Effect of Carbon-based Additives on Hydrogen Production in the Air/Steam Gasification of Dried Sewage Sludge

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Introduction

- This paper discusses the challenges associated with sewage sludge disposal and the potential of thermochemical conversion, specifically gasification, as a sustainable and efficient disposal method.
- The addition of air and steam mixtures to gasification has been shown to be an economically viable method.
- Carbon materials, such as activated carbon, bio char and lignin char, have also been identified as potential catalysts for gasification.
- However, the poor physicochemical properties of raw biochar and the tendency of catalysts to coke and sinter on the biochar surface limit their effectiveness.
- Despite these limitations, the presence of inherent alkali and alkaline earth metals (AAEMs) in biochar makes them effective as catalyst supports for tar cracking/reforming and enhancing the water gas shift reaction in gasification applications.
- The article also highlights the water-gas shift and steam methane reforming reaction

Materials and Methods

Feedstock and catalyst

- Feedstock: Sewage sludge (SWS) was obtained from a wastewater treatment facility in South Korea and dired at 110 °C in oven for 24 h to obtain dried sewage sludge (DSS).

- Physicochemical properties of DSS, AC, bio char and Lignin char

Proximate analysis (%)	DSS	Activated carbon	Bio char	Lignin char
Moisture	2.5	1.15	0.67	0.85
Volatile matter	56.8	8.26	24.18	36.4
Ash	40.7	11.19	75	28.81
Fixed carbon	-	79.39	0.14	33.94

Ultimate analysis (%)	DSS	Activated carbon	Bio char	Lignin char
C	49.3	83.77	77.28	63.69
H	5.1	0.57	2.65	1.16
N	5.3	0.27	0.69	0.8
O	39.5	15.13	19.38	32.6
S	0.9	0.26	-	1.75

Catalyst analysis

- BET analysis

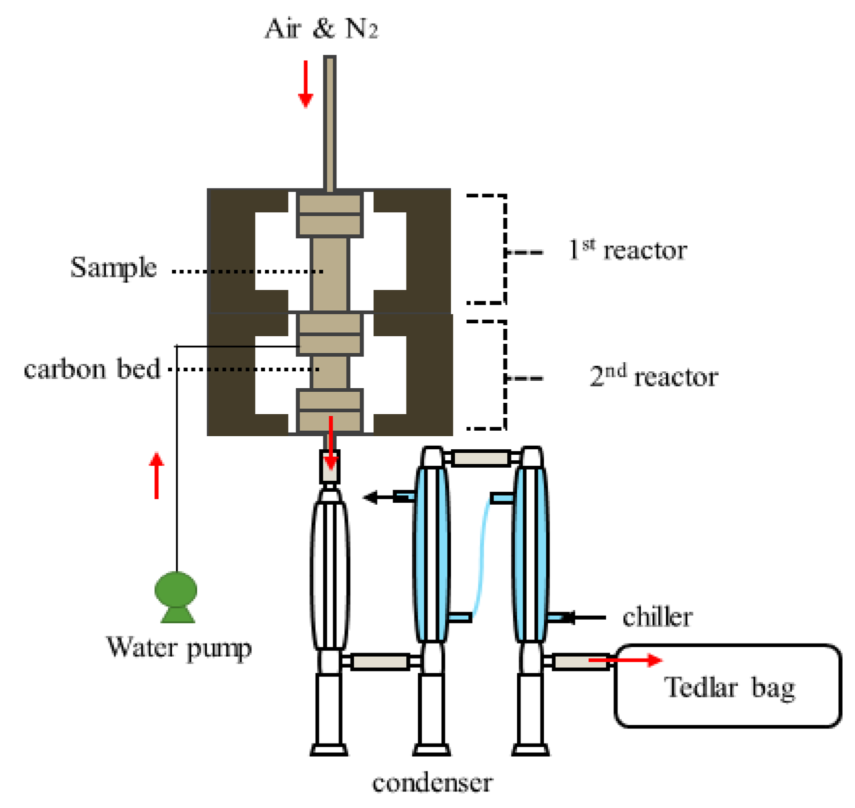
- The physical characteristics of carbon based additives were determined using BET analysis on surface area and a porosity analyzer (3Flex, version 3.02, Micrometrics, USA).
- 0.3 mg of each catalyst was first preheated at 180 ˚C for 8h in a vacuum by N_2 adsorption-desorption at -196 ˚C.

Gasification experiment

- Parameters for gasification experiments for all runs

	Non catalytic	Activated carbon			Bio char			Lignin char		
		0.5~1.7mm								
Reaction number	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Catalyst Bed Temperature	-	750	800	850	750	800	850	750	800	850
Steam(ml)		5	10	15	5	10	15	5	10	15
ER	0.2									

- Schematic setup for the catalytic gasification dried sewage sludge (DSS) using air and air with steam.



