PRODUCTION OF BIODIESEL FROM ALGAE

SOCIETAL PLAYERS THAT CONTRIBUTED TO COVID-19 VACCINE TRUST

A Thesis Prospectus
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By
Kazunori Yoshizaki

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Technical Project Team Members
Avery Black
Joseph Kwon
Thomas (Hunter) O'Quinn

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Richard Jacques, Department of Engineering and Society

Eric Anderson, Department of Chemical Engineering

Introduction

Climate change has become a predominant problem recently; biofuels are a potential solution due to their absorption of carbon dioxide from the atmosphere. Biodiesel produced from algae will be the focus of this project; this project will address the need for an environmentally friendly fuel source that is able to meet the necessary specifications. Biodiesel has the potential to be used within existing infrastructure, which is partially due to its ability to be used in existing diesel motors. Unlike traditional designs that convert algae into biodiesel, this process will involve the simultaneous use of a closed photobioreactor and open raceway pond. Research supports that hybrid systems outperform isolated systems in algal growth and productivity (Narala, 2016), so the goal of this project is to design a system which delivers biodiesel at a comparable wholesale price to that of petroleum diesel, which is around $2.50/gallon (U.S. Energy, n.d.). This makes algae biofuels a favorable alternative.

Technical Project

In this process, there are three main steps after selecting the algae strain and nutrient source: 1) cultivation, where algae are allowed to grow and increase in lipid content, 2) extraction, where lipids are extracted from the harvested algae, and 3) refining, where lipids are purified to biodiesel.

Project Design: Sourcing

The algae that will be used is *Chlorella Vulgaris*, which is well-researched. The advantages of using *C. Vulgaris* include its high oil content, short growth cycle, and wide growth space (Mao et al., 2020). The nutrient source will be chicken litter from the Shenandoah Valley region, with approximately 200,000 tons of chicken litter being produced per year (Fears, n.d.).

This is a cheaper option than traditional sources of nutrients (*Maximizing Value: 2021 Spring Application*, n.d.).

Project Design: Cultivation

The two methods for cultivating algae for biodiesel production are closed photobioreactors and open raceway ponds, the latter being the cheaper option (Yun, 2018). However, one concern with raceway ponds is the potential introduction of bio-contaminants, which compete with algae growth (Yun, 2018). A hybrid system which simultaneously uses a photobioreactor and a raceway pond is a possible solution for this concern.

This system works by inoculating a culture of cells within a photobioreactor, and transferring a portion of the growing cells for continued growth in an raceway pond, which stimulates lipid biosynthesis through nutrient depletion (Narala, 2016). By using a hybrid system, the bio-growth phase and lipid-accumulation phase are separated into different parts of the process (Narala, 2016).

Project Design: Extraction

Once the algae have been grown, the lipids in the algal cells need to be extracted. The industry standard for this extraction is a dry extraction process, where an organic solvent is used to extract oils from dry algae cells, which are typically at a water content of around 10% (Ranjith, 2015). The harvested algae will first need to be dewatered to its maximum cell concentration, then dried into a solid powder. Traditional methods of dewatering involve the use of dissolved air flotation, followed by centrifuging the resulting algal sludge. The sludge is then dried and any lipids are extracted using organic solvents such as chloroform or hexane (Ozer, 2014). The primary design questions for this step are how much the wet algae should be dewatered, the drying method to be used, and the solvent to be used.

Project Design: Refining

Biodiesel in the form of fatty acid methyl esters (FAME) are commonly derived through transesterification of algal lipids, with the goal of using triglycerides. While transesterification is recognized as the simplest method, it requires high temperatures and catalysis to run efficiently (Kröger, 2012). Our goal is to take the triglycerides extracted from the algae cells.

The successful refinement of algae biofuels from the lipid extraction will be the consequence of many experimental factors. The main variables of concern that can influence transesterification are the algal species, reaction time, temperature, moisture, as well as the order and mixture of chemicals into the rector (Kröger, 2012). One major approach under investigation will be in the heating process of the reaction. Previous research has shown high yields and short reaction times with microwave heating mechanisms in contrast to traditional heating methods (Marwan, 2015).

