Algae-based integrated system for biomethane fuel purification and carbon sequestration

Uttam Roy[1], Jonathan Wagner[2] and Tanja Radu[1]

School of Architecture, Building and Civil Engineering[1]; Department of Chemical Engineering[2]

Loughborough University

Introduction

Anaerobic digestion (AD) is a well-established technology for converting biomass and wastes into biogas, a mixture of methane (50 - 80%) and carbon dioxide (30 - 45%) [1, 2]. Biogas can be purified into biomethane, allowing direct export to the national grid, however most commercial treatment processes are uneconomic for small to medium-sized AD processes [3]. Instead, biogas is incinerated for local electricity generation, releasing most of captured CO_2 back to the atmosphere. This project seeks to develop a novel, algae-based biogas purification process, to produce high purity biomethane together with the sequestration of remaining biomass and biogas carbon. The produced algae biomass can be recycled to the digester to enhance biogas production or converted into higher-value by-products [4, 5].

Project objectives

- Select and test suitable algae strains for cultivation on bicarbonate-rich medium
- Investigate absorption of CO_2 from biogas into carbonate solutions and spent algal growth medium
- Establish a sequential AD-HTC system to permanently sequester carbon into biochar and recover nutrients for algae cultivation

Process overview

1. Anaerobic digestion (AD) is used to convert feed biomass into biogas and wet digestate (digestion residue).
2. Biogas CO_2 is removed via reaction with carbonate solution to form bicarbonate
3. Carbonate solution is regenerated in algae photobioreactor, releasing CO_2 required for algae growth
4. AD digestate is stabilized via hydrothermal carbonization (HTC), aqueous nutrients are used to supplement algae growth
5. Algae biomass is harvested and recycled to digester to supplement biogas yields.

