# Combustion Performance of Hydrochars from the Hydrothermal Co-carbonization of Sewage Sludge and Organic Waste

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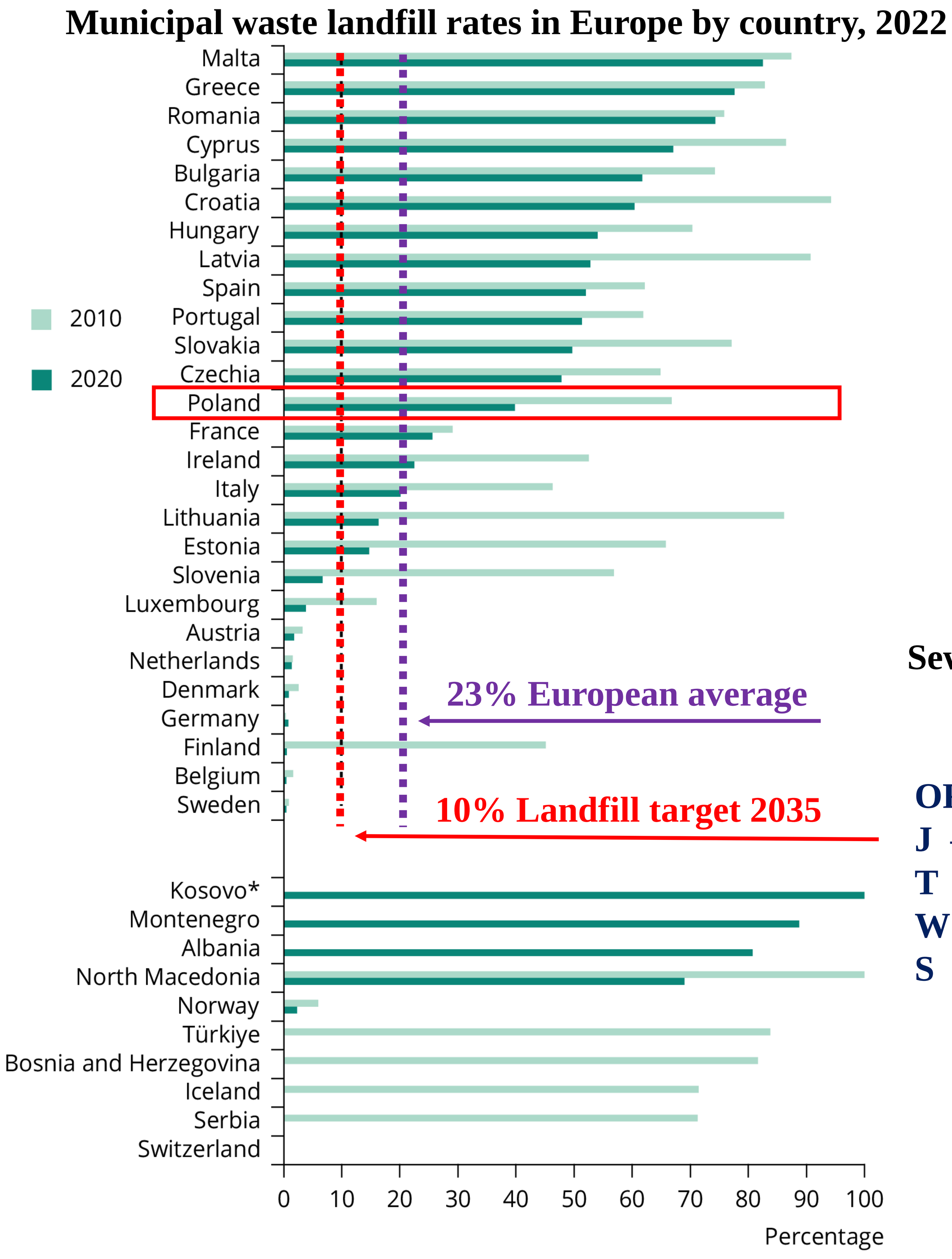
## MOTIVATION

