónoma de Madrid


TYPES OF
NUTRIENTS
A
Primar
nutrients
Nitrogen
Phosphorus
Potassium
B
Secondary
nutrients
Calcium
Sulfur
Magnesium
C
Micronutrients
Molybdenum
Chlorine
Iron
Copper
Zinc
Boron
Manganese


N N
N N
You shall not pass!!


50 years later…
Nice! There is not much Phosphorus!

Types of organic waste

Biomass rich in nutrients

Sewage sludge

Animal manure

Food waste

Non suitable biomass for nutrient recovery

Garden & park waste
Chicken Meat & Bones Meal (C-MBM)

Type of organic waste	TP g/kg	TN g/kg
Sewage sludge	20-30	60-70
Animal manure	15-20	30-35
Food waste	3-40	25-90
Chicken Meat & Bones Meal (C-MBM)	25-35	70-80

Chicken Meat & bone meal (C-MBM)

Rising development of livestock sector

Restricted as animal feed

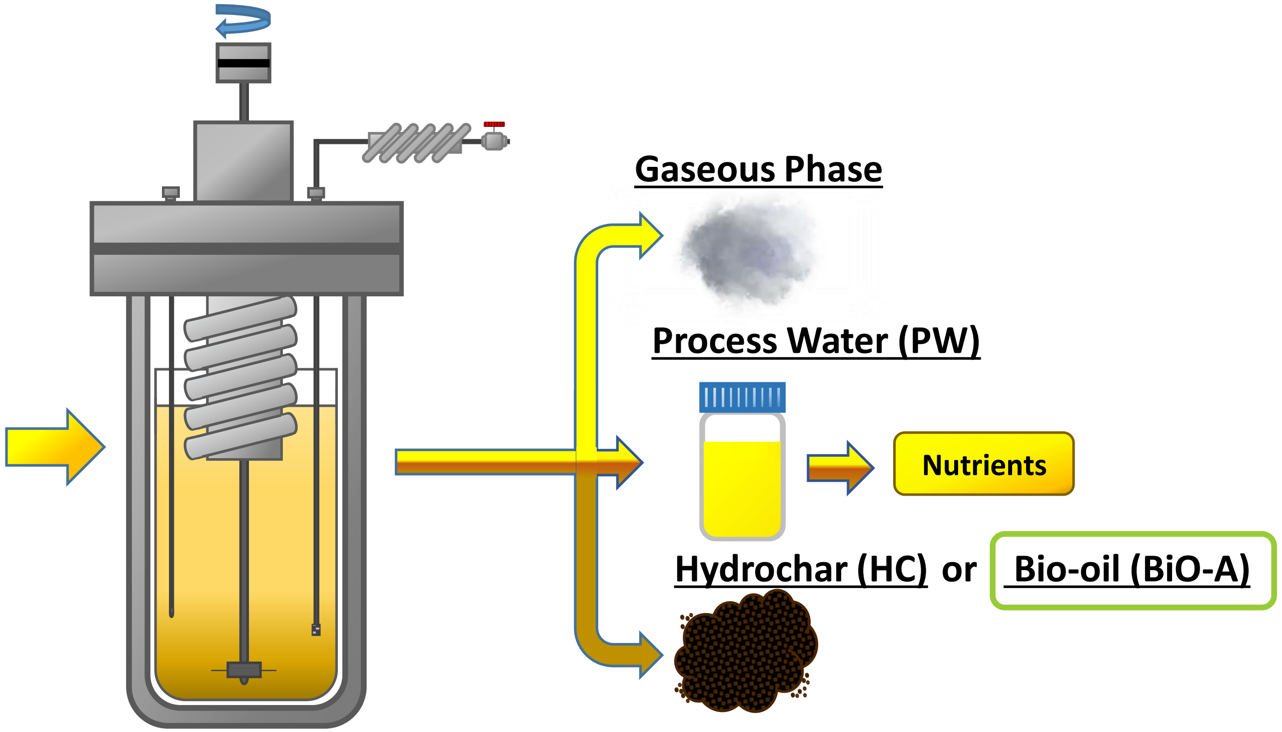
fossil-fuel replacement

High costs in fouling management

New applications for circular economy

Hydrothermal Carbonization process (HTC)

