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Chicken meat and bone valorization by hydrothermal carbonization and anaerobic digestion: biofuel production and nutrient recovery

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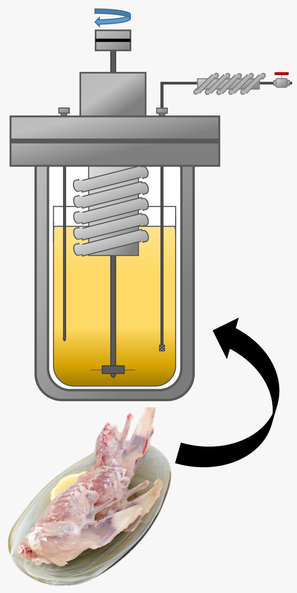
INTRODUCTION

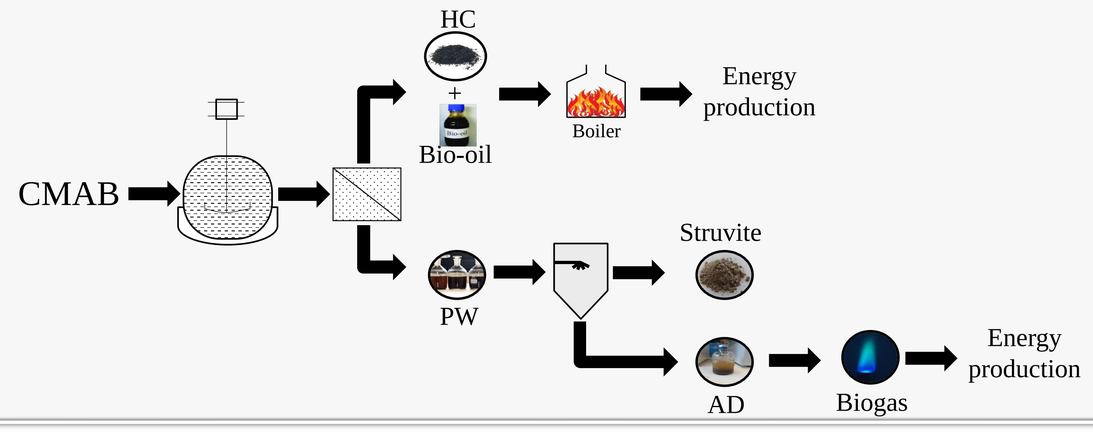
Hydrothermal carbonization (HTC) is a thermochemical process that allows to process organic waste with high moisture under mild temperatures (170 – 250 °C), low residence times (5 – 240 min) and autogenous pressure. The main products of HTC are a carbonaceous hydrochar (HC), with characteristics like lignite coal, and a process water (PW) containing soluble organic compounds, mineral salts and nutrients.

In this work, a raw chicken meat and bones meal (C-MBM) was treated by HTC at 170, 200 and 230 °C for 1 h. To enhanced the leaching of nutrients in the PW and charring of feedstock, HTC in absence or presence of HCl were performed, and the resulting biocarbon and bio-oil was characterized according to ISO/TS 17225-8 to know its potential as biofuel at industrial level. In addition, from PW the nutrients (P, N and Mg) was recovered in form of struvite and the resulting PW with high organic soluble matter was evaluated for methanogenic potential by anaerobic digestion (AD).



MATERIALS AND METHODS

C-MBM feedstock is characterized by wetness ≈ 92.8% and high fat content. The HTC runs were performed in an electrically heated 4 L ZipperClave® pressure vessel. The HC, Bio-oil and PW samples are denoted according to the operating temperature. HC170 is the hydrochar obtained at 170 °C. The elemental composition, proximal and thermogravimetric analysis were performed to HC and Bio-oil to evaluate the energy and combustion characteristics. From PW the nutrients were recovered by add of Mg^{2+} and neutralization with NaOH until pH 9. The resulting PW was submitted to AD at mesophilic condition (35 °C) with an inoculum-to-substrate ratio (ISR) of 2 on volatile solids basis.



RESULTS AND DISCUSSION

Table 1. Physicochemical and combustion characteristics of HC and Bio-oil

	CMAB	HC170	HC200	HC230	Bio-oil-200	Bio-oil-230
C (%)	53.7	28.1	23.5	46.7	75.1	75.3
H (%)	7.5	4.1	2.2	6.7	11.2	11.2
N (%)	7.8	2.3	1.5	1.5	0.3	0.5
S (%)	0.53	0.245	0.1	0.07	0.08	0.105
O* (%)	17.8	24.7	26.5	4.7	13.0	12.6
HHV (MJ kg^{-1})	25.41	10.87	11.56	19.8	38.1	38.2
Volatile matter (%)	86.2	59.0	52.3	55.3	98.5	98.8
Fixed carbon (%)	1.0	0.4	1.5	4.4	1.3	1.0
Ash (%)	12.8	40.6	46.3	40.3	0.2	0.2
Ti (ºC)	249	280	300	302	239	212
Tm (ºC)	369.0	336.0	322.0	398.0	405.0	379.0
Tb (ºC)	725	654	582	520	492	485
CCI ($min^{-2}×ºC^{-3}$)	$6.57×10^{-7}$	$4.39×10^{-7}$	$2.23×10^{-7}$	$5.61×10^{-7}$	$2.19×10^{-6}$	$9.21×10^{-6}$
Ea (kJ mol^{-1})	41.0	39.8	41.8	29.4	19.6	11.4