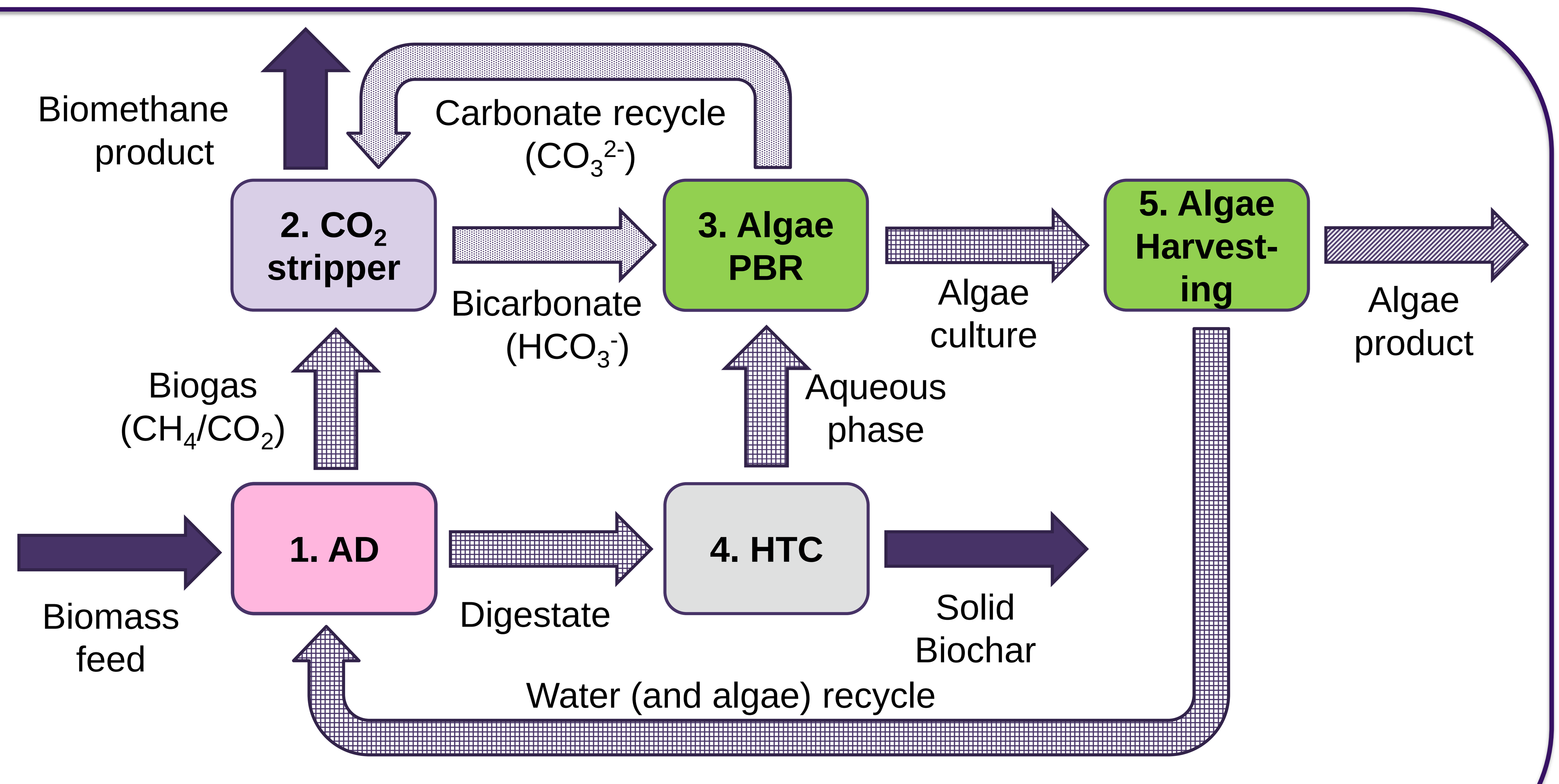


Figure 1. Schematic of integrated process for microalgae-based biomethane purification and