C-MBM	
Total nitrogen (g/kg)	79
Total phosphorus (g/kg)	27
Solid content (%)	10



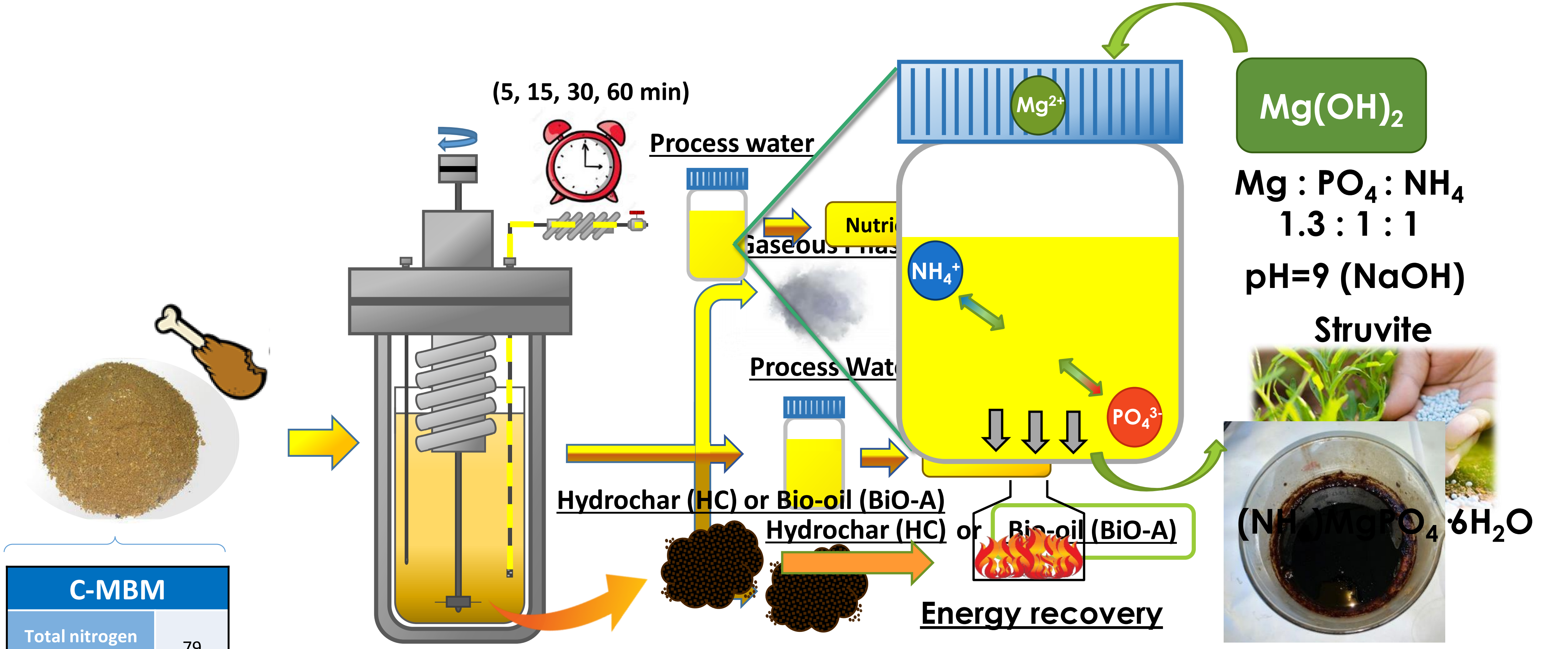
HTC + **0.5 M HCl**

170 – 230 ºC
1h

- Exothermic reaction
- Self-generated pressure

- **Substitute of fossil fuel**
- Phenolic compounds recovery
- Asphalt industry

Hydrothermal Carbonization process (HTC)



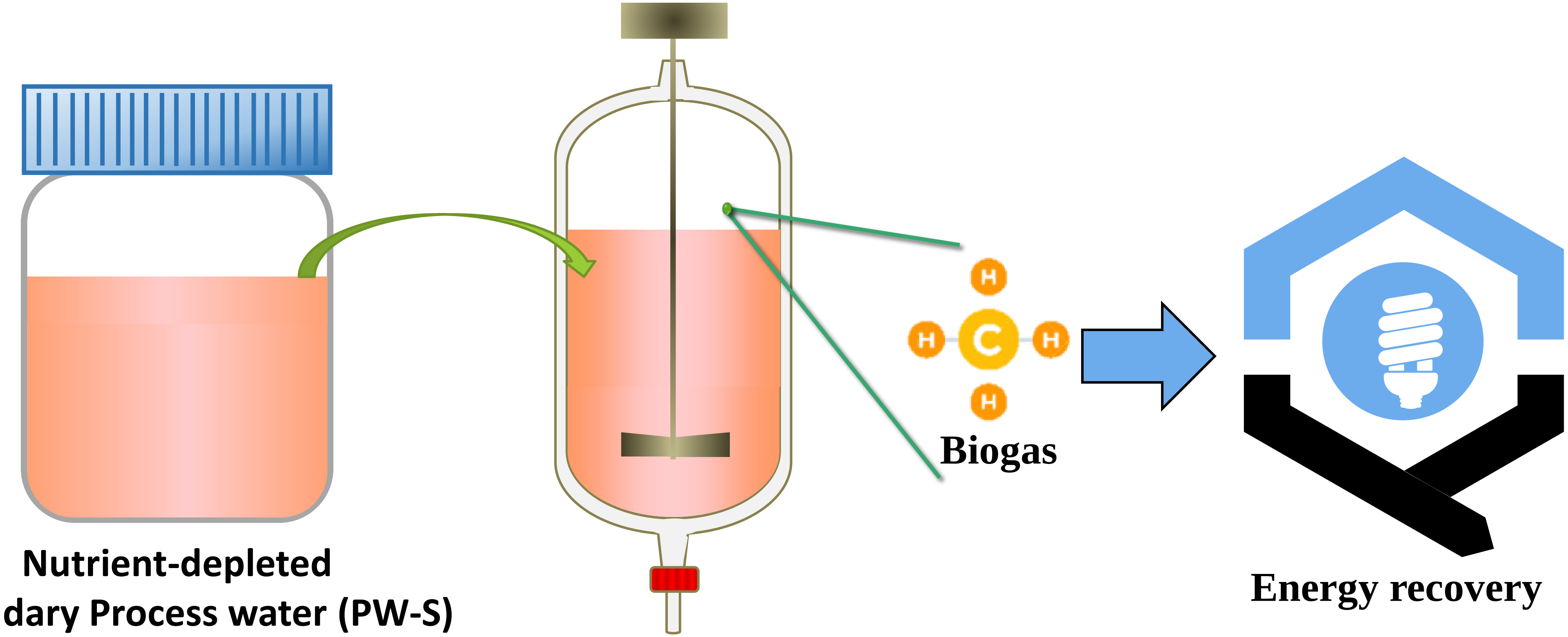
C-MBM	
Total nitrogen (g/kg)	79
Total phosphorus (g/kg)	27
Solid content (%)	10

HTC + **0.5 M HCl**

170 – 230 ºC
1h

- Substitute of fossil fuel
- Phenolic compounds recovery
- Asphalt industry

Anaerobic Digestion process (AD)



Nutrient-depleted
Secondary Process water (PW-S)

