Choosing optimal RDF gasification medium for H_2-rich syngas production

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Introduction:

Gasification and pyrolysis are the two main thermochemical technologies for producing hydrogen (H_2) from refuse-derived fuel (RDF) (Mensah et al 2022; Pandey et al 2019). Among them, gasification is the ideal technology for producing H_2-rich syngas. Nguyen et al (2024) reported a high H_2-rich syngas yield of 70% volume for gasification compared to a high yield of 55.67% volume of H_2-rich syngas for pyrolysis.

Pandey et al (2019) observed that the different gasification medium including steam, carbon dioxide (CO_2), oxygen and air affect the yield of H_2 fraction in syngas. This article is novel as it seeks to compare the different gasification media using the best-worst method (BWM) with the object of selecting the optimum gasification medium for optimum H_2-rich syngas production.

Methodology:

Best-Worst Method (BWM)

The best-worst method is a newly developed multi-criteria decision making (MCDM) method by (Rezaei, 2015, 2016). It is not complicated and employs the pairwise comparisons approach to find the weights of the criteria as it is commonly referred to. Unlike other MCDM methods, BWM requires less data; yet, the evaluations are exact and executed in a more structured manner.

The following rudimentary five steps in determining the weights of the criteria as proposed by Rezaei were followed:

Step 1. Determine a set of criteria. In this study, the set of criteria will be selected from examining 15 peer-reviewed scientific papers, published in the last ten years (2014-2024).

Step 2. Select the best and worst criteria. The best and worst criteria will be selected by the investigator/decision maker based on the outcome of step 1.

Step 3. Compare the best criterion with the other criteria in the score of 1-9.

Step 4. Compare the other criteria with the worst criterion in the score of 1-9.

Step 5. Calculate the optimal weights from equation 1 and the consistency ratio (CR) using equation 2. NB: The closer the value of CR to zero the higher the consistency and vice versa.

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \le \xi, \text{ for all } j$$

$$\left|\frac{w_j}{w_w} - a_{jW}\right| \le \xi, \text{ for all } j$$

$$\sum_j w_j = 1$$

$w_j \geq 0$, for all j.............................. (eqn.1) (Rezaei, 2015, 2016)

$Consistency\ ratio = \frac{\xi^*}{Consistency\ index}$......... (eqn.2) (Rezaei, 2015, 2016)

Results and discussion:

Table 1. List of selected criteria in this study

Category	Criteria	Acronym
Syngas fuel quality	Calorific value	C_1
	H_2/CO	C_2
	CCE	C_3
	CGE	C_4
Syngas fuel yield	H_2 yield	C_5
	Overall syngas yield	C_6
Economic	Cost	C_7
	Availability	C_8
Environmental	CO_2	C_9
	CH_4	C_{10}
	H_2S	C_{11}
	NH_3	C_{12}

Conclusions:

In this study, a comprehensive evaluation of the different gasification methods based on the gasifying agents, namely, steam gasification, air gasification, CO_2 gasification and oxygen gasification were ranked to select the optimum one for the production of H_2-rich syngas using RDF as feedstock. Next, 12 different decision criteria were selected to assess the performance of the gasification alternatives based on the syngas fuel quality, syngas fuel yield, economic and environmental perspectives. Finally, the BWM was used to determine the weights of the criteria.

References

Mensah, I., Ahiekpor, J. C., Bensah, E. C., Narra, S., Amponsem, B., & Antwi, E. (2022). Recent Development of Biomass and Plastic Co-Pyrolysis for Syngas Production. *Chemical Science International Journal*, 41–59. https://doi.org/10.9734/csji/2022/v31i130275

Nguyen, V. G., Nguyen-Thi, T. X., Phong Nguyen, P. Q., Tran, V. D., Ağbulut, Ü., Nguyen, L. H., Balasubramanian, D., Tarelko, W., A. Bandh, S., & Khoa Pham, N. D. (2024). Recent advances in hydrogen production from biomass waste with a focus on pyrolysis and gasification. *International Journal of Hydrogen Energy*, *54*, 127–160. https://doi.org/10.1016/j.ijhydene.2023.05.049

Pandey, B., Prajapati, Y. K., & Sheth, P. N. (2019). Recent progress in thermochemical techniques to produce hydrogen gas from biomass: A state of the art review. In *International Journal of Hydrogen Energy* (Vol. 44, Issue 47, pp. 25384–25415). Elsevier Ltd. https://doi.org/10.1016/j.ijhydene.2019.08.031

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega (United Kingdom)*, *53*, 49–57. https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega (United Kingdom)*, *64*, 126–130. https://doi.org/10.1016/j.omega.2015.12.001