Recirculation of process water on hydrothermal carbonization of garden and park waste: Effect on hydrochar properties

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Introduction

Hydrothermal carbonization (HTC) can transform wet biomass waste, at mild temperatures (180 – 250 °C), low residence time (5 – 120 min) and autogenous pressure into a solid biofuel called hydrochar and a liquid fraction named process water (PW) with an inherent profitable approach to be valorized. Hydrochar could be used in a wide range of applications including biofuels, activated carbons precursors, soil amendments and carbon storage (Fig. 1). A high proportion of the C contained in the raw feedstock remains in the process water in form of soluble organic compounds (such as acids, sugars, furans which can be used as substrate for anaerobic digestion, phosphorus recovery, liquid fertilizer or dark fermentation (Fig 1). Another alternative can be recirculation in the HTC process, saving water and reducing the cost of its management.

Materials and methods

HTC experiments were conducted in an electrically heated 4 L ZipperClave® pressure vessel (180 ºC, 1h). Garden and park waste (GPW) was mixed with tap water (GPW:TW, 20:80 wt.%). After each HTC cycle, the PW obtained was recirculated. 3 recirculation were performed, the hydrochar and PW obtained from first cycle (using TW) were designated as HC1 and PW1, the subsequent hydrochar obtained with PW were called according to the cycle of PW reuse.

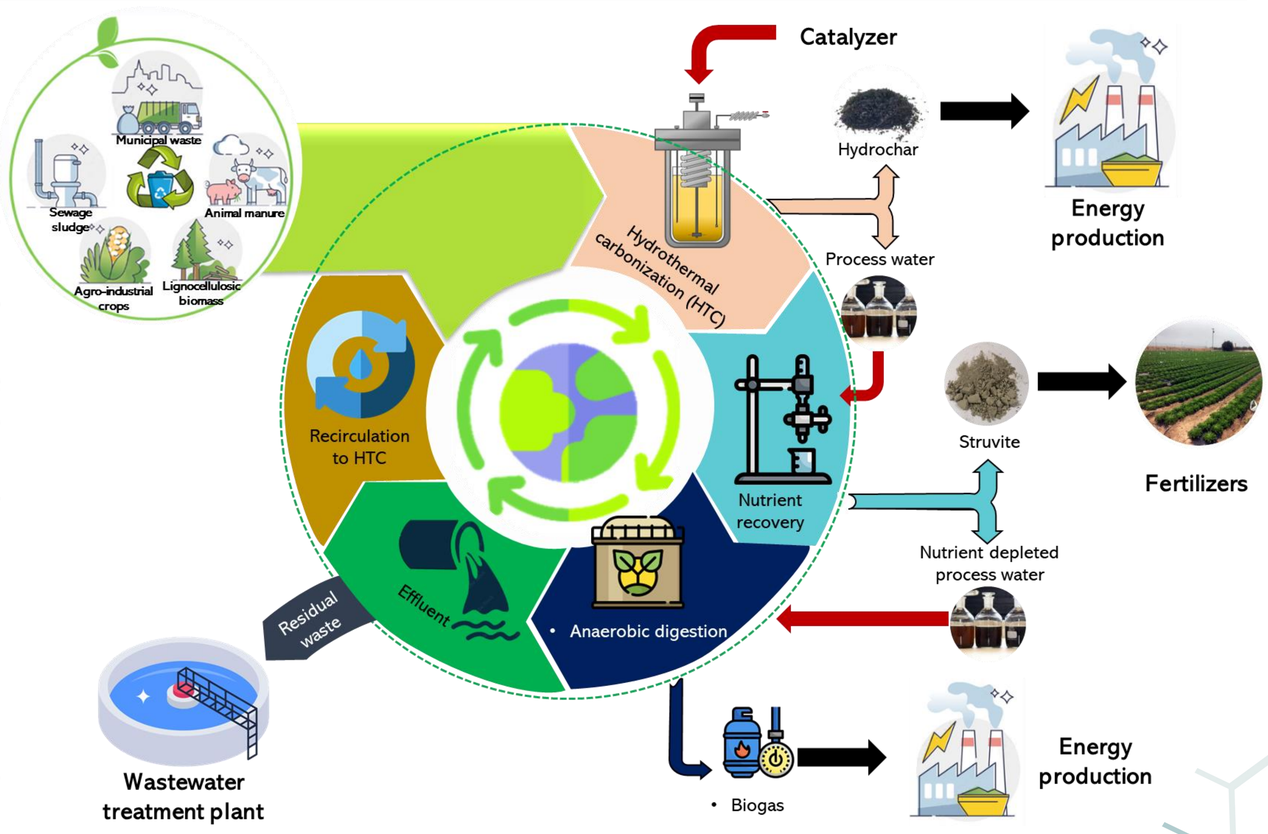

Figure 1. Biomass waste valorization proposal by HTC, nutrient reclamation and anaerobic digestion

Results

Table 1. Main characteristics of garden and park waste and hydrochars

	GPW	HC1	HC2	HC3	HC4
VM (wt.%)	76.5(0.6)	67.1(0.2)	74.1(0.5)^{c}	77.4(0.4)^{a}	78.9(0.4)^{d}
Ash (wt.%)	5.1(0.2)	3.2(0.1)	7.1(0.1)^{c}	7.3(0.2)^{c}	7.3(0.2)^{c}
C (wt.%)	45.9(0.5)	49.8(0.2)	51.9(0.1)^{c}	51.2(0.3)^{d}	52.2(0.1)^{c}
N (wt.%)	0.9(0.1)	1.3(0.1)	1.1(0.1)^{c}	1.7(0.1)^{d}	1.6(0.1)^{e}
S (wt.%)	0.4(0.1)	0.2(0.1)	0.1(0.0)^{c}	0.1(0.0)^{c}	0.1(0.0)^{c}
Y_{HC} (wt.%)	-	75.5(3.4)	79.3(7.8)^{a}	89.3(4.7)^{b}	85.5(2.0)^{b}
HHV (MJ kg^{-1})	18.7(0.3)	19.5(0.1)	21.3(0.1)^{b}	20.1(0.4)^{c}	20.9(0.0)^{b}
E_{yield} (%)	-	79.3(0.3)	85.6(0.3)^{b}	91.3(0.5)^{c}	90.7(0.4)^{c}