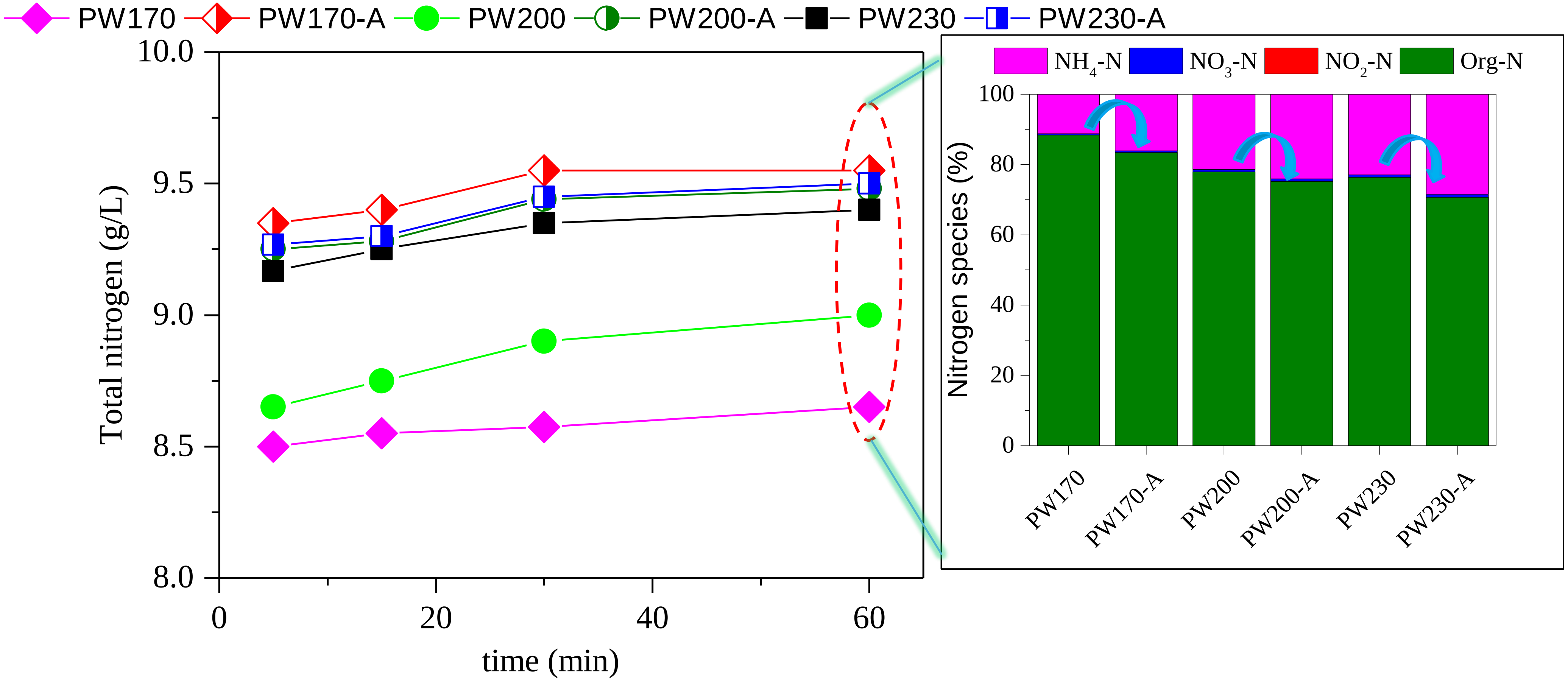
Mesophilic
Anaerobic Digestion (AD)

Energy recovery

OBJECTIVE

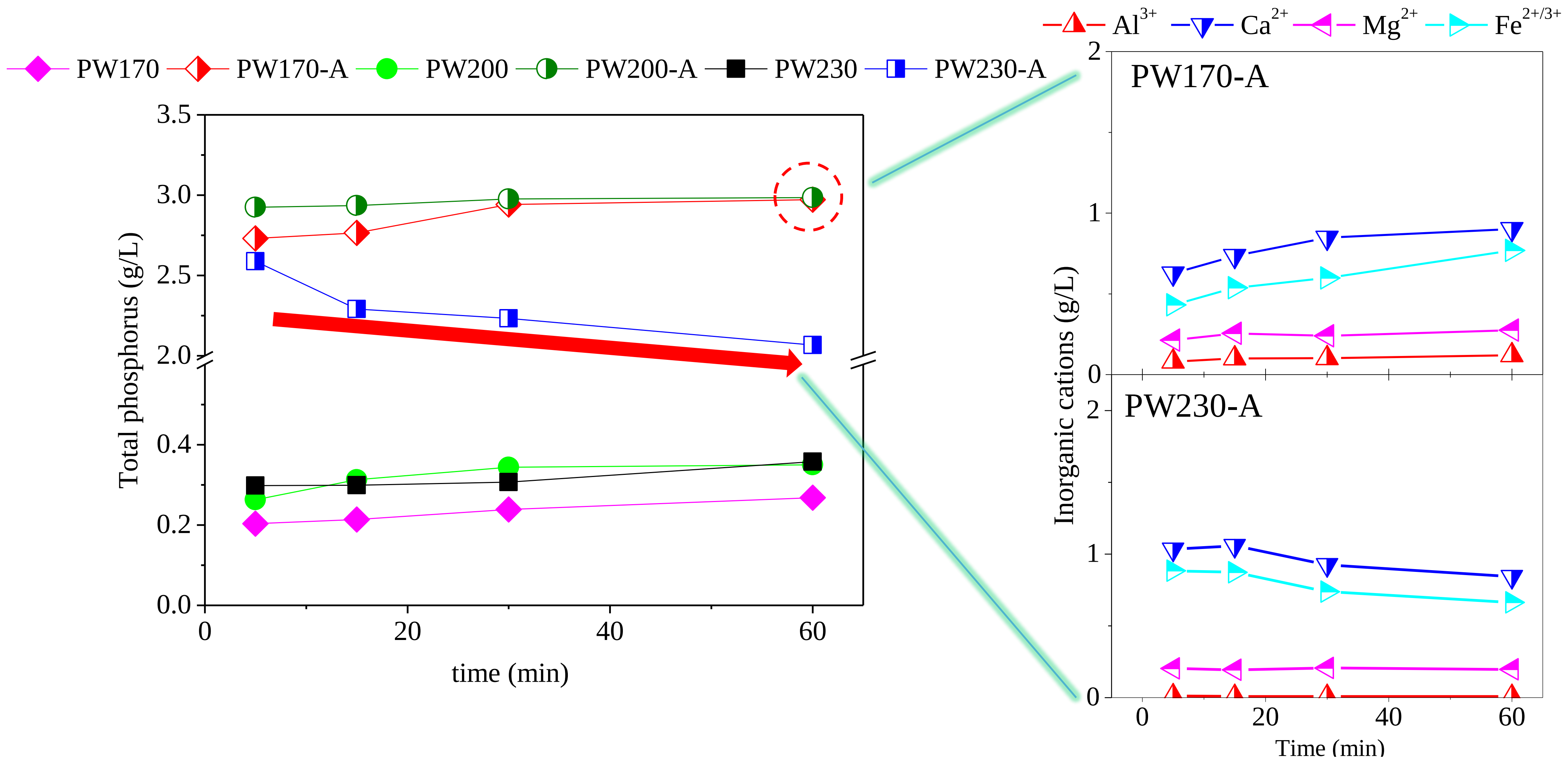
To evaluate the nutrient recovery from the process water obtained in the hydrothermal treatment of C-MBM and the energy recovery of both hydrochar and process water, free of nutrients, via combustion and anaerobic digestion, respectively.