Figure 1. TG and DTG profiles of HC and Bio-oil

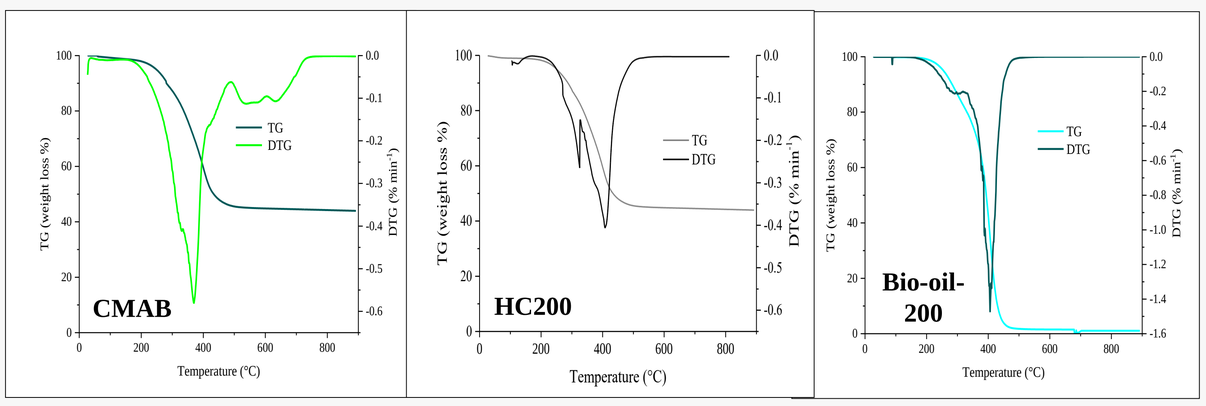
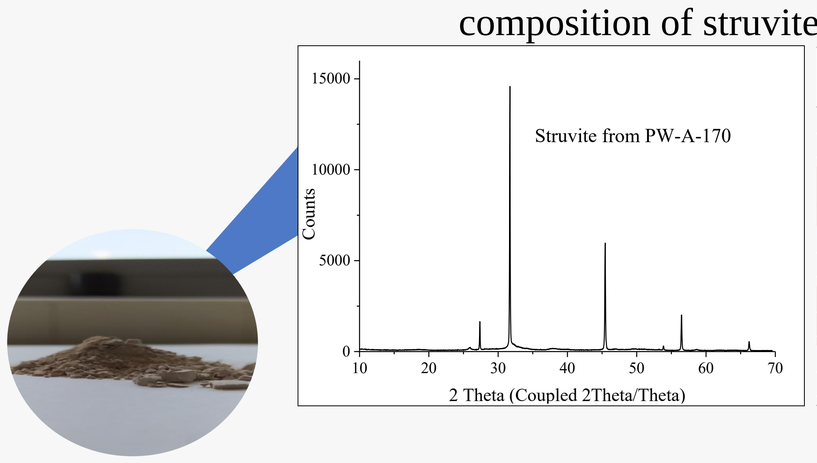
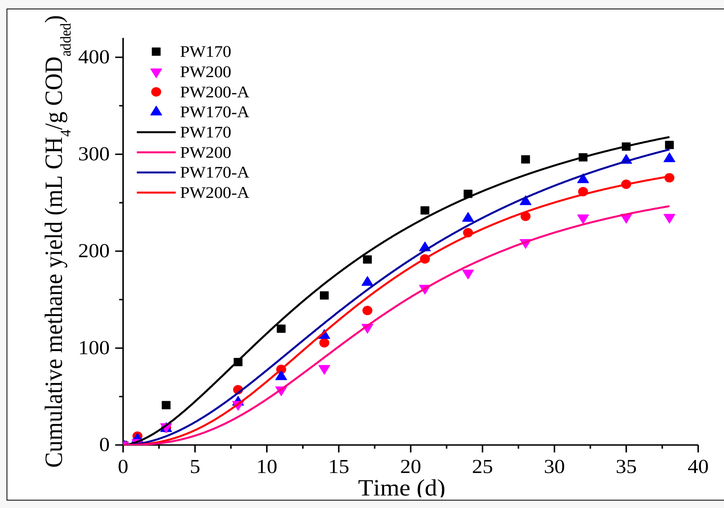


Figure 2. 2-theta XRD graph of struvite from PW-A-170 and mineral composition of struvite



Mineral (g/kg)	
Na	2.6
Ca	4.3
K	4.7
Mg	99.5
P	126.3

Figure 3. Cumulative methane yield. Symbols represent experimental values and solid lines indicate theoretical values



BMP ($mLCH_4/g\ COD_{added}$)	Exp.	Fitted	k (d^{-1})	COD removal (%)
CMAB	402 ± 7	446 ± 27	0.041	47.1
PW170	299 ± 3	322 ± 14	0.059	75.3
PW200	266 ± 4	283 ± 8	0.051	42.2
PW-A-170	275 ± 5	302 ± 13	0.048	32.2
PW-A-200	235 ± 3	241 ± 8	0.05	71.9

CONCLUSIONS

- The HC obtained in the HTC without acid show to be a poor characteristics to be used like bio-combustible due to the low calorific value and C content and higher ash content.
- Bio-oil present improved physicochemical characteristics, higher C, calorific value and minimal ash content linked with better combustion behavior like higher CCI and low ignition temperature and energy activation in the combustion, which proves to be a suitable product to be used as an energy source.
- Acid-assisted HTC show be an excellent process to nutrients recovery because phosphorus, nitrogen and magnesium were almost completely transferred to PW.
- After neutralization of the PW with NaOH, the solid obtained was analyzed by X-ray diffraction, showing that this material corresponds to struvite, which is a crystalline solid of high added value and used in agriculture as a fertilizer. Furthermore, this material has high concentrations of essential minerals for plants such as Mg, K, Na and low concentrations of heavy metals.
- The PW recovered nutrients showed high methanogenic potential with methane production between 235 – 299 $mLCH_4/gCOD_{added}$ and high COD removal up to 75%.

ARQUIMEA

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