carbon sequestration

Strain tolerance to $NaHCO_3$

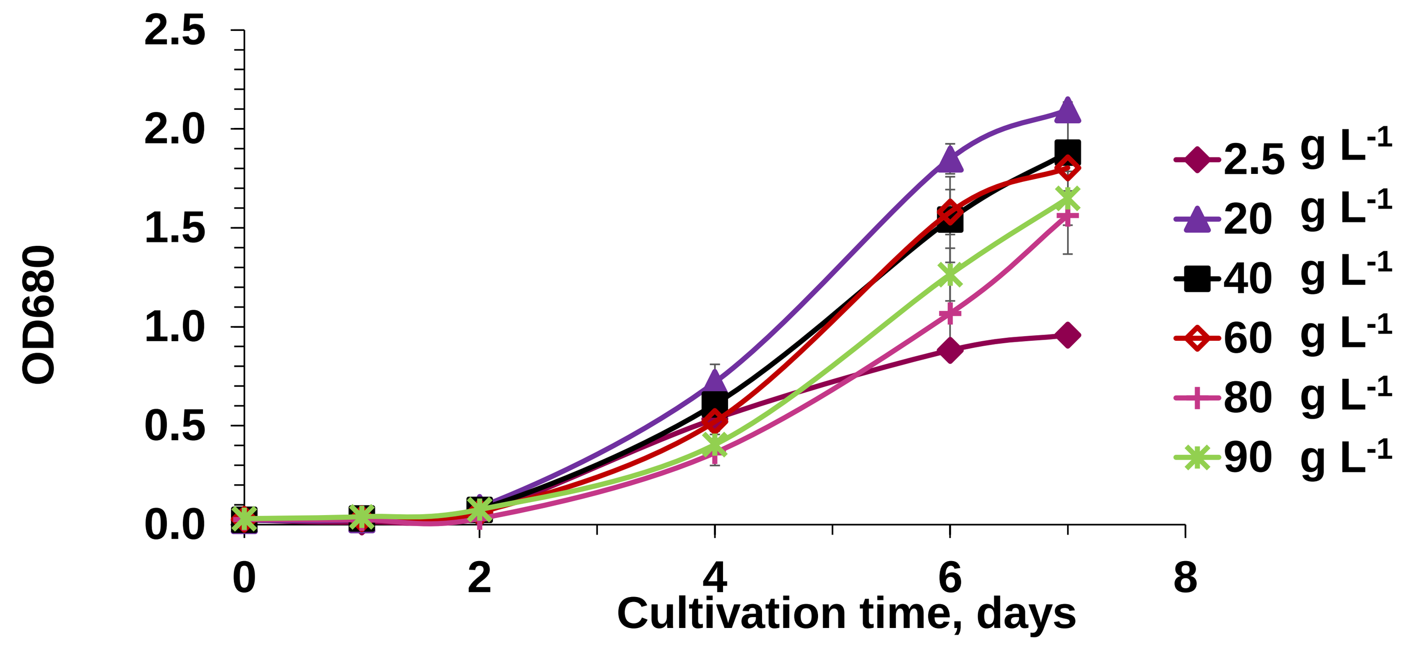
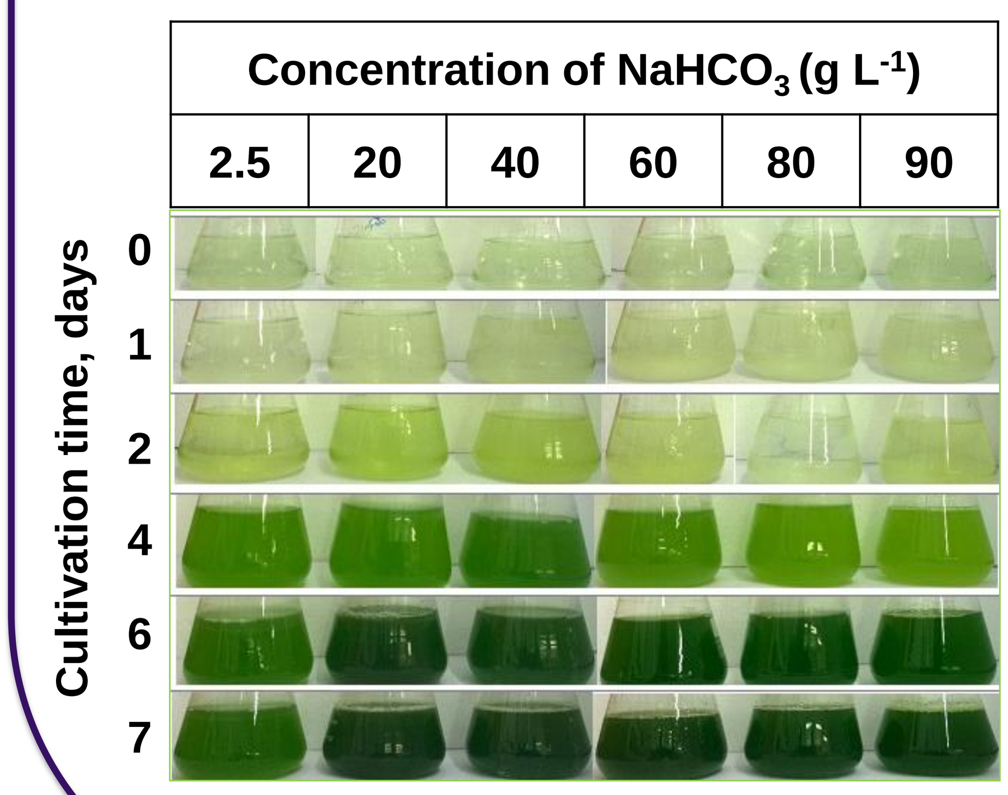