Work Division

This is a two-semester, 4-person team project done for CHE 4474/4476. The work will be done in a collaborative style with small tasks divided up, with subtasks focusing on individual parts of the overall process. We will discuss the objectives of our project bi-weekly to ensure group members are contributing. Disputes will be handled cordially and major decisions will be put to a vote. If any group members are unable to honor their commitment to the team, we will discuss and consider the situation at hand and bring it to the attention of our instructor if needed.

Design Data Acquisition/Computational Tools

Physical data pertaining to chemical feedstocks used can be obtained from chemical data sources, such as Perry's Chemical Engineering Handbook. Data pertaining to algal and nutrient feedstocks will be obtained from peer reviewed journals. If necessary, algal data can be obtained using in-house equipment. After obtaining the design data, a simulation software, such as Aspen, will be used to model and assess the process.

STS Project

The eventual substitution of petroleum based fuel with plant source fuel will likely have immense positive consequences for the environment. Biofuels are of interest because, unlike petroleum fuel, the production process (growth of biomass through photosynthesis) removes carbon dioxide from the atmosphere. Although it seems promising on paper, there needs to be further investigation on what the environmental and societal implications are surrounding this shift towards biofuels.

Biofuels are, in theory, a more environmentally attractive option due to its edge as a carbon neutral option, but sourcing the space which grows, processes, and delivers biofuel requires deforestation (Biofuels Reform), which have negative environmental consequences. One report found that the shift to biofuels could lead to 7 million hectares of tropical forest deforestation, due to the increased demand for palm oil and soy oil, which are key components in the commercial production of biofuels (Ho). In addition to this deliberate land clearing for agriculture space, 3.6 million hectares will likely face peatland drainage (Ho), which is when carbon stored in the organic matter of the wet soil is released to the atmosphere as carbon dioxide, removing needed carbon sources for wildlife and affecting the ecosystem, as well as driving up CO_2 emissions. Deforestation has devastating environmental consequences, including loss of habitat for the 70% of land animals and plant species that live in forests, increased greenhouse gases from the loss of healthy forests which absorb carbon dioxide from the atmosphere, and reduced water in the atmosphere which leads to infertile soils (Pachamama Alliance). Furthermore, the deforestation and clearing of spaces required to build facilities to process biofuel will likely increase the global CO_2 emissions by 11.5 billion tons (Ho), which raises the question of how practical the solution (replacing petroleum fuel with biofuel) is, considering that current methods will worsen the situation by emitting more CO_2 into the atmosphere before it will be a successfully implemented system.

The main societal concern that comes with shifting towards biofuels is the way it interacts and competes with food. Because the biofuel manufacturing process require a large plot of land to grow and process the biomass, these facilities compete for land with agricultural spaces (Biofuels Reform). There are two implications for this: food prices increase, and indigenous communities are driven out of their homes.

Land used for a biofuel facility is land not used for agriculture. As more of these facilities are being built in spaces that used to grow crops, less food is being produced, which results in food scarcity and an increase in price. This reality is being observed in EU, where they have implemented the Renewable Energy Directive (RED), which mandates that 20% of all energy be produced from renewable sources by 2020 (International Council of Clean Transport). In the EU, the average global price of crops had increased by 3% between 2008 and 2009 (Baier). The price increase was even more drastic in the US, where increased biofuel production resulted in the increase of prices of corn by 22% and soybean by 15% in the same time (Baier). This dramatic increase in food costs will be problematic for consumers around the world, but more so for people in developing countries and families in lower income brackets, who devote a greater share of their income towards food (Biofuels Reform).

