



A new biorefinery process boosts the biofuel production from algae

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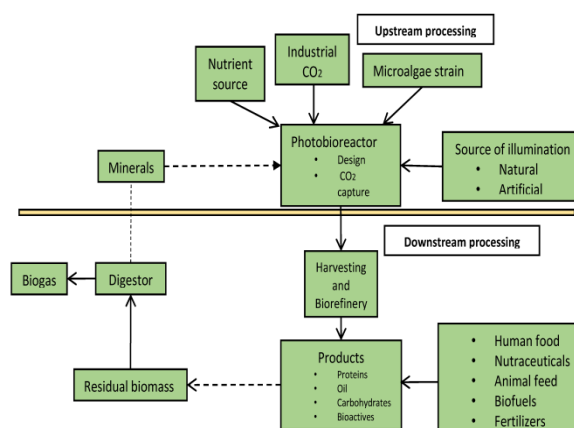
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Abstract : A new biorefinery process developed by scientists at the Energy Department's National Renewable Energy Laboratory (NREL) has proven to be significantly more effective at producing ethanol from algae than previous research. In that work, scientists examined two promising algal strains, *Chlorella* and *Scenedesmus*, to determine their applicability as biofuel and bioproduct producers. They concluded *Scenedesmus* performed better in this process with impressive demonstrated total fuel yields of 97 gallons gasoline equivalents (GGE) per ton of biomass. Cost of algal biofuel production is still a major challenge and the Energy Department has made reducing the costs of both algae production and conversion of algal intermediates to fuels significant goals. In traditional processes, the algae produce lipids that get converted into fuels. These results led to the conclusion that the novel CAP process is capable of reducing the cost of algal biofuel production by nearly \$10/GGE compared to a "lipids only" process, taking the modeled cost down to \$9.91/GGE. While this is not nearly low enough to compete with petroleum, this approach can be combined with reduced costs for biomass production to provide a path forward to achieve that goal.

Keywords: biorefinery , Chemical reactor, Catalyst.

INTRODUCTION

In recent years, the rapid depletion of fossil fuels, increase in energy demand, global warming, increase in price of fossil fuels depends on economic and political behaviors increased orientation to alternative energy sources. In this context, biodiesel that is one of the renewable alternative energy sources draws attention because of its useful features such as easily biodegradable and environmentally friendly. However, biodiesel production from oil crops does not meet the required demand of vehicle fuel, and recently it is not economic and feasible. It needs to be improved to produce more economically to be able to compete with diesel in the market. Vegetable oils and crops which biodiesel produced from are a kind of human food sources and the shortage on food source cause to go up prices and make the biodiesel high-priced. To meet the requirements, the interest on algae is increased day by day since this technology has potential to meet global demand. Microalgae have higher productivity per area and no need for farm field to grow as opposed to oil crops and animal fat. Microalgae use sunlight to reduce CO₂ to biofuels, foods, fertilizers, and valuable products. Furthermore, microalgae can be used to get different types of biofuels. Using microalgae as fuel source is not a novel idea but recently the prices of diesel and global warming hit this solution to the top. The other significant feature is that algae can grow everywhere and every season in a year since there are thousands of algae species that have different adaptations and different properties. They can grow in saltwater, freshwater, lakes, deserts, marginal lands, etc. In addition to biodiesel production, algae can be also used as feedstock to produce different valuable products such as fertilizer, energy, nutraceuticals, protein, animal feed etc. The other significant property is that microalgae can remove some heavy metals, phosphorous, and nitrogen from water during its growth. Algae also clean up the water. Moreover, microalgae sequester lots of carbon by photosynthesis. Utilization of carbon dioxide by algae is significantly lowering the risk for greenhouse gas effects. Lastly, usage of microalgae for biodiesel almost cancels out the carbon dioxide and sulfur release to atmosphere (N.D. Weiss et al., 2009).

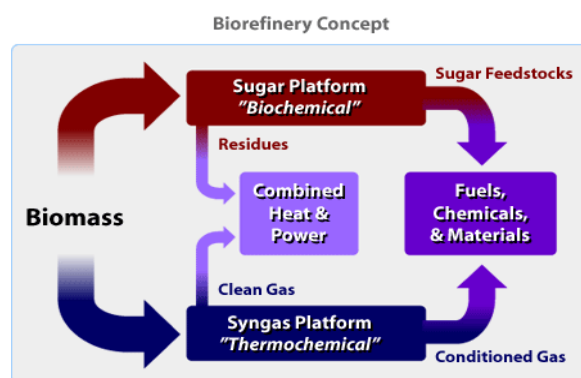


A new project to develop technology to drive forward an algae-based biorefinery which aims to develop and validate technological processes designed to obtain biodiesel through algae cultivation. Cost of algal biofuel production is still a major challenge and the Energy Department has made reducing the costs of both algae production and conversion of algal intermediates to fuels significant goals. In traditional processes, the algae produce lipids that get converted into fuels. However, simply increasing the amount of lipids in algae isn't expected to bring costs down enough (T. Donget al., 2015). NREL determined further progress could be made by more completely using all algal cellular components instead of just relying on the lipids. By applying certain processing techniques, microalgal biomass can produce carbohydrates and proteins in addition to lipids, and all of these can be converted into co-products.

Chemical composition (% dry matter basis) of selected microalgae (Bruton et al., 2009).