**Municipal waste landfill rates in Europe by country, 2022**

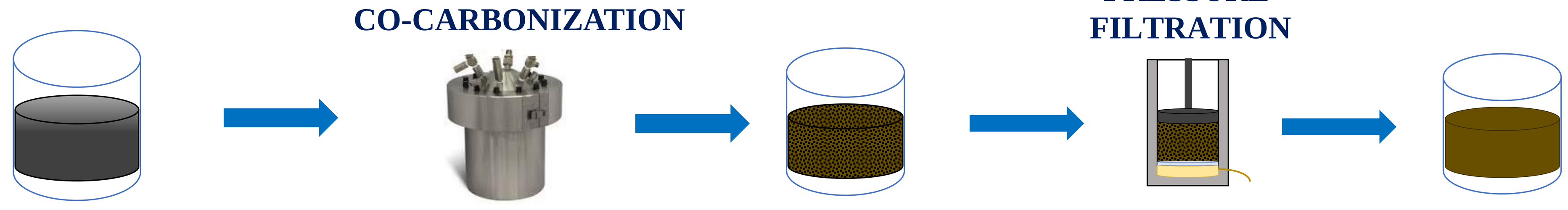



www.eea.europa.eu/ims/diversion-of-waste-from-landfill (accessed 20 of April 2023)

## AIM

SEWAGE SLUDGE → „sludge-to-energy” HYDROTHERMAL CO-CARBONIZATION of SEWAGE SLUDGE and ORGANIC WASTE → IMPROVED FUEL PROPERTIES of HYDROCHAR

## MATERIAL and METHODS



Sewage sludge (OS) + additives → HYDROTHERMAL CO-CARBONIZATION: 200°C, 2h, 150 rpm, aqueous environment, autogenous pressure → Hydrothermally treated slurry → PRESSURE FILTRATION: 4 bar → Filtrate → WASTE DISPOSAL

4 bar → FILTER CAKE = HYDROCHAR → THERMAL UTILISATION

**ORGANIC WASTE ADDITIVES:**
- J – fir
- T – straw
- W – charcoal
- S – undersieved fraction of municipal solid waste

**COMBUSTION PERFORMANCE:**
1. Ultimate and proximate analysis
2. Higher heating value determination
3. Combustion behaviour and key combustion parameters based on TGA data

