Improving Syngas Fermentation Acetic Acid Production Using Active Carbon

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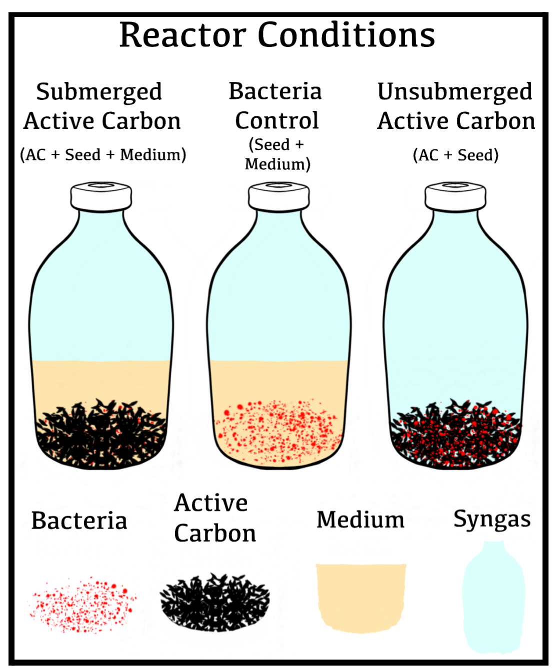
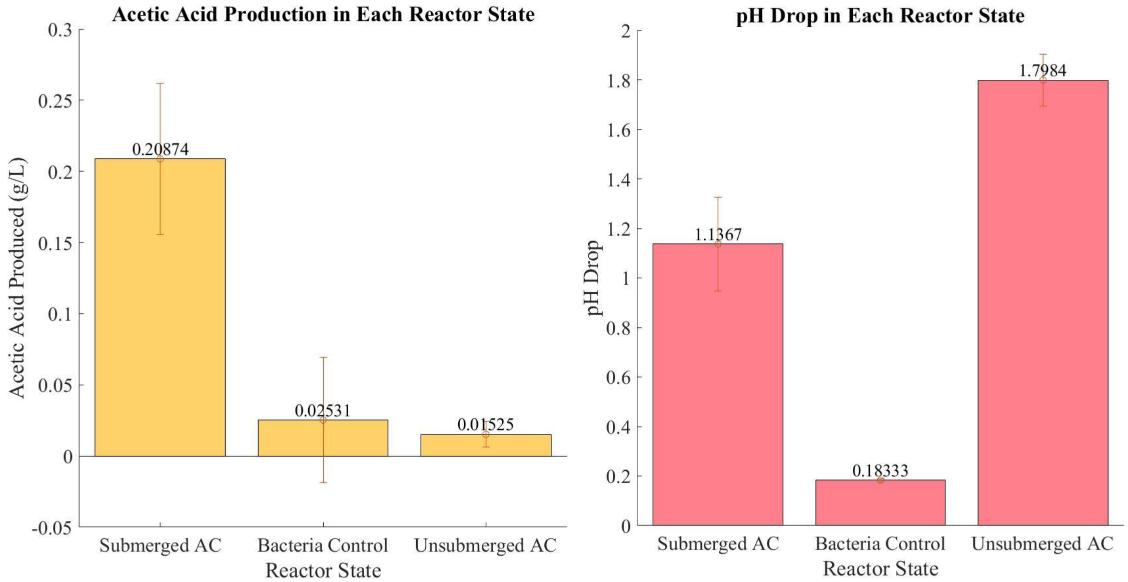
Introduction & Methods