Fate of nutrients



Time course of nitrogen in process water for acid-free and HCl-mediated HTC

Fate of nutrients

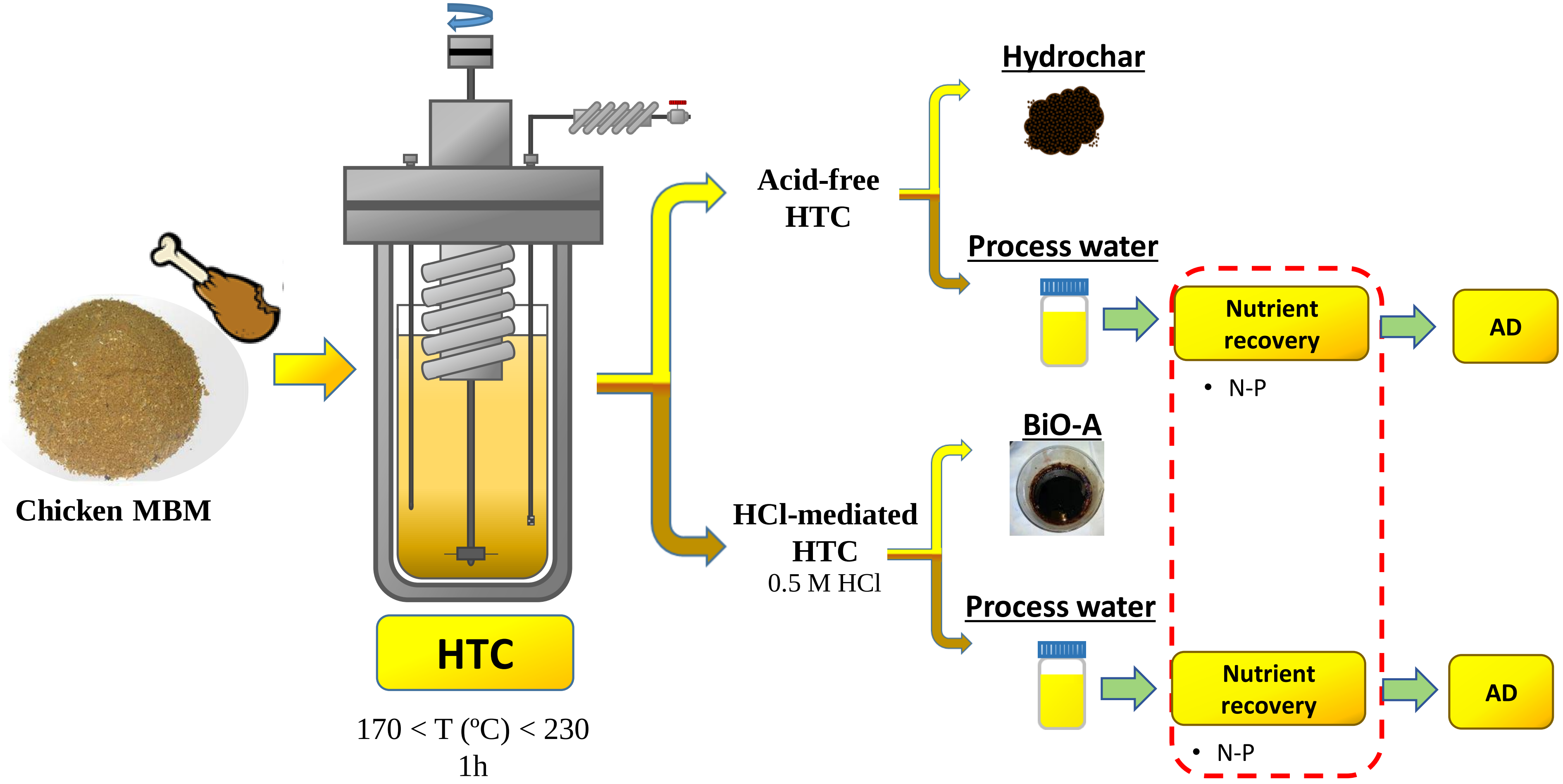


Time course of phosphorus in process water for acid-free and HCl-mediated HTC

Concentration of nutrients in process water

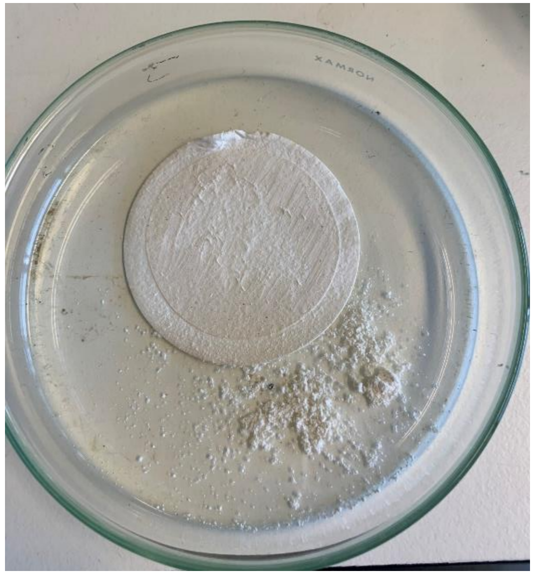
Operating conditions (T, t, HCl)	N / NH_4-N		P	
	($g/kg_{C\text{-}MBM}$)	(%)	($g/kg_{C\text{-}MBM}$)	(%)
170 ºC, 60 min	72/ 8.1	90 / 10	2.2	8
170 ºC, 60 min, 0.5 M	80 / 13	100 / 16	25.4	95
200 ºC, 60 min	75/ 15.9	94 / 20	2.9	11
200 ºC, 60 min, 0.5 M	80 / 20	100 / 25	25.6	95

