Biochar for enhancing anaerobic digestion of food waste

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BIOCHAR FOR ENCHANING ANAROBIC DIGESTION OF FOOD WASTE

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1. Keywords

Biogas, biomethane, biowaste, propionate, pyrolysis

2. Highlights

- Preliminary results from a meta-analysis on AD enhancement by biochar addition
- Biochar seems effective even at lowest dosages
- Performance amelioration seems more significant with high substrate loading rates
- Lack of biochar characterization jeopardizes the evaluation of process mechanisms

3. Purpose

Anaerobic digestion (AD) is recognized as one of the most energy-efficient and environmentally beneficial technologies for treating and transforming organic residues into biomethane (energy) and digestate (fertilizer) [1-2]. However, AD of highly concentrated and biodegradable substrates such as FW is prone to failure if not properly managed. The main issue is the accumulation of biological inhibitors such as free ammonia and volatile fatty acids [1]. Recently, conductive material addition as biochar in AD reactor has been proven to trigger microbial enhancement, electron transfer among syntrophic consortia, ammonia/organic acid tolerance, providing buffering capacity and globally improving biogas production kinetics [3].

Addressing a major scientific gap, the objectives of this meta-analysis are to clarify such mechanisms and identify optimal biochar characteristics and doses as an additive for the enhancement of food waste AD.

4. Materials and methods

This review is based on a literature exploration using the query *(“anaerobic digestion“ AND (“food waste“ OR “biowaste”) AND “biochar”)* in title and abstract and performed in *ScienceDirect* for peer-reviewed articles since 2000. The resulting articles were then manually screened by title and abstract. Experiments dealing with organic substrate other than source-separated biowaste were excluded (notably agricultural residues and sewage sludge, except for some co-digestion cases). For each article, the information summarized in Table 1 was extracted or calculated from the available information if possible, and then organized as a database where each line represents a single experimental condition from each study. This ongoing work has resulted so far in a library of 11 peer-reviewed articles (list available under request) representing a database of 72 experimental conditions (including control tests without biochar).

5. Results and discussion

As can be observed in Figure 1, left: improvement of CH_4 rate max range from 0 to 150%; right: reduction of time to reach plateau range from 0 to 50%. Biochar doses inferior to 10 $g.L^{-1}$ always improved maximum methane rate. Increasing the biochar dosage tended to attenuate this advantage, although kinetics remained at least equal to control conditions for all biochar doses (Figure 1, left).

Another glaring observation is that the reduction of *time to reach CH_4 plateau*[1] increases with S/X (substrate over inoculum ratio). It is possible that this observation would be explained by the improvement of volatile fatty acids syntrophic oxidation and microbial activities [7].

Table 1 - Overview of parameters selected for the meta-analytical study

a) Parameters of experimental conditions

Parameter	unit	Obs[a]
Pyrolysis temperature	°C	62
Pyrolysis duration	h	41
H / C[b]		31
Biochar average particle size	µm	57
Biochar specific surface	$m^2 . g^{-1}$	34
Biochar pore volume	$cm^3 . g^{-1}$	21
Biochar dose	$g . L^{-1}$	73
S / X[c]	$g\ VS.g\ VS^{-1}$	47
OLR	$g\ VS.L^{-1}.day^{-1}$	63

b) AD performance indicators

Parameter	unit	Obs[a]
Methane yield*	$mL\ CH_4 .g\ VS^{-1}$	58
Rate max*	$mL\ CH_4 . gVS^{-1}\ day^{-1}$	34
Highest VFA peak*	$mg\ COD . L^{-1}$	42
Highest propionate peak*	$mg\ COD . L^{-1}$	41
Time to reach CH_4 plateau*	day	35
Lag phase*	day	51

**the analysis included the variation of these parameters in the conditions with biochar compared to the control from the same study. a. Number of observations -b. Hydrogen to carbon ratio -c. Substrate to inoculum ratio in AD. OLR: Organic loading rate in AD.-VFA: Volatile fatty acids. COD: chemical oxygen demand. VS: volatile solids.*

Several biochar quality parameters could clarify mechanisms for AD enhancement, such as atomic O/C ratio, cation exchange capacity, electrical conductivity, electron donating/accepting capacity (redox capacity) [4-9]. The identified articles so far provided poor biochar characterization. Thus, the underlying mechanism of FW AD improvement by biochar are still unclear.

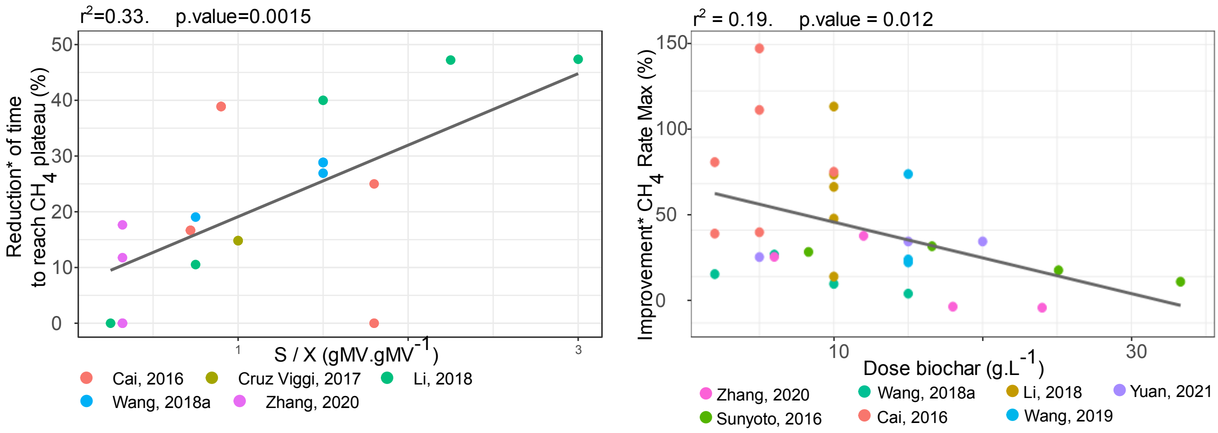

*Figure 1: Effect of biochar on AD performance. *Calculated as: 1 – (result by adding biochar to AD / results of control).*

6. Conclusions and perspectives

Biochar can be an expensive material (up to 500 – 2000 €/t). The preliminary results from this study suggest that biochar is mostly effective at low doses (<10 $g.L^{-1}$). Biochar addition can thus be an attractive opportunity to enhance food waste AD while promoting carbon sequestration. The results will be confirmed by extending the database and performing further statistical analysis. In the future, an economic and environmental assessment is recommended. Additionally, it is expected that this work could set best practices in terms of biochar characterization for future experiments on AD enhancement by conductive material.

[1] time for methane production curve to approach asymptote.

7. References

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