## RESULTS

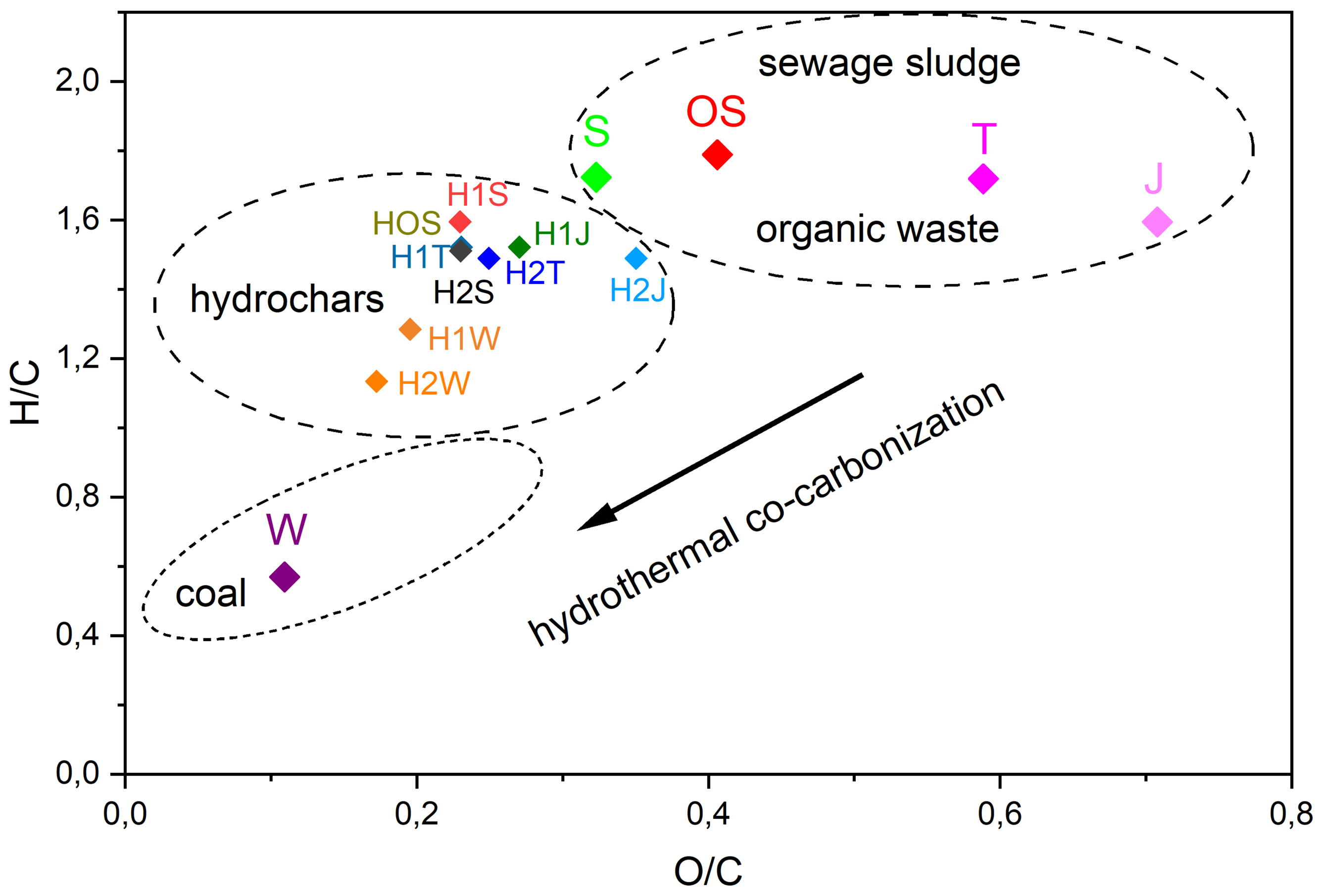



**Fig. 1**. Van Krevelen diagram

**Table 1**. Ultimate and proximate analysis

| | C, % | H, % | N, % | S, % | O, % | FC, % | Ash, % | VM, % | FC/VM | HHV, MJ/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| OS | 36.9 | 5.50 | 5.99 | 1.57 | 19.98 | 8.52 | 28.04 | 61.42 | 0.14 | 15.78 |
| J | 47.5 | 6.31 | 0.39 | 0 | 44.83 | 17.59 | 0.97 | 81.44 | 0.22 | 17.66 |
| T | 39.8 | 5.70 | 2.43 | 0 | 31.23 | 9.25 | 16.71 | 69.91 | 0.13 | 15.86 |
| W | 77.8 | 3.69 | 0.66 | 0.06 | 11.35 | 66.07 | 3.14 | 27.49 | 2.40 | 30.49 |
| S | 43.3 | 6.22 | 1.23 | 0 | 18.65 | 6.63 | 30.6 | 62.77 | 0.11 | 17.29 |
| HOS | 35.3 | 4.69 | 3.36 | 1.23 | 10.81 | 9.21 | 44.61 | 46.18 | 0.20 | 15.84 |
| H1J | 36.5 | 4.63 | 3.53 | 1.19 | 11.22 | 13.35 | 40.99 | 45.66 | 0.29 | 16.33 |
| H2J | 37.3 | 4.63 | 3.52 | 1.16 | 12.40 | 14.92 | 35.97 | 49.11 | 0.30 | 17.09 |
| H1T | 36.5 | 4.63 | 3.53 | 1.19 | 11.22 | 10.89 | 42.93 | 46.18 | 0.24 | 15.96 |
| H2T | 37.3 | 4.63 | 3.52 | 1.16 | 12.40 | 11.40 | 40.99 | 47.61 | 0.24 | 16.14 |
| H1W | 41.1 | 4.40 | 3.27 | 1.14 | 10.71 | 18.09 | 39.38 | 42.53 | 0.43 | 17.37 |
| **H2W** | **45.6** | **4.31** | **3.08** | **1.09** | **10.47** | **25.92** | **35.44** | **38.64** | **0.67** | **18.83** |
| H1S | 35.3 | 4.69 | 3.36 | 1.23 | 10.81 | 9.21 | 44.61 | 46.18 | 0.22 | 16.05 |
| H2S | 36.7 | 4.62 | 3.29 | 1.15 | 11.26 | 10.15 | 42.98 | 46.87 | 0.21 | 16.32 |