Nutrient recovery: Struvite precipitation



Nutrient recovery: Struvite precipitation

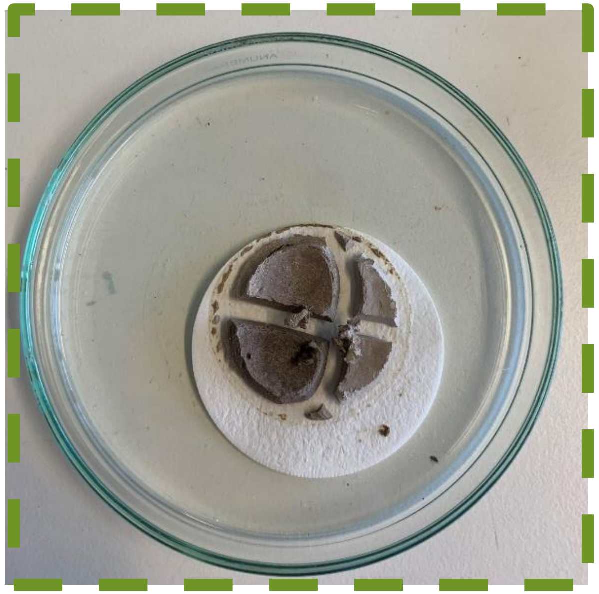
a) **ST170**



b) **ST200**

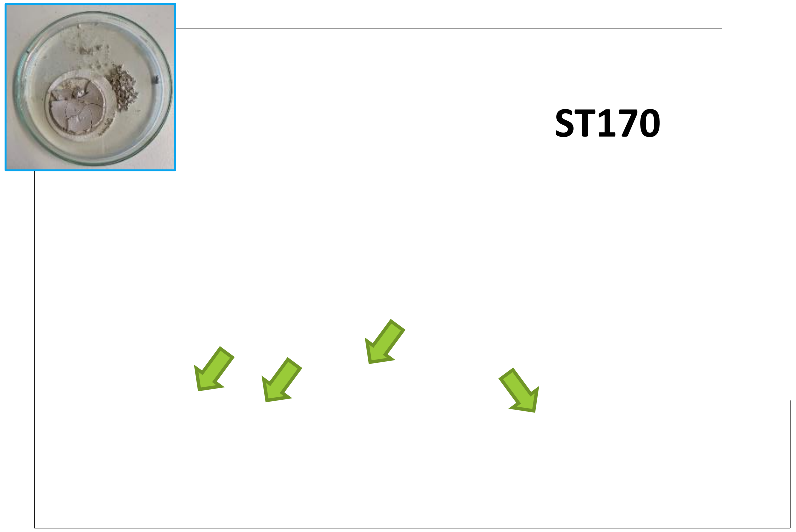
c) **ST170-A**

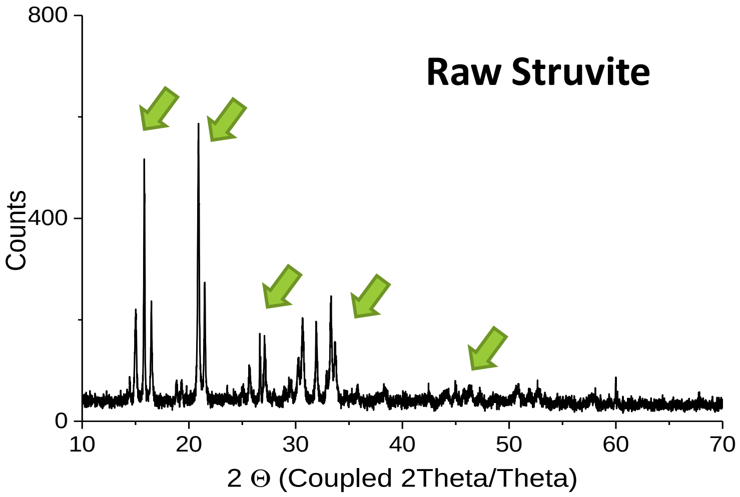
d) **ST200-A**

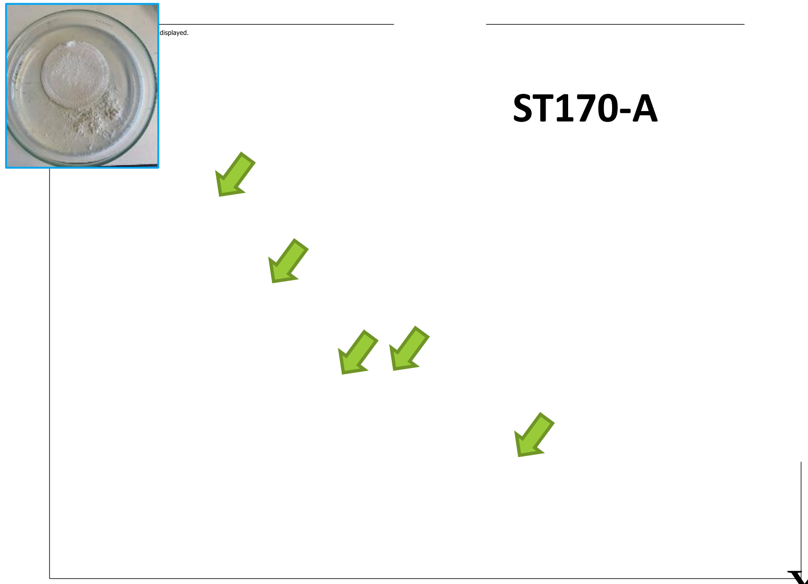


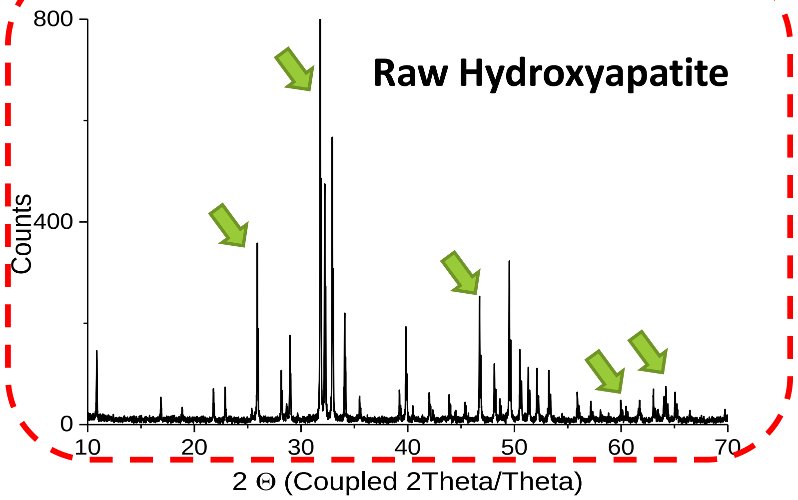
Resulting precipitates [a) ST170, b) ST200, c) ST170-A and d) ST200-A] from chemical precipitation of process water

