BIOCHAR PRODUCTION THROUGH HYDROTHERMAL CARBONIZATION: ENERGY EFFICIENCY AND COST ANALYSIS OF AN INDUSTRIAL-SCALE PLANT

Michela Lucian, University of Trento, Italy
Fabio Merzari, University of Trento, Italy
Luca Fiori, University of Trento, Italy
luca.fiori@unitn.it

Key Words: Hydrothermal carbonization; HTC; wet torrefaction; energy analysis; cost analysis.

Hydrothermal carbonization (HTC) is an induced coalification process that converts raw biomass into a coal-like product, called hydrochar, characterized by high carbon content and high calorific value. This type of thermo-chemical conversion, also referred to as wet pyrolysis (or wet torrefaction), can be applied to a variety of non-traditional sources such as the organic fraction of municipal solid waste, wet agricultural residues, sewage sludge. Unlike traditional dry pyrolysis, the HTC process allows for the treatment of substrates with elevated moisture content, up to 75%–90%, without requiring a drying pre-treatment step. The HTC process is performed in high-pressure vessels by applying relatively high temperature (generally in the range 180–250 °C) and pressure (approximately 10–50 bar) to biomass in liquid water for a few hours (0.5–8 h) in the absence of air. Considering the emerging interest in the HTC process and the current state of the art, and to allow the technology to make a step forward from research to innovation, it is necessary to provide an in-depth analysis of the energy balance of the HTC process and to evaluate its economic feasibility and profitability. These are the main objectives of the present study, which reports detailed energy and cost analyses of a proposed HTC plant layout (Figure 1).
HTC of two different organic residues - off-specification compost (OSC) and grape marc (GM) - is modelled at different HTC process conditions (reaction temperature T: 180, 220, 250 °C; reaction time θ: 1, 3, 8 h; dry biomass to water ratio B/W in the range 0.07-0-19) [1].
In the most favourable conditions, i.e., when processing GM at T=220 °C, θ=1 h and DB/W=0.19:

- a plant energy efficiency of 78% is achieved;
- specific thermal energy consumption is equal to 1.17 kWh/$kg_{hydrochar}$ (0.31 kWh/$kg_{feedstock}$) – Figure 2;
- specific electric energy consumption is equal to 0.16 kWh/$kg_{hydrochar}$ (0.04 kWh/$kg_{feedstock}$);
- the production cost of pelletized hydrochar is equal to 157 €/$ton_{hydrochar}$;
- the hydrochar break-even value for a plant repayment period of 10 years is equal to 200 €/$ton_{hydrochar}$, competitive with the price of wood pellets (150–200 €/ton_{wood}).

Overall, the competitive price of pelletized hydrochar compared with pelletized wood seems promising and could encourage a large industrial-scale development of the HTC technology in the future.

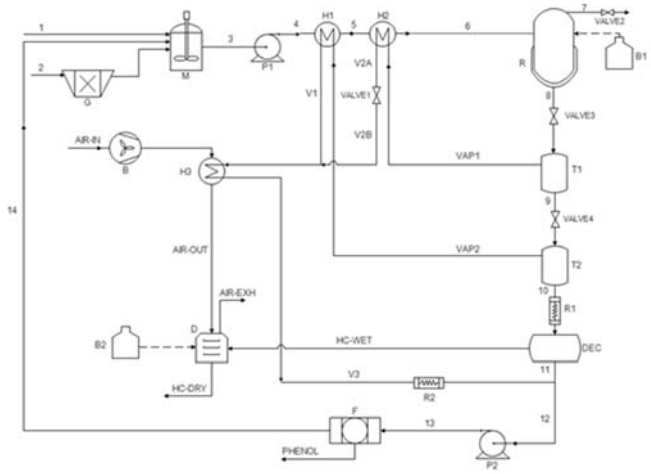

Figure 1: schematic flow sheet of the HTC plant.

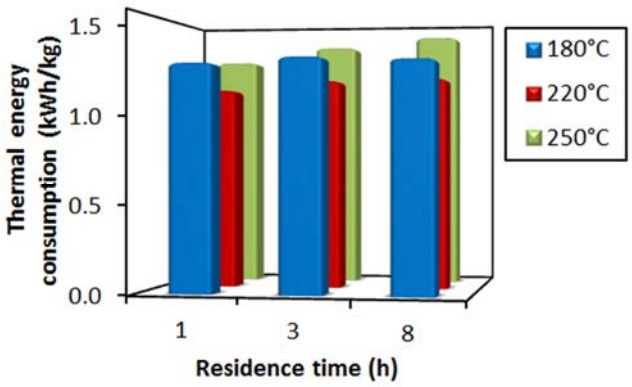

Figure 2: specific thermal energy consumption (kWh/kg_{char}) at different HTC temperatures (180, 220, 250 °C) and residence times (1, 3, 8 h; data refers to HTC of grape marc with B/W=0.19.

[1] Lucian M., Fiori L., Hydrothermal carbonization of waste biomass: process design, modeling, energy efficiency and cost analysis, Energies 2017, 10(2), 211; doi:10.3390/en10020211