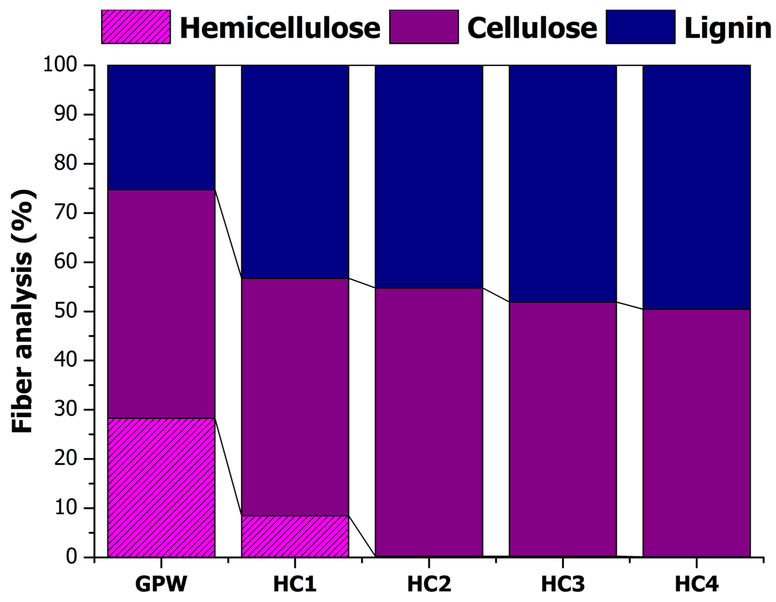

Figure 2. Fiber analysis of feedstock and hydrochars

Table 2. Combustion properties and fouling and slagging indexes of garden and park waste and hydrochars

	GPW	HC1	HC2	HC3	HC4
Ti (ºC)	239.0(4.0)	242.0(5.0)	244.0(3.0)	240.0(4.0)	235.0(4.0)
CCI×10^{7} (min^{-2} ºC^{-3})	7.8(0.3)	8.0(0.2)	8.2(0.2)	8.3(0.3)	8.2(0.2)
Ea (KJ mol^{-1})	61.6(1.1)	62.3(0.5)	60.6(0.3)	57.2(0.4)	56.5(0.2)
SI	0.5(0.0)	0.1(0.0)	0.2(0.0)	0.3(0.0)	0.3(0.0)
FI	7.5(0.1)	3.4 (0.1)	4.7(0.2)	6.6(0.2)	6.2(0.2)

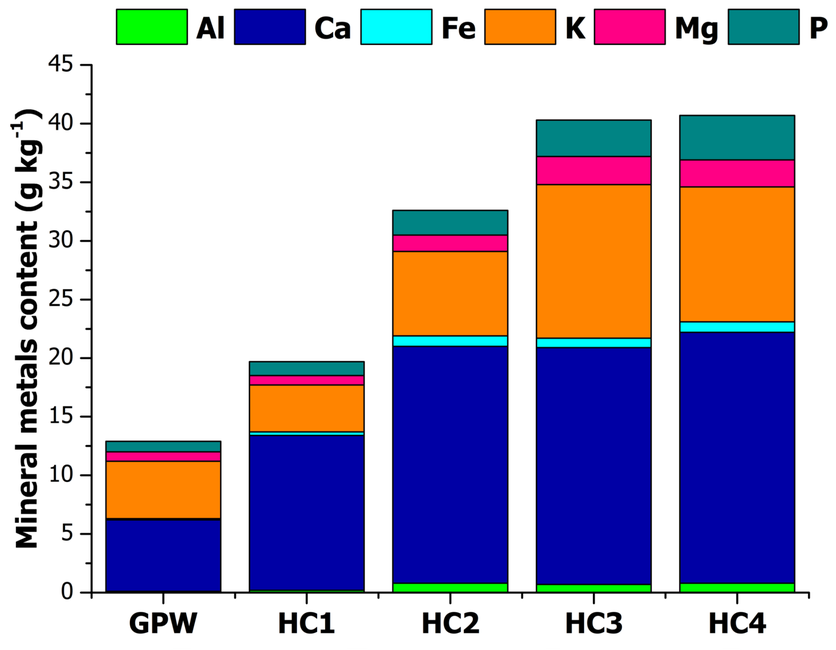

Figure 3. Mineral content of feedstock and hydrochars

Conclusions

- Process water recirculation increased the hydrochars yield, C content and HHV, meeting the requirements for use as industrial biofuels (ISO 17225-8).
- The decline and rise trend in activation energy (Ea) and compressive combustion index (CCI), respectively, indicates better combustion performance of hydrochars, while slagging (SI) and fouling (FI) indexes indicate low ash agglomeration during combustion.
- The hemicellulose was completely removed after second cycle HTC, while cellulose and lignin remained unchanged.
- The mineral content of hydrochar increases with the process water recirculating (specially Ca, K, Mg and P), as well the hydrochar shows minimal heavy metals content fulfilling the CE 1009/2019, to be used as soil amendment.
- Recycling PW is a suitable solution for biomass with low moisture content, increasing the quality, yield and thus carbon recovery into the hydrochar

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