Figure 2. *D. tertiolecta* CCAP 19/30 growth curve for different $NaHCO_3$ concentrations



- *D. tertiolecta* CCAP 19/30 selected based on initial screening of 5 strains
- Tolerant to bicarbonate concentrations up to 90 g L^{-1}
- Maximum cell density and growth obtained at 20 - 40 g L^{-1} $NaHCO_3$

CO_2-stripper system

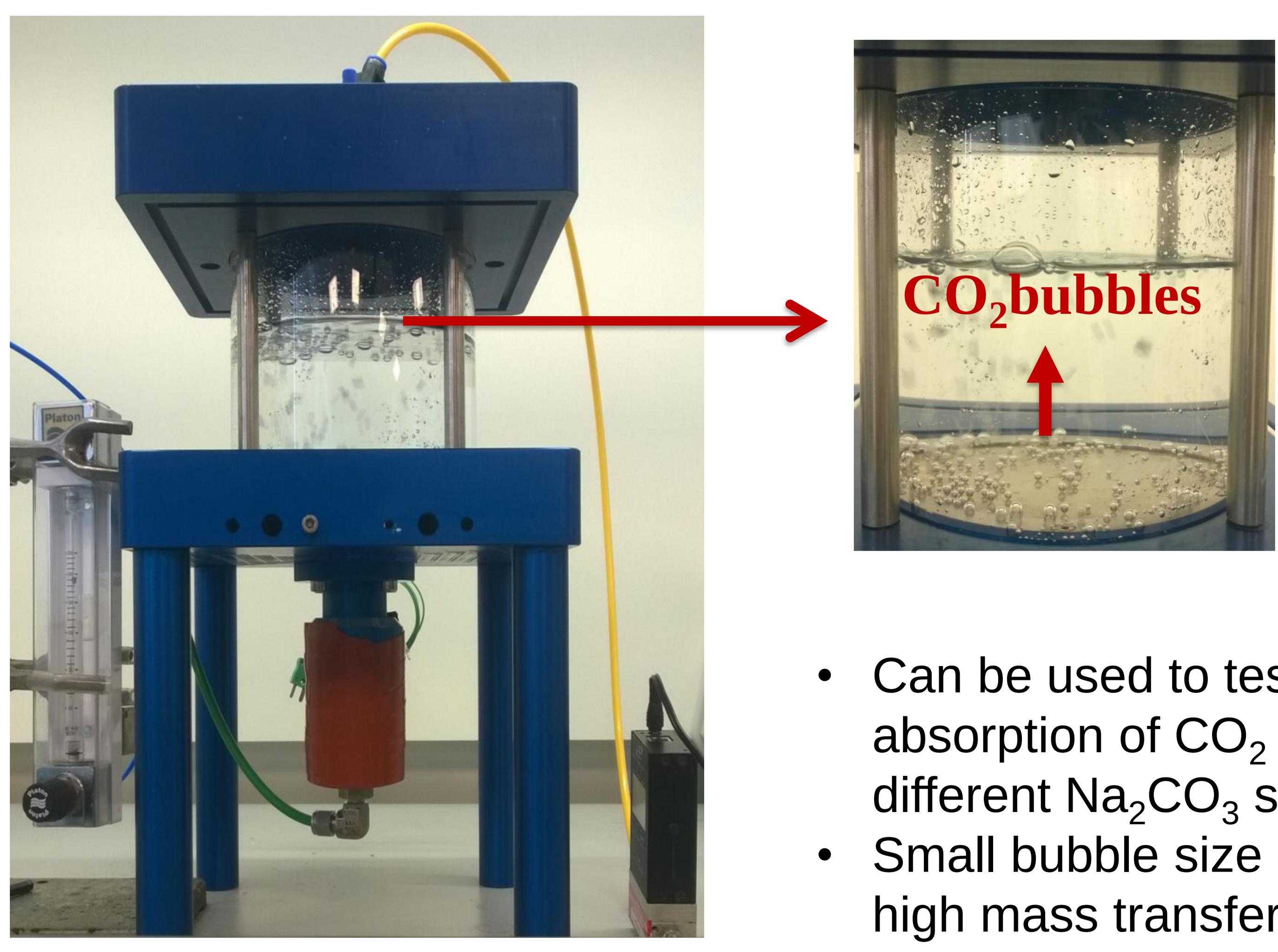


Figure 3. CO_2 -Stripper system

- Can be used to test absorption of CO_2 into different Na_2CO_3 solutions
- Small bubble size ensures high mass transfer between gas and liquid

Conclusion and future work

- *D. tertiolecta* CCAP 19/30 has high tolerance for bicarbonate-rich medium
- Data from strain testing and CO_2 adsorption experiments will be combined to determine best system operating conditions
- AD digestate will be treated by HTC to produce nutrient-rich aqueous phase for algae growth
- AD feed will be combined with algae to determine yield enhancement

REFERENCES

1. Srinuanpan, S., Cheirsilp, B., Kitcha, W. and Prasertsan, P., 2017. Strategies to improve methane content in biogas by cultivation of oleaginous microalgae and the evaluation of fuel properties of the microalgal lipids. *Renewable energy*, *113*, pp.1229-1241.
2. Wu, N., Moreira, C., Zhang, Y., Doan, N., Yang, S., Phlips, E., Svoronos, S. and Pullammanappallil, P., 2019. Techno-Economic Analysis of Biogas Production from Microalgae through Anaerobic Digestion. In *Biogas*. IntechOpen.
3. Milledge, J.J., Nielsen, B.V., Maneein, S. and Harvey, P.J., 2019. A brief review of anaerobic digestion of algae for bioenergy. *Energies*, *12*(6), p.1166.
4. Zhang, R.L., Wang, J.H., Cheng, L.Y., Tang, Y.J. and Chi, Z.Y., 2019. Selection of microalgae strains for bicarbonate-based integrated carbon capture and algal production system to produce lipid. *International Journal of Green Energy*, *16*(11), pp.825-833.
5. Chi, Z., Xie, Y., Elloy, F., Zheng, Y., Hu, Y. and Chen, S., 2013. Bicarbonate-based integrated carbon capture and algae production system with alkalihalophilic cyanobacterium. *Bioresource technology*, *133*, pp.513-521.

ACKNOWLEDGEMENTS

Sincere thanks to lab technicians in Water and Chemical Engineering lab

CONTACT INFORMATION

School of Architecture, Building and Civil Engineering
Loughborough University
Leicestershire LE11 3TU UK
E. t.radu@lboro.ac.uk
www.lboro.ac.uk/Water Engineeing