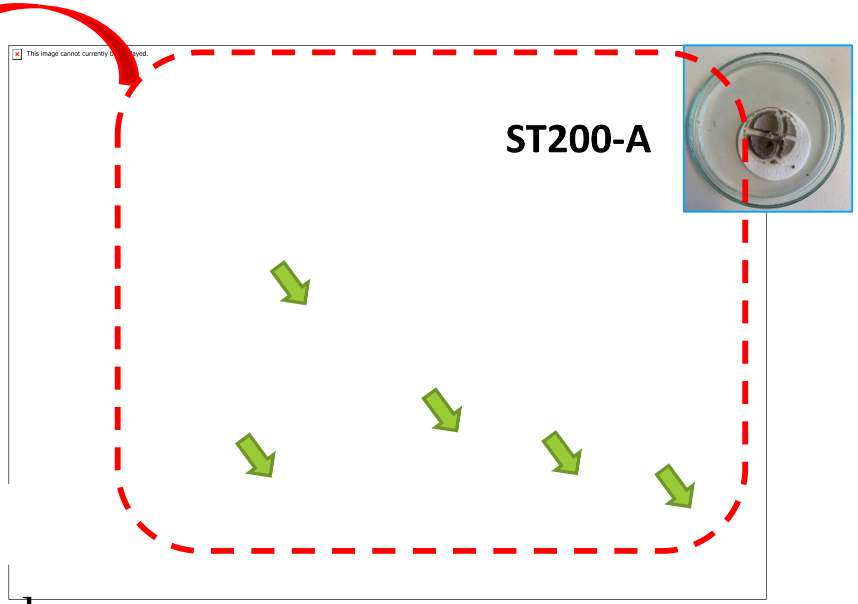
Characterization of precipitates











X-ray diffractogram of precipitate samples

Characterization of process waters

Characterization of process waters and secondary process waters

	PW170	PW200	PW170-A	PW200-A	PW170-S	PW200-S	PW170-A-S	PW200-A-S
pH	6.5±0.1	6.8±0.1	1.5±0.1	1.8±0.1	8.1±0.1	8.3±0.1	8.1±0.1	8.2±0.1
TN (mg/L)	8,700±0.1	9,000±0.1	9,600±0.1	9,500±0.1	5,800±0.2	5,400±0.2	5,700±0.1	4,600±0.1
NH_4-N (mg/L)	1,000±0.1	1,900±0.1	1,500±0.1	2,300±0.1	600±0.0	600±0.1	400±0.0	600±0.0
Org-N (mg/L)	7,700±0.1	7,000±0.1	8,000±0.1	7,100±0.1	5,200±0.2	4,800±0.2	5,300±0.2	4,000±0.1
PO_4-P (mg/L)	268±1.6	350±1.2	2973±1.2	2984±1.3	< 0.1±0.0	< 0.1±0.0	1.0±0.2	0.5±0.1
Ca (mg/L)	0.7±0.0	0.3±0.0	900±6.0	885±4.1	< 0.1±0.0	< 0.1±0.0	401±1.0	0.1±0.0
Mg (mg/L)	0.9±0.0	0.6±0.0	110.1±0.2	124.8±0.1	< 0.1 ±0.0	< 0.1±0.0	4.3±0.2	1.5±0.1

Anaerobic digestion

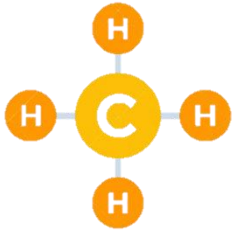
Characterization of secondary process waters

	PW170-S	PW200-S	PW170-A-S	PW200-A-S
pH	8.1±0.1	8.3±0.1	8.1±0.1	8.2±0.1
TCOD (g/L)	74.1±0.9	80.5±0.3	64.7±0.6	60.7±1.7
TS (g/L)	58.2±1.1	61.0±0.3	79.5±1.0	75.5±0.5
VS (g/L)	52.3±1.8	56.0±0.0	50.7±1.0	47.6±1.4
TVFA (g acetic acid/L)	0.6±0.0	0.6±0.0	0.5±0.0	0.5±0.0
NH_4-N (g/L)	0.6±0.0	0.6±0.1	0.4±0.0	0.6±0.0

Biomethane potential test

ISR = 2

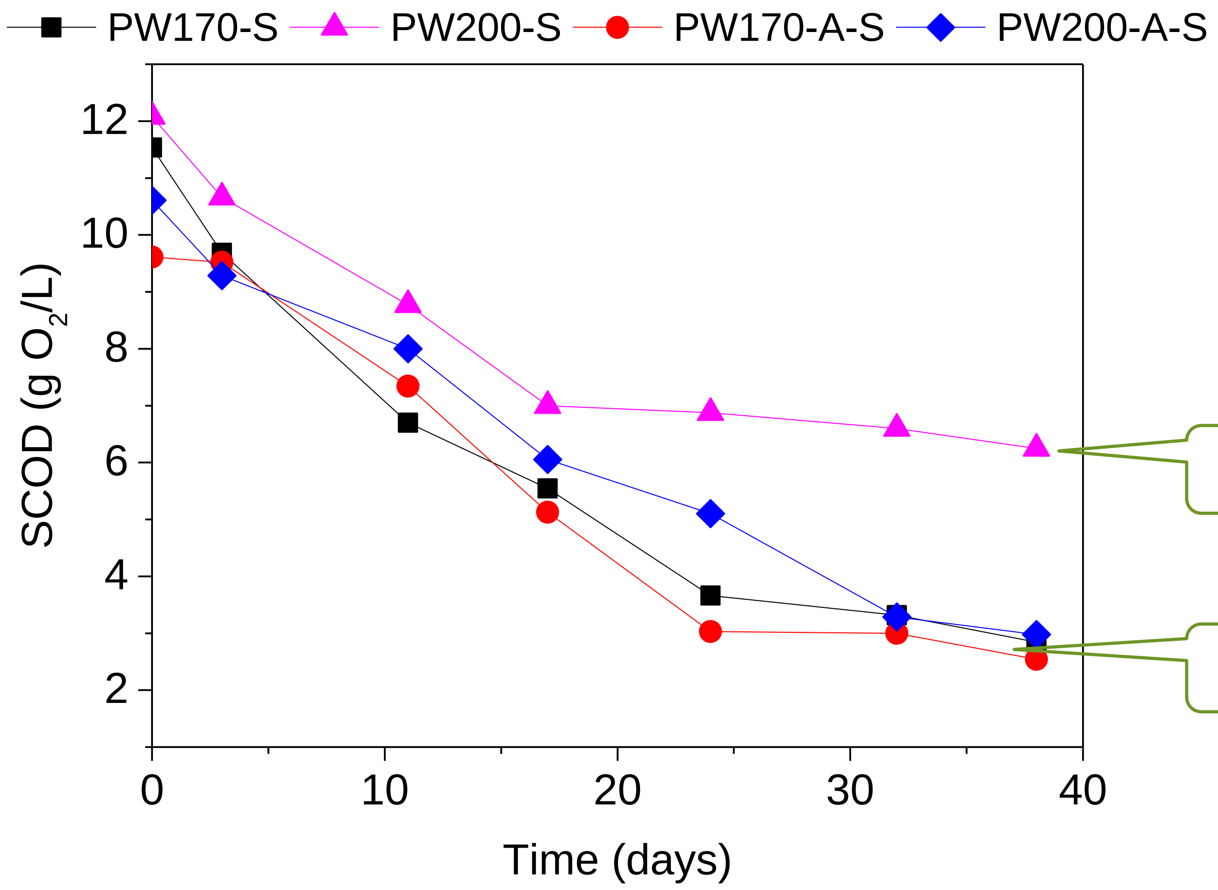
- 15 g VS/L granular anaerobic sludge
- 7.5 g VS/L substrate



