Supplementary Data

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Original Research Paper

Coupling hydrothermal carbonization with anaerobic digestion: an evaluation based on energy recovery and hydrochar utilization

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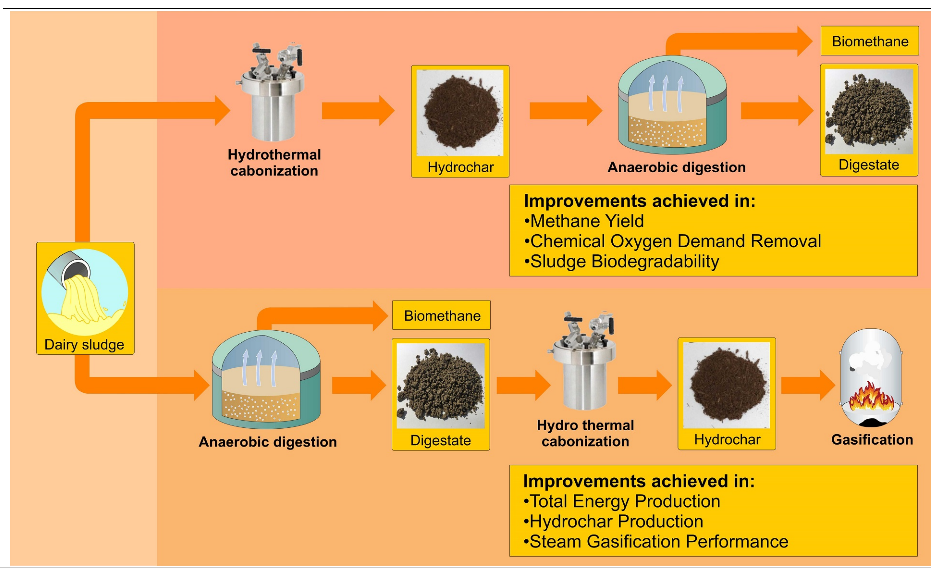
HIGHLIGHTS

- Coupling hydrothermal carbonization (HTC) pretreatment with anaerobic digestion (AD) increased methane production by 192%.
- HTC improved fuel quality and sludge biodegradability of dairy sludge.
- A positive net energy of 4.28 kWh/kgsludge was obtained by HTC pretreatment.
- HTC post-treatment to AD resulted in higher net energy gain (5.2 kWh/kgsludge).
- HTC post-treatment improved steam gasification performance of AD digestate.

GRAPHICAL ABSTRACT



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ABSTRACT

This work evaluates the effect of hydrothermal carbonization (HTC) as a pretreatment and post-treatment technique to anaerobic digestion (AD) of dairy sludge. HTC's effect on AD was evaluated based on energy recovery, nutrient transformation, and hydrochar utilization. The first approach was executed by performing HTC under a range of temperatures before mesophilic AD. HTC optimal pretreatment temperature was 210 °C for 30 min residence time. HTC pretreatment significantly increased the methane yield potential by 192%, the chemical oxygen demand removal by 18%, and the sludge biodegradability during AD by 30%. On the other hand, the application of HTC after AD (post-treatment) increased the total energy production, i.e., in addition to methane, a hydrochar with a caloric value of 10.2 MJ/kg was also obtained. Moreover, HTC post-treatment improved the steam gasification performance of the AD digestate. From the fertilizer quality point of view, HTC implementation generally boosted the concentrations of macro, micro, and secondary nutrients, suggesting its suitability for use as a liquid fertilizer. Overall, the findings of the present study indicate that if bioenergy production were the main target, HTC post-treatment following AD would lead to the most promising outcomes.

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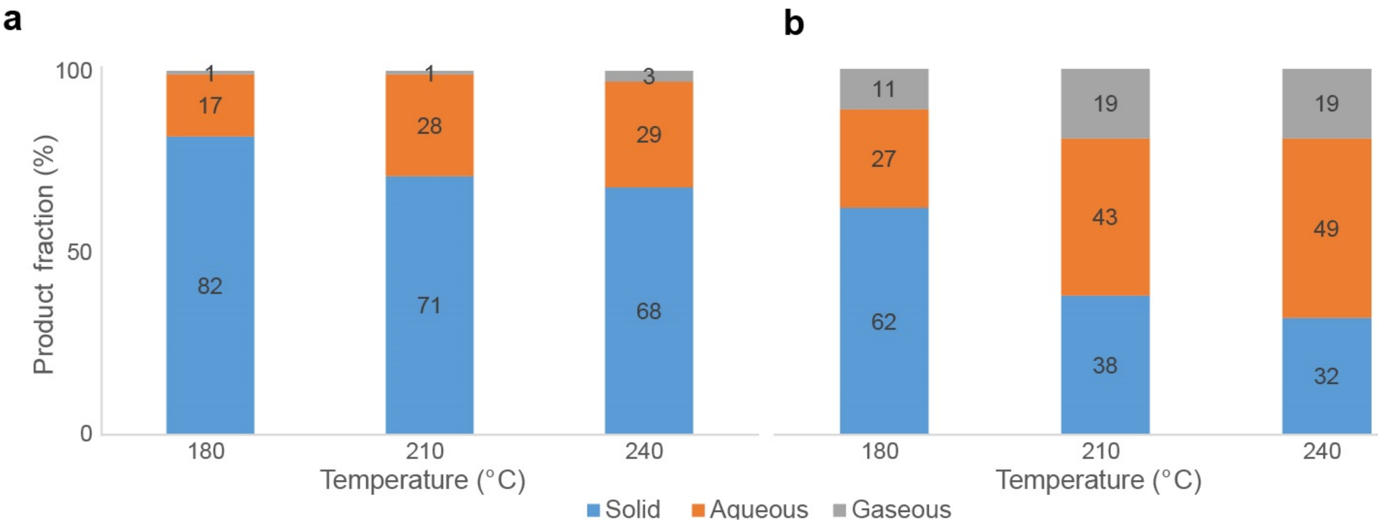

Fig. S1. Hydrothermal carbonization (HTC) product fractions; **(a)** raw dairy sludge and **(b)** digestate.

Table S1.
Volatile fatty acids (VFAs) concentrations in dairy sludge.

Parameter (mg/L)	Raw dairy sludge	HTC aqueous phase	Relative increase (%)
Acetic acid	331± 71^{a}	949± 99^{b}	187
Propionic acid	51± 13^{a}	173±37^{b}	240
Butyric acid	62±11^{a}	579±52^{b}	834
Iso-Butyric acid	319±19^{a}	912±199^{b}	186
Caproic acid	120±45^{a}	380± 47^{b}	216
Total VFAs	883	2993	239

^{a,b} Statistical differences are indicated by different superscript letters.

Table S2.
Hydrothermal carbonization (HTC) energy balance.

Temperature (°C)	Energy input		
	Energy to heat water (kJ/kg of sludge)	Energy to heat dry content (kJ/kg of sludge)	Total energy to heat sludge (kJ/kg of sludge)
180	599	20	619
210	714	23	737
240	857	27	884

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