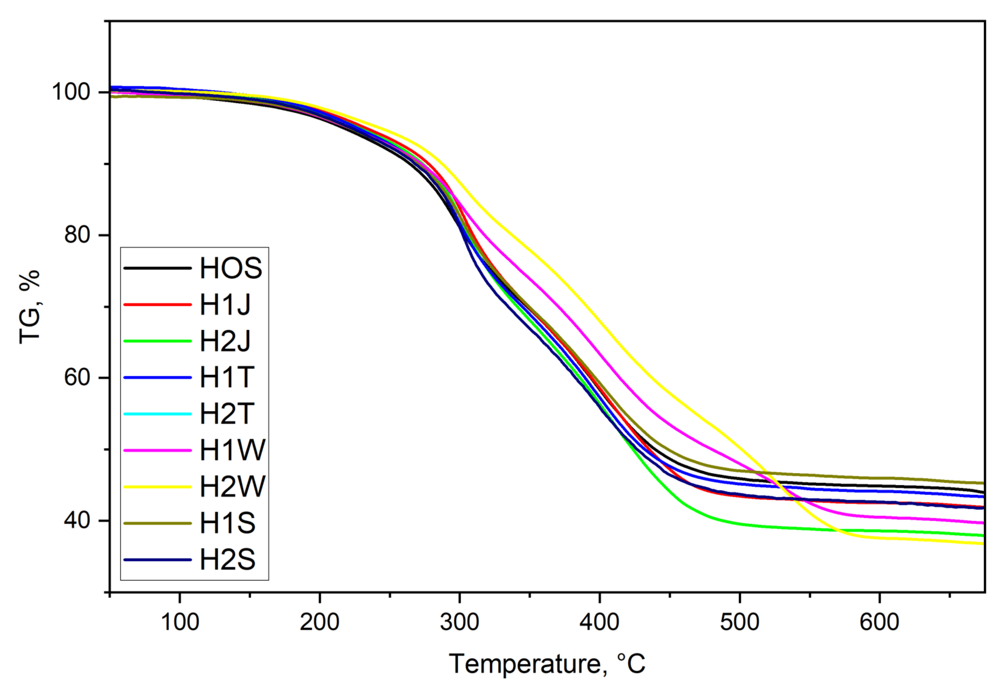



**Fig. 2**. TG of hydrochars with and without additives

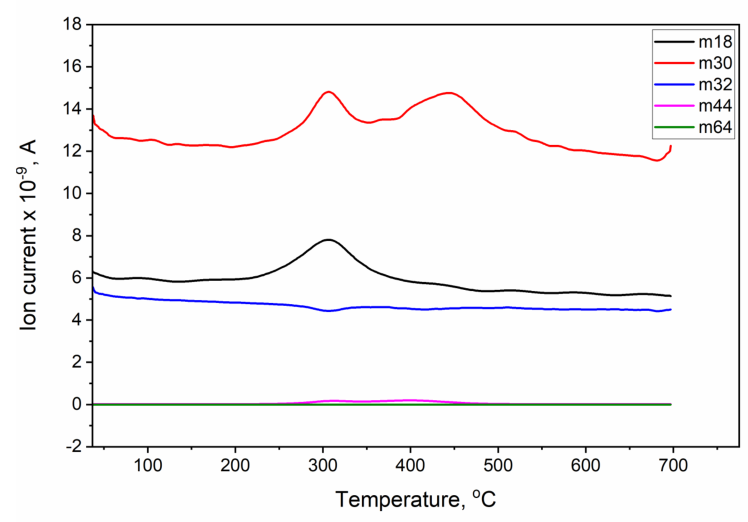



**Fig. 4**. MS for HOS without additive

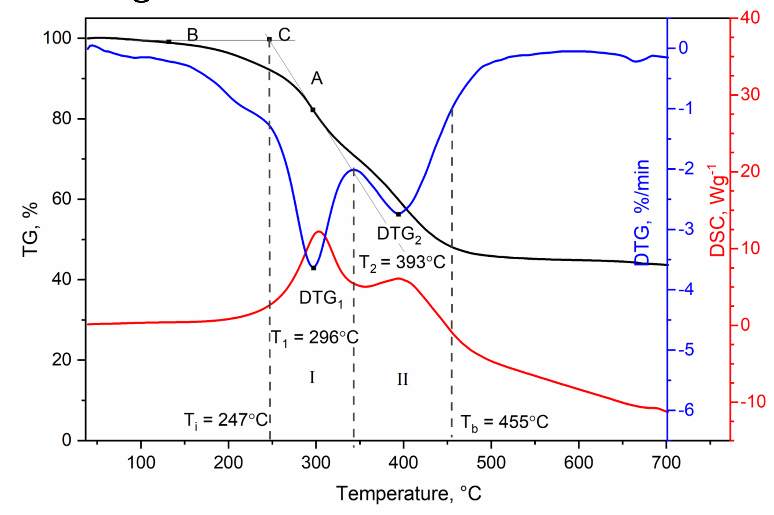



**Fig. 5**. TGA for HOS without additive

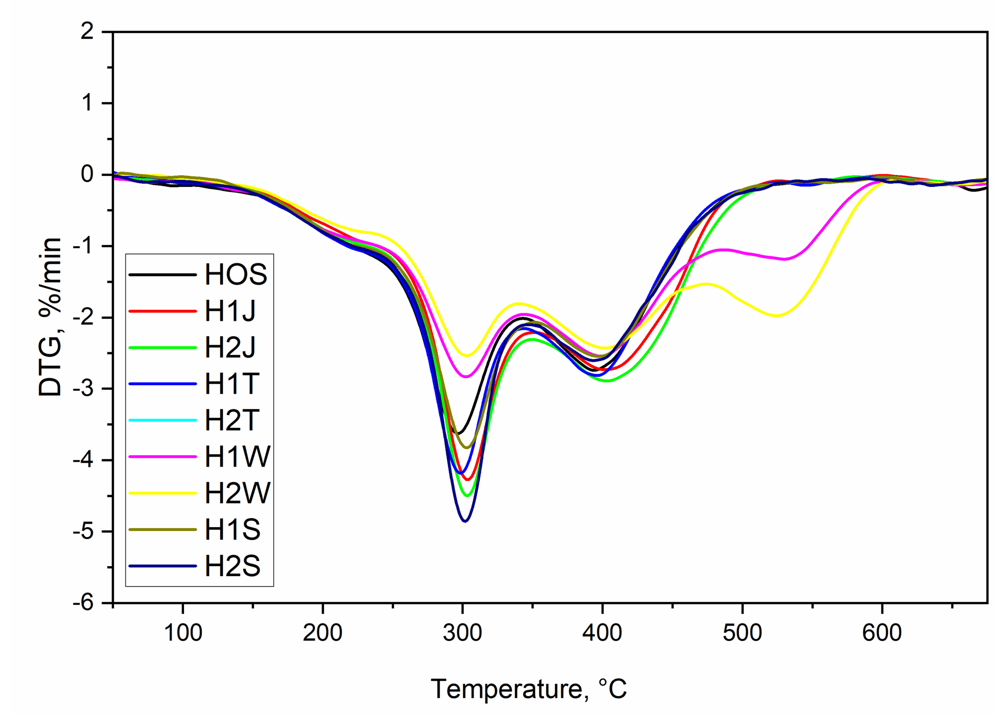



**Fig. 3**. DTG of hydrochars with and without additives

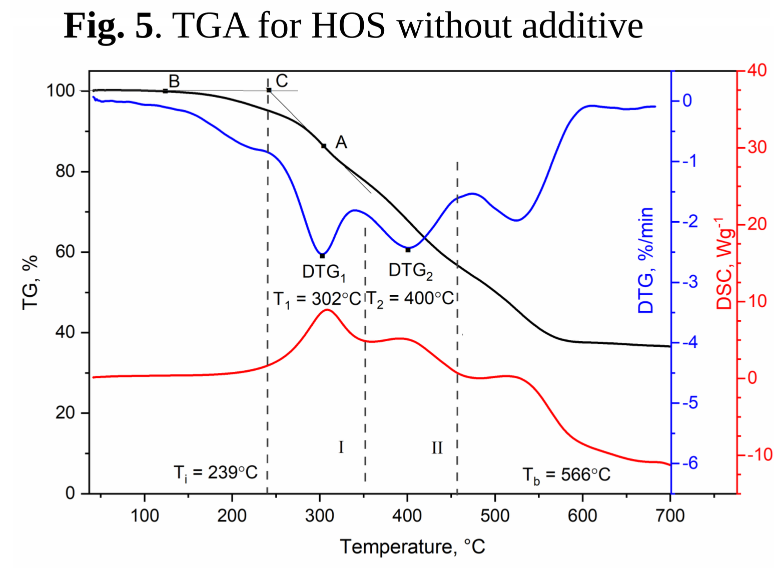



**Fig. 6**. TGA for H2W with 20% of charcoal additive

**Table 2.** Key combustion parameters

| | $T_i$, °C | $T_b$, °C | $D_i$, %·min$^{-3}$ | S, %·min$^{-2}$·°C$^{-3}$ | $H_f$, %·min·K$^{-2}$ |