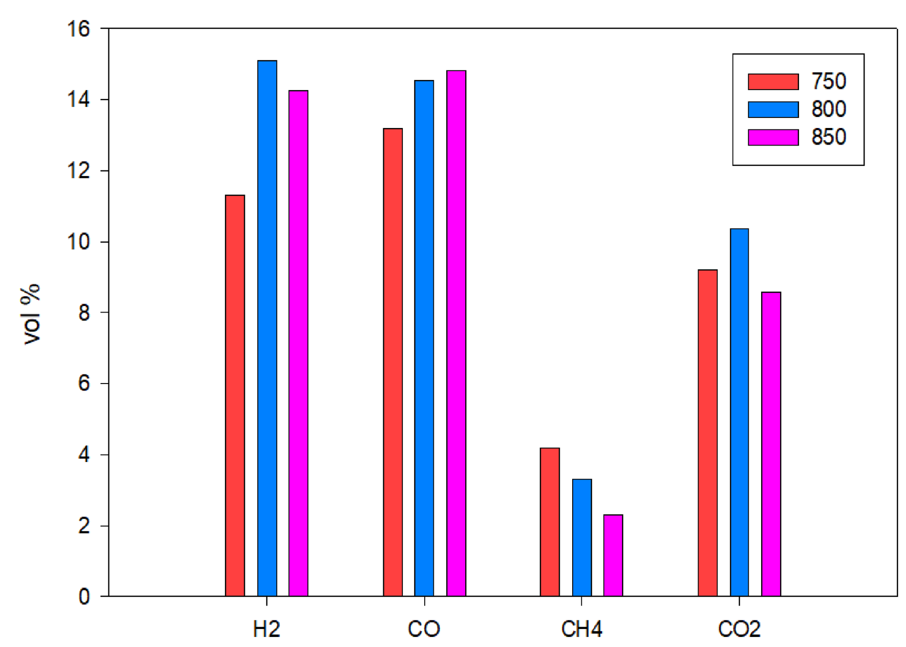
$$ER: \frac{Actual\ air}{Stoichiometric\ air}$$

Results

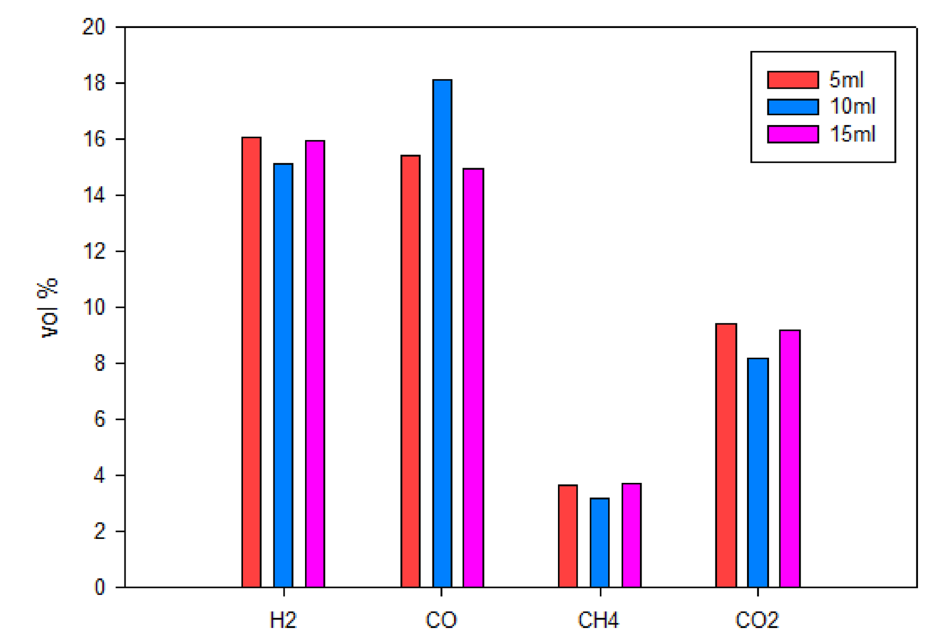
Physical characteristics of the catalysts in this study

Catalyst	Surface area (m^2/g)	Total pore volume (cm^2/g)
Activated carbon	1043.31	0.519
biochar	14.05	0.012
lignin char	3.28	0.007

Effect of air/steam injection and reaction temperature on gas selectivity of DSS gasification(Activated carbon)

