Fuel Oil from Algal Biomass: Evaluation on CO_2 Emission and Economy

The production of fuel oil from algal biomass through photosynthesis has been attracting attention as a fuel for aircrafts that are difficult to electrify, and the attempts for commercial scale production have begun. By clarifying the production cost and CO_2 emission with the results of our process design based on the basic data of three cases, 1) University of Tsukuba Group, 2) US Department Of Energy (DOE), and 3) New Zealand's National Institute of Water and Atmospheric Sciences Research (NIWA), the challenges for realizing the low carbon fuel oil are shown.

- University of Tsukuba G: Fuel oil Production by *Botryococcus braunii* [Case 1].
- U.S. Department Of Energy (DOE): Combining a large culture pond with a fuel oil production process [Case 2].
- New Zealand NIWA: Use sewage treatment plant effluent as raw materials [Case 3].
- The production costs of case 1 and 3 are much higher than the current cost of fuel oil (50 JPY/kg) and case 2 is about three times higher. Factors such as the structure of the culture pond, the CO_2 concentration in the CO_2 resource, the production scale, and residence time make these differences.
- Even for CO_2 emissions, cases 1 and 2 are greater than the 70 g-CO_2/MJ of current gasoline fuel. For case 3, it's about 0.6 times because of feeding the carbon neutral CO_2. Even if renewable energy is used for power, each case produces 134, 108 and 20 g-CO_2/MJ respectively. This means it is impossible to produce the carbon free fuel oil from algal biomass through above study.

Conclusion

It is obvious that low carbon fuel oil from algal biomass can not be realized with feeding CO_2 derived from fossil fuel as the carbon source. In order to realize carbon free fuel in the future, further studies on using the non fossil resources or combination with Direct Air Capture (DAC) will be needed.

Table 1: Comparisons of fuel oils from algae

	Case 1 University of Tsukuba G	Case 2 DOE	Case 3 NIWA
Algae	***Botryococcus***	***Scenedesmus***	**Algae colony**
Productivity (g/m^2/day)	20	25	20
Days cultured	20	5	9
Size of culture ponds (ha)	1	4	1.25
CO_2 source	**Exhaust gas from thermal power plant: CO_2 concentration of 5%, recycling of unreacted CO_2**	**Exhaust gas collected from thermal power plant: CO_2 concentration of 100%**	**Exhaust gas from sewage treatment digestion of gas-based power plant: concentration of 5%**
Annual production per-module (t/y)	66	3,300	82.5
Number of modules	1	50	1
Fuel oil production (t/y)	33	79,900	33
(TJ/y)	1.38	3,040	1.38
Annual variable cost (million JPY)	**1.9**	**5,400**	**1.2**
Annual facility cost (million JPY)	41.4	7,150	12.2
Annual labor cost (million JPY)	5	540	5
Annual fixed cost (million JPY)	**46.4**	**7,690**	**17.2**
Total annual cost (million JPY)	**48.3**	**13,090**	**18.4**
Fuel oil cost (JPY/kg)	**1,462**	**164**	**558**

	CO_2 emission (g/MJ)		
Feedstock origin	**88**	**82**	**0**
Sub-feedstock origin	**0**	**24**	**0**
Power origin (400g-CO_2/kWh)	**36**	**9**	**25**
Construction material origin	**46**	**2**	**20**
Total	**170**	**117**	**45**

[1] JST Strategic Basic Research Programs CREST, "Oil-producing green algae (Research Completion Report: Sophisticated Utilization of Alkaliphilic Strains of Oil-producing Green Alga, *Botryococcus*", 2012)
[2] R. Davis et al., "Process Design and Economics for the production of Algal Biomass", NREL/TP-5100-64772, 2016.
[3] M.A.Borowitzka et.al., "Algae for Biofuels and Energy", Springer, 2013.