Anaerobic digestion

- ✓ pH (8.1 – 8.3)
- ✓ Alkalinity (> 2.5 g $CaCO_3$/L)
- ✓ Total ammonia nitrogen (1700 mg/L < inhibition values)

➡ **Adequate for the AD process**

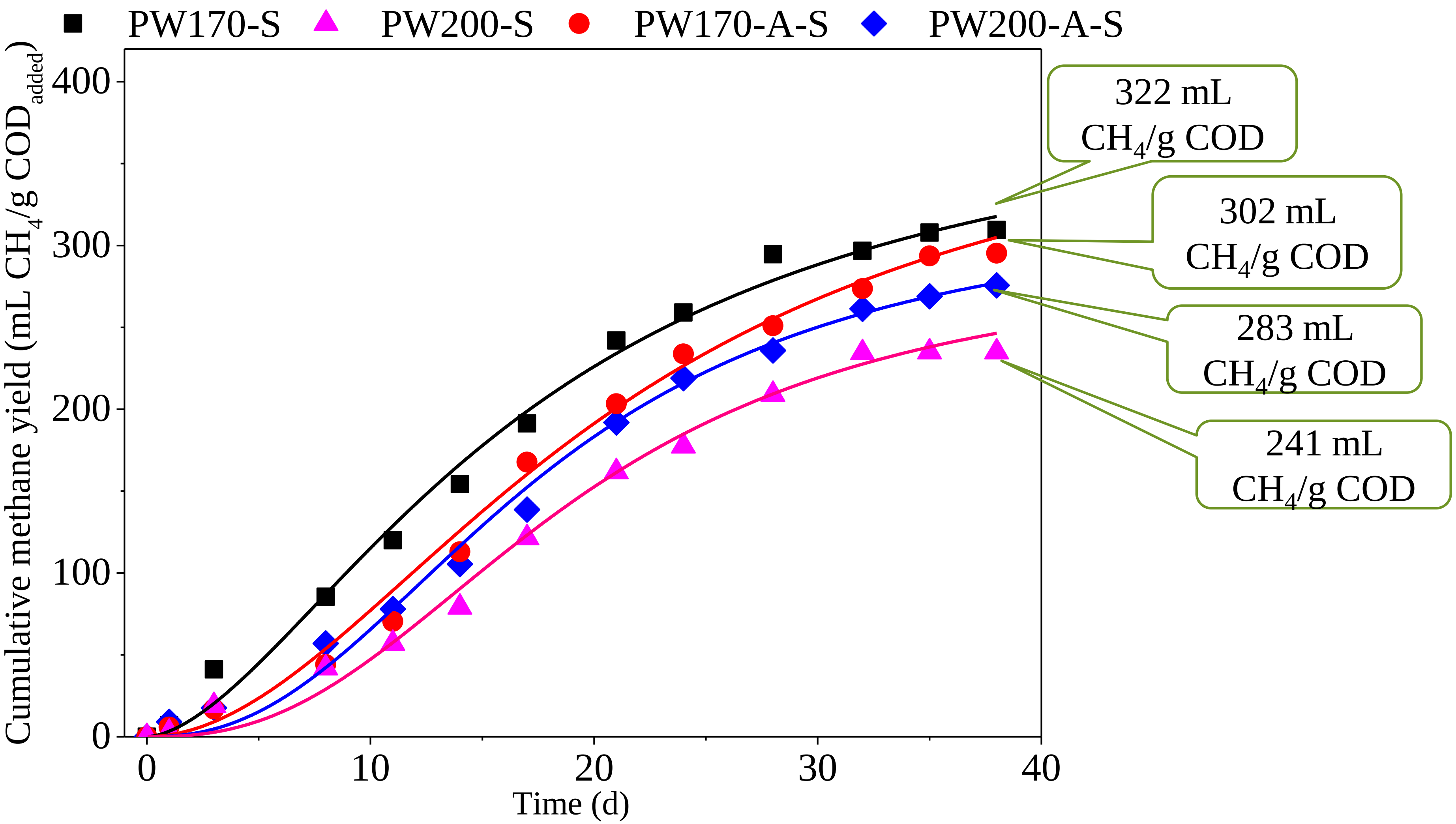


48%

71 - 75%

COD removal

Anaerobic digestion



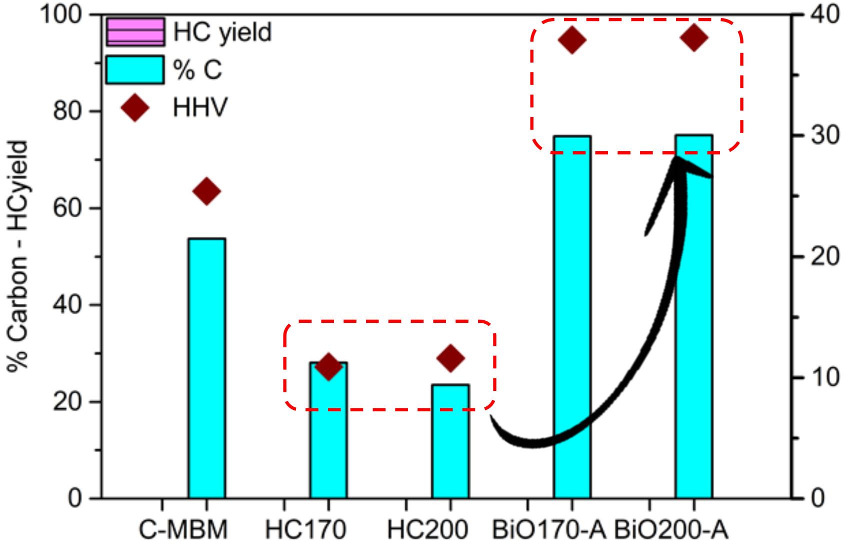
C-MBM

*410-430 mL CH_4/g COD

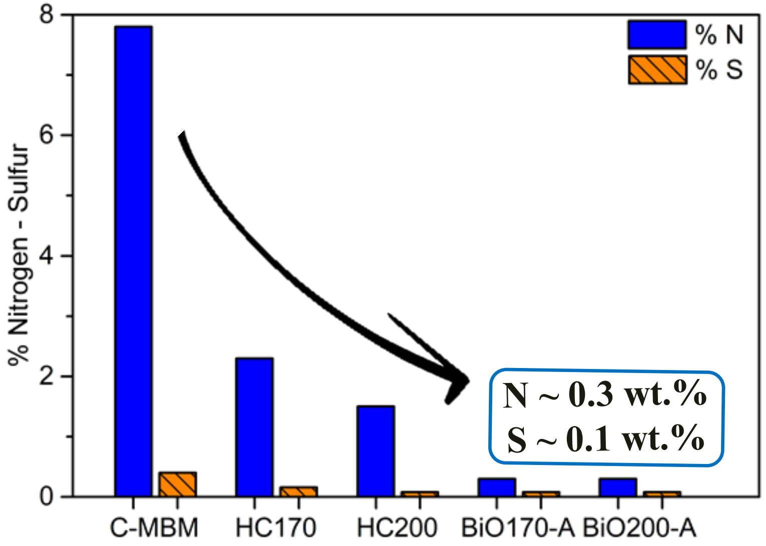
* F.J. Andriamanohiarisoamanana et al. 2017. Energy for Sustainable Development 40 11–18

Characterization of solid phase

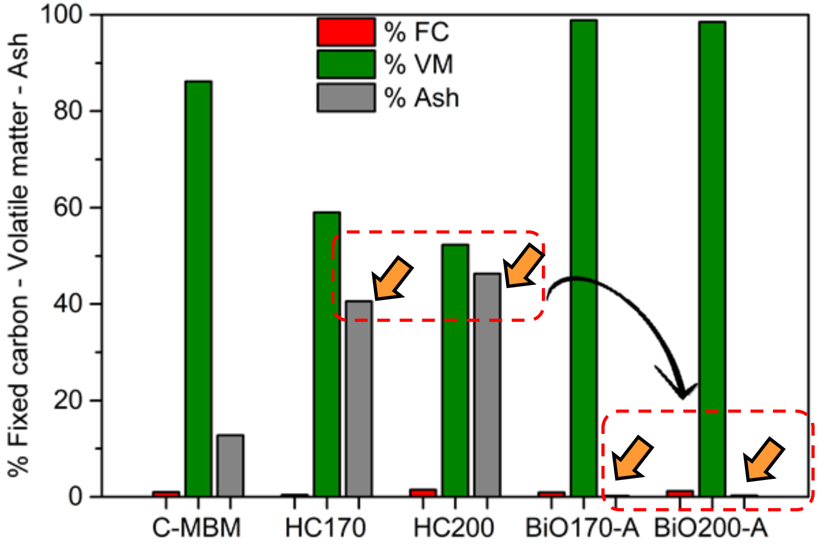
HCyield, Elemental analysis and energy (HHV)



Nitrogen and Sulfur content