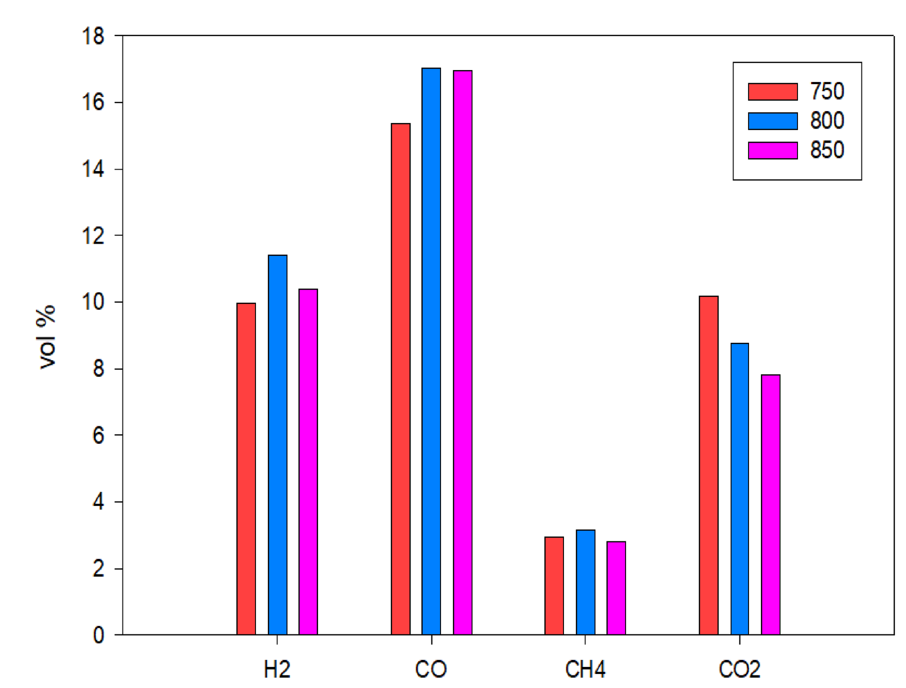


(a) Temperature℃

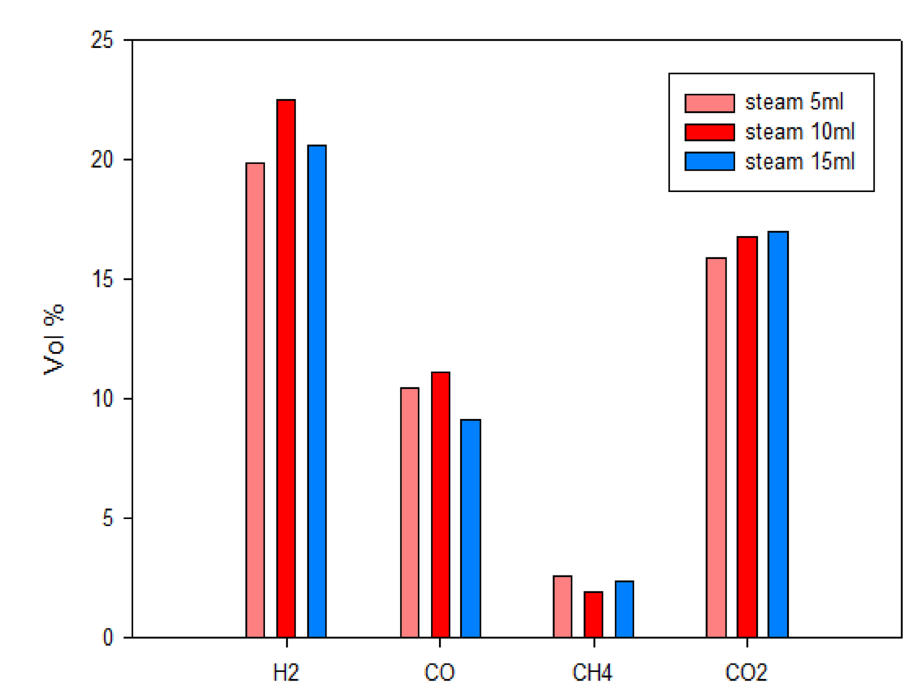


(b) Steam

Effect of air/steam injection and reaction temperature on gas selectivity of DSS gasification(Bio char)