	Protein	Carbohydrate	Lipids	Nucleic acid
Freshwater algal species				
<i>Scenedesmus obliquus</i>	50–56	10–17	12–14	3–6
<i>Scenedesmus quadricauda</i>	47	–	1.9	–
<i>Scenedesmus dimorphus</i>	8–18	21–52	16–40	–
<i>Chlamydomonas reinhardtii</i>	48	17	21	–
<i>Chlorella vulgaris</i>	51–58	12–17	14–22	4–5
<i>Chlorella pyrenoidosa</i>	57	26	2	–
<i>Spirogyra</i> sp.	6–20	33–64	11–21	–
<i>Euglena gracilis</i>	39–61	14–18	14–20	–
<i>Spirulina platensis</i>	46–63	8–14	4–9	2–5
<i>Spirulina maxima</i>	60–71	13–16	6–7	3–4.5
<i>Anabaena cylindrica</i>	43–56	25–30	4–7	–
Marine algal species				
<i>Dunaliella bioculata</i>	49	4	8	–
<i>Dunaliella salina</i>	57	32	6	–
<i>Pyrenidium parvum</i>	28–45	25–33	22–38	1–2
<i>Tetraselmis maculata</i>	52	15	3	–
<i>Porphyridium cruentum</i>	28–39	40–57	9–14	–
<i>Synechococcus</i> sp.	63	15	11	5

In their initial work, NREL researchers determined that through the use of a solid-liquid separation process, the carbohydrates can be converted to fermentable sugars, which can then be used to produce ethanol. However, as much as 37 percent of the sugars were lost during that process. Those trapped sugars "cannot be used for fermentation without a costly washing step, resulting in a loss of overall fuel yield," according to the Algal Research report. In their most recent work, NREL researchers hypothesized the amount of ethanol could be significantly increased by simplifying the processing. By skipping the solid-liquid separation process and exposing all algae components directly to fermentation conditions, both ethanol (from the carbohydrate fraction) and lipids can be recovered simultaneously. Using *Scenedesmus* and the CAP, and after upgrading the lipids to renewable fuels, scientists were now able to produce a total fuel yield estimated at 126 GGE per ton. That's 88 percent of the theoretical maximum yield and 32 percent more than the yield from lipids alone (A. Sluiter et al., 2008). The NREL researchers also were able to recover 82–87 percent of the lipids from the CAP, even after ethanol fermentation and distillation, indicating that the initial fermentation of sugars in the pretreated biomass slurry doesn't significantly impede lipid recovery. These results led to the conclusion that the novel CAP process is capable of reducing the cost of algal biofuel production by nearly \$10/GGE compared to a "lipids only" process, taking the modeled cost down to \$9.91/GGE. While this is not nearly low enough to compete with petroleum, this approach can be combined with reduced costs for biomass production to provide a path forward to achieve that goal.



An integrated algal biorefinery process, termed CAP, is successfully demonstrated by Y. Chisti, 2007. The algal slurry after acid pretreatment is a sufficient medium for cultivating yeast to produce ethanol without any additional nutrients. Almost all the fermentable sugars were utilized in CAP. The utilization efficiency of carbohydrates is significantly improved (ethanol yield of 31 GGE/ton biomass) compared to previous refinery design cases (ethanol yield of 20 GGE/ton biomass). Lipid yield is not adversely affected by fermentation and ethanol removal, reaching 87% of FAME recovery. CAP can further reduce microalgal biofuel cost by 9% achieving a modeled energy yield of 126 GGE/ton of total fuel products with \$9.91/GGE from *S. acutus* biomass (J. Shekiri et al., 2012). Removing an additional SLS reduced capital and operating cost resulting in a simplified and robust process. It is likely that a number of high-value co-products, such as PUFA and protein residue, may also be produced via the CAP processing concept, resulting from the process' relatively non-destructive nature of fractionating whole algal biomass to individual component constituents. High-value co-product opportunities possess potential to significantly reduce the high cost of algal biofuel production, especially from the extracted stillage fraction, which, in our current analysis, is relegated to anaerobic digestion for biogas production. The NREL lab used a solid-liquid separation process to convert the carbohydrates to fermentable sugars, which can then be used to produce ethanol. A substantial part of the sugars, up to 37%, were lost during that process, though. The new research

skips the separation process and exposes all algae components directly to fermentation conditions. Thus both ethanol and lipids can be recovered simultaneously. After upgrading the lipids to renewable fuels, scientists achieved a total fuel yield of 126 gallons gasoline equivalents (GGE) per tonne of biomass. Increasing ethanol yield by using all algal components instead of just the lipids can help decrease the cost for algal biofuel production. The goal is to develop sustainable, cost-competitive biofuels from feedstocks, including algae, which can help to reduce dependence on foreign oil, reduce greenhouse gas emissions, and create economic opportunities.

Microalgae are the untapped resource with more than 25,000 species of which only few are in use. The overarching goal of microalgal biotechnology is to improve the productivity of these organisms in order to meet the demands of a rapidly growing market. Large-scale open ponds had lower productivity than required for economic deployment, probably due to low night temperatures in the areas where these open ponds were tested. Studies are being carried out with methyl acetate as a substrate which avoids glycerol formation and lipase inhibition. Unsaturated fatty acid content is high in algal oils and their presence lowers esterification yields.

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