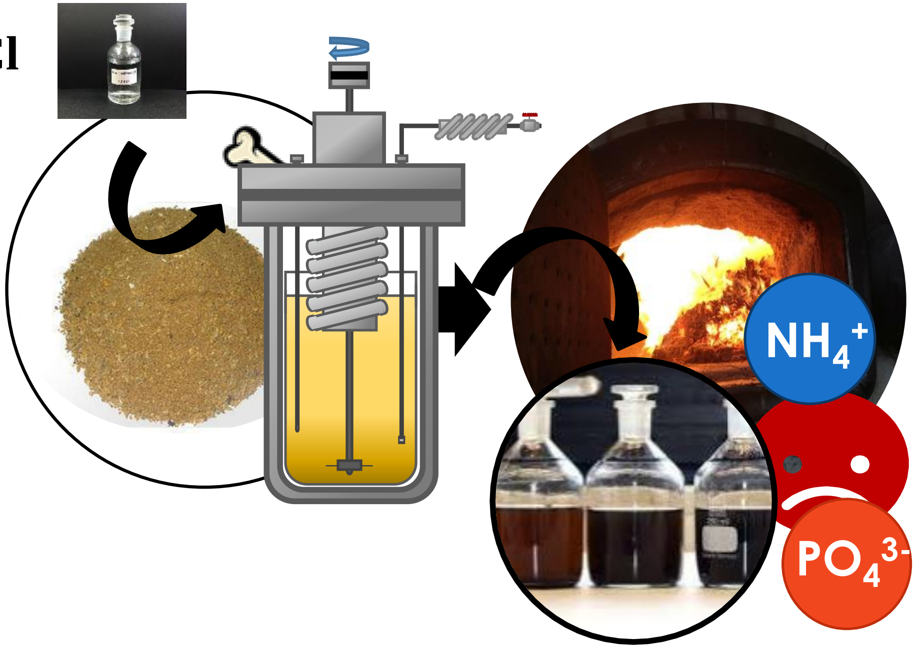


Proximate analysis



Conclusions

HCl

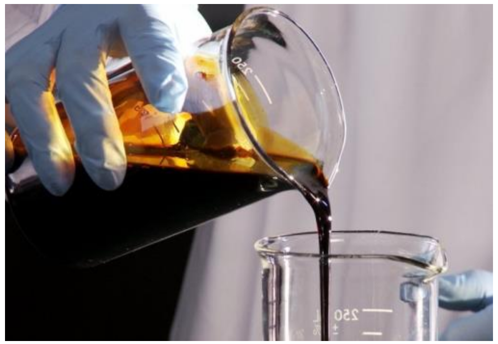


Struvite

Nutrient recovery

Biogas

Bio-oil



Energy recovery

Nutrient and energy recovery from chicken meat & bones meal by hydrothermal treatment and anaerobic digestion

GOBIERNO DE ESPAÑA | MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

Santander

THANK YOU

Acknowledgements

CTM2016-76564-R and BES-2017-081515 (Spanish MINECO),
UAM Santander 2017/EEUU/07 and S2018/EMT-4344 (Madrid Community)

La Suma de Todos

CONSEJERÍA DE EDUCACIÓN
Comunidad de Madrid

Universidad Autónoma de Madrid