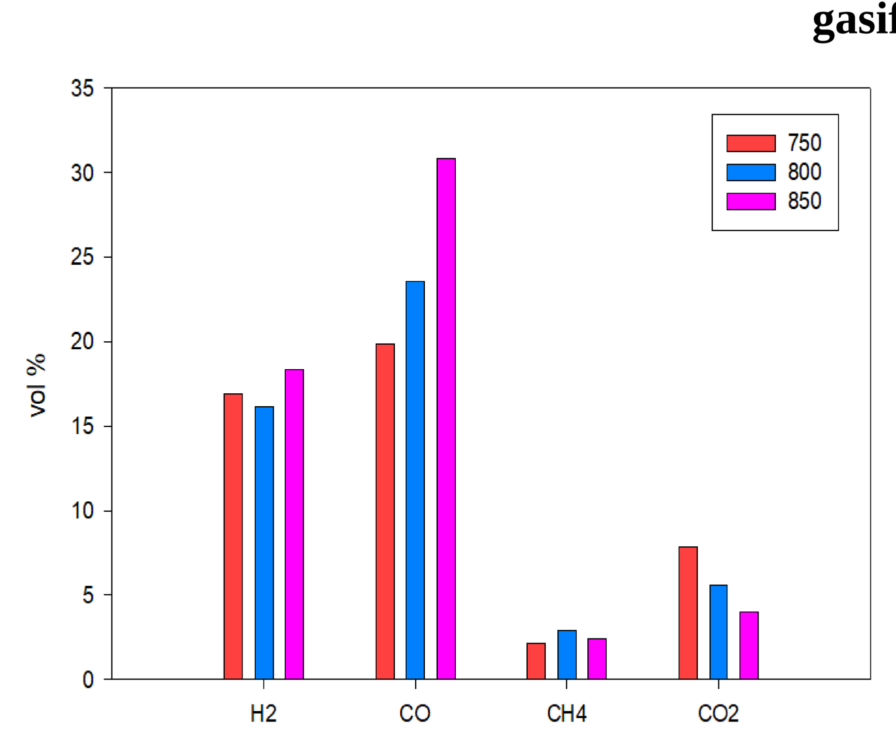


(a) Temperature℃

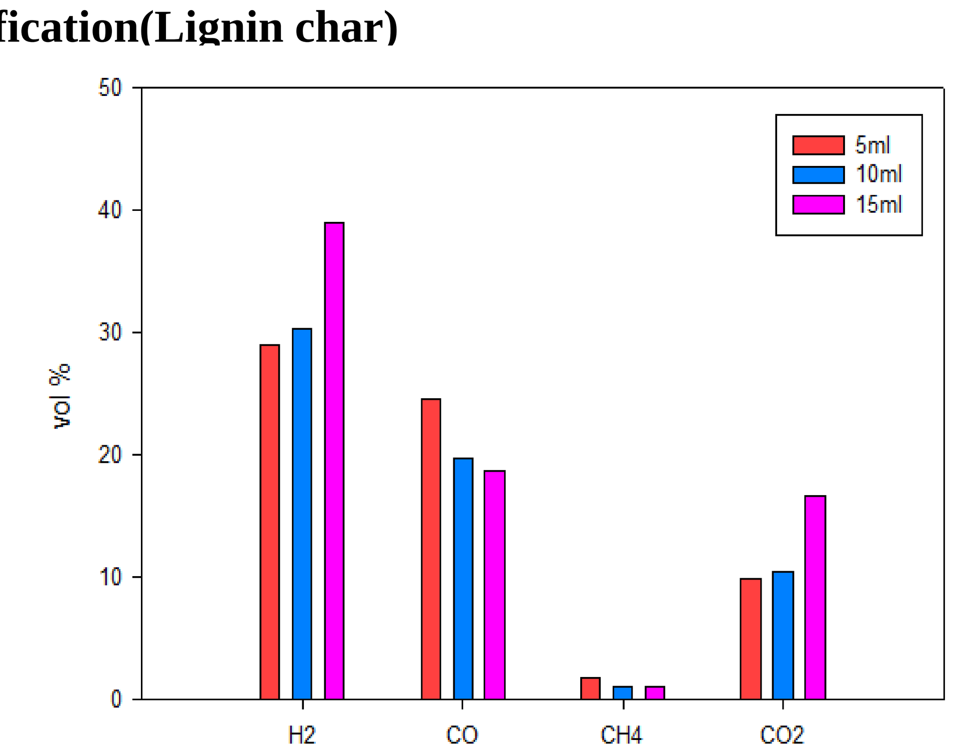


(b) Steam

Effect of air/steam injection and reaction temperature on gas selectivity of DSS gasification(Lignin char)



(a) Temperature℃



(b) Steam

Conclusions

- The carbon based additives particle size of 0.5 mm–1.7 mm and temperature of 800 °C showed optimum results in terms of higher gas yield, high H_2, and low CO_2 in the product gas when air was used as the gasifying agent.
- The induction of steam only showed a positive effect in the case of biochar and lignin char because the water-gas shift reaction and hydrocarbon reforming, resulting in a higher H_2 selectivity of ~35vol%.
- It can be concluded that the presence of AAEMs in biochar is more efficient for higher H_2 generation via an enhanced water–gas shift reaction than the higher surface area of activated carbon with no AAEMs.
- This study provides an excellent and sustainable solution for enhancing H_2 generation using activated carbon and low-cost biochar and lignin char catalysts under different gasification conditions.

Acknowledgement

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