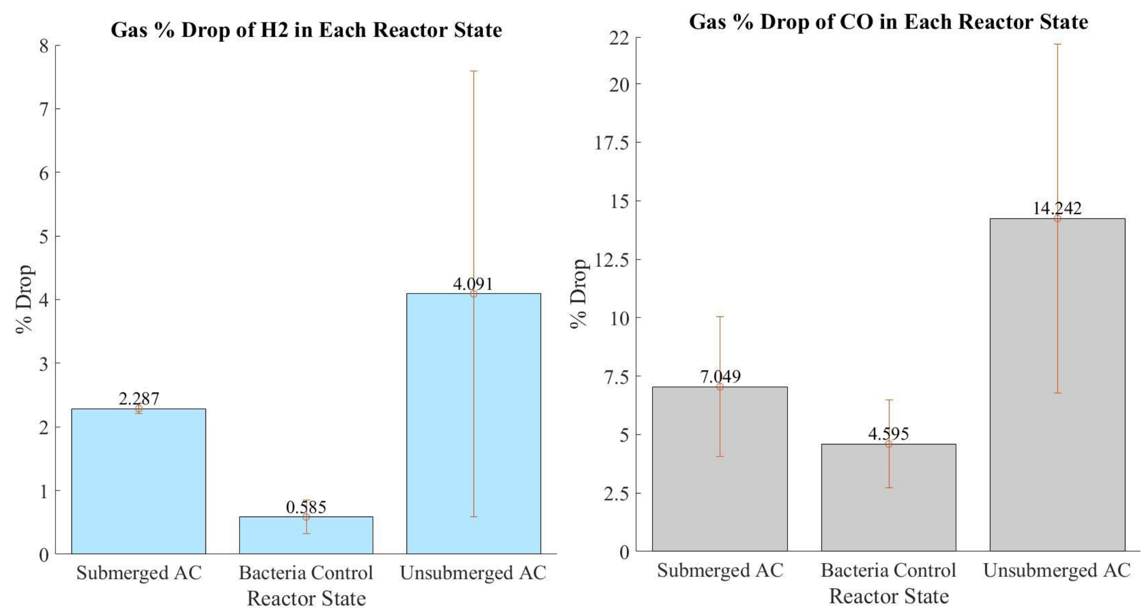
Lignocellulosic biomass, a plant-based biowaste, is one the most common forms of biomass. A drawback is its few uses, one being conversion to syngas, which consists of carbon monoxide and hydrogen. This research focuses on the anaerobic conversion of syngas to acetic acid, which can then be converted to single cell proteins: a protein source for animal feed, food additives, bioplastics, and organic soil additives.[1] Other studies using biochar for syngas fermentation focused on ethanol production. Most use poultry litter biochar, and all either used C. ragsdalei or C. carboxidivorans. To test a way to improve the production of acetic acid, an acetogenic, or acetic acid-producing, bacteria was grown on active carbon (AC). The purpose of using AC, a very porous material, was in hopes of increasing the active surface area for the bacteria to access its carbon source. This would lead to an increased production of acetic acid. The bacteria Clostridium Ljungdahlii was first accumulated with only the medium for 1-2 weeks to make "seed"; the source of carbon being fructose. Separate medium was prepared and with 5 mL of seed, placed in 2 types of reactors: with active carbon and without. There was a third type with only the seed and active carbon. The reactors were left for a week with nitrogen and syngas: made of hydrogen and carbon monoxide. The carbon monoxide served as the carbon source to replace to consumed fructose. In submerged AC state, there was improvement in acetic acid production than the other conditions. The small quantity of liquid sample available in the unsubmerged active carbon condition means it is possible there was more acetic acid production, since there was a more drastic decrease in syngas and higher drop in pH.



Results



Figures 1 & 2: Acetic acid measured in small liquid samples for each condition, and the pH drops. There is a significant difference between the two left conditions where the Submerged AC has a higher production and pH drop. Initial pHs were 9.01, 9.37, and 8.08 from left to right.



Figures 3 & 4: Percent drops for hydrogen gas and carbon monoxide. Initial percentages were 20% & 55% for H_2 & CO respectively. There is a consistent difference between the two left conditions where the Submerged AC has a higher gas consumption.

Discussion

Over all figures, Submerged AC was more successful than the bacteria control. More acetic acid was produced, which caused a higher pH drop, and syngas consumption was significantly higher. In all but figure 1, it appears the Unsubmerged AC was even more successful than the submerged. There was only a total of 5 mL of liquid added to this condition (5 mL needed to be strained through to get a liquid sample), making analysis for acetic acid unreliable for that condition. If the acetic acid could be measured more efficiently, it may have been the most effective condition. The submerged case produced 8 times more acetic acid per volume, with a 6 times decrease in pH. Overall the use of AC proved to be successful in increasing the efficiency of acetic production using C. Ljungdahlii. The unsubmerged condition indicates a possibility of less nutrients needed for a 1 week cycle, and that gas-liquid surface area may have been more important to produce more acetic acid. In an experiment that used biochar, the higher surface area led to higher catalytic activity, supporting this possibility.[2]

Conclusion & Reflection of UROP Experience

As hypothesized, active carbon has shown itself to be efficient at increasing acetic acid production in C. Ljungdahlii using syngas as its carbon source. Submerged active carbon is most reliably the most efficient of the three tested conditions, but unsubmerged active carbon has potential to be even moreso. To expand on this project, other porous materials could be explored, or perhaps more shapes of active carbon, such as tubes or slices, could be tested as well. By changing the method of measurement for acetic acid, the unsubmerged condition with a large amount of gas-liquid surface area could be more thoroughly explored, to see to what extent it increases efficiency of acetic acid production. I was humbled to be able to learn how to use many pieces of scientific equipment such as the autoclave and furnace, and about multiple methods of analysis such as High-Performance Liquid Chromatography and Micro-Gas Chromatography to collect my data. Having firsthand experience of the scientific method has been a very valuable experience for I aim to apply in my studies and work henceforth.

References

1. Matassa, S.; Papirio, S.; Pikaar; etc. Upcycling of biowaste carbon and nutrients in line with consumer confidence: the "full gas" route to single cell protein. *Green Chem* [Online] **2020**, *15*, 4912-4929. https://doi-org.ezp2.lib.umn.edu/10.1039/D0GC01382J (accessed May 13, 2021).
2. Dehkhoda, A.; Ellis, N. Biochar-based catalyst for simultaneous reactions of esterification and transesterification. *Catalytic Processes for Clean Energy, Waste Minimization and Green Chemicals* [Online] 2013, 207. https://doi-org.ezp1.lib.umn.edu/10.1016/j.cattod.2012.05.034 (accessed May 13, 2021).