|---|---|---|---|---|---|
| HOS | 247 | 455 | 0.0048 | $11\cdot10^{-8}$ | 1048 |
| H1J | 258 | 470 | 0.0057 | $13\cdot10^{-8}$ | 1075 |
| H2J | 257 | 473 | 0.0060 | $12\cdot10^{-8}$ | 1100 |
| H1T | 244 | 453 | 0.0059 | $14\cdot10^{-8}$ | 1072 |
| H2T | 238 | 566 | 0.0059 | $12\cdot10^{-8}$ | 1080 |
| H1W | 239 | 547 | 0.0037 | $7\cdot10^{-8}$ | 1074 |
| H2W | 239 | 566 | 0.0033 | $6\cdot10^{-8}$ | 1080 |
| H1S | 239 | 455 | 0.0053 | $13\cdot10^{-8}$ | 1060 |
| **H2S** | **252** | **456** | **0.0072** | **$16\cdot10^{-8}$** | **1092** |

## CONCLUSIONS

1. **Hydrothermal co-carbonization of sewage sludge and organic waste improved fuel properties of hydrochars when compared to sewage sludge.**
2. **An addition of 20% of charcoal to sewage sludge led to an increase in hydrochars with the highest values of HHV, C and FC, but prolonged the time of combustion.**
3. **Combustibility indexes confirmed slightly easier and more stable combustion to hydrothermally treated sludge without an additive giving the most optimal results for organic waste additives such as undersieved fraction of municipal solid waste.**

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