By the same token, the extreme land requirement for biofuel facilities have displaced many communities from their home. This is called land grabbing, where cheap land is bought by corporations to build facilities, and indigenous members living in the area are forcibly evicted to allow way for palm oil plantations (Biofuels Reform). To make matters even worse, these indigenous members are rarely represented in meetings discussing land procurement in Brussels, which has forced these communities to seek refuge in deeper parts of the forest and adjust certain parts of their lifestyle, like growing different foods that grow in the new environment (Biofuels Reform).

With setting up facilities that produce biofuel, land space will be an absolute necessity. With the mass deforestation that corporations carry out to find viable land, however, there are negative implications for both the environment and society, which is why checks and balances need to be implemented which regulate how corporations procure land. It must be done in a socially ethical and equitable way, and government regulations will likely keep companies in check to ensure violations are not being made.

Conclusion

Algae biofuels is a rapidly growing area of research as a carbon neutral fuel option, and the environmental benefits they propose, at first glance, look promising. However, the way the solution is implemented is extremely important in this case, and further investigation shows that the deforestation that comes with building facilities that grow and process algae can actually cause more harm than the solution does good. Special consideration will be made in the technical project to attempt to optimize the design of the plant such that it requires as minimal land space as possible, which helps to minimize the deforestation required to build this facility.

Word Count: 1695

References

Narala, Rakesh R., et al. "Comparison of Microalgae Cultivation in Photobioreactor, Open Raceway Pond, and a Two-Stage Hybrid System." *Frontiers in Energy Research*, vol. 4, 2016, https://doi.org/10.3389/fenrg.2016.00029.

"U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." *Today in Energy - Daily Prices - Prices - U.S. Energy Information Administration (EIA)*, https://www.eia.gov/todayinenergy/prices.php.

Mao, G., Shi, K., Zhang, C., Li, J., Chen, S., & Wang, P. (2020). Biodiesel Fuel from *Chlorella vulgaris* and Effects of Its Low-Level Blends on the Performance, Emissions, and Combustion Characteristics of a Nonroad Diesel Engine. *Journal of Energy Engineering*, *146*(3), 04020016. https://doi.org/10.1061/(ASCE)EY.1943-7897.0000668

Fears, D. (n.d.). Nearly 200 million chickens, turkeys and cows are making a mess of the Shenandoah River. *Washington Post*. Retrieved October 7, 2021, from https://www.washingtonpost.com/news/energy-environment/wp/2017/04/26/nearly-200 million-chickens-turkeys-and-cows-are-making-a-mess-of-the-shenandoah-river/

Maximizing Value: 2021 Spring Application of Broiler Litter for Grain Crop Production | Agricultural Economics. (n.d.). Retrieved October 18, 2021, from https://agecon.ca.uky.edu/maximizing-value-2021-spring-application-broiler-litter-grain-

c

rop-production

Yun, Jin-Ho, et al. "Hybrid Operation of Photobioreactor and Wastewater-Fed Open Raceway Ponds Enhances the Dominance of Target Algal Species and Algal Biomass Production."

Algal Research, vol. 29, 2018, pp. 319–329., https://doi.org/10.1016/j.algal.2017.11.037.

Ranjith, Kumar R., Hanumantha, Rao P., & Arumugam, M. (2015) Lipid extraction methods from microalgae: a comprehensive review. *Front. Energy Res.* **2**:61. Doi: 10.3389/fenrg.2014.00061

Ozer, Richard W. (2014). Green Vegetable Oil Processing || Algae Drying and Extraction., (), 81–105. doi:10.1016/b978-0-9888565-3-0.50008-x

Michael Kröger & Franziska Müller-Langer (2012) Review on possible algal-biofuel production processes, Biofuels, 3:3, 333-349, DOI: 10.4155/bfs.12.14

Marwan et al. (2015) Preparation of Biodiesel from Microalgae and Palm Oil by Direct Transesterification in a Batch Microwave Reactor. J. Phys.: Conf. Ser. 622 01204

Biofuels Reform. (n.d.). *The Butterfly Effect of EU Biofuels Policy*. Social impact of biofuels. Retrieved October 28, 2021, from https://biofuelsreform.org/social-impact-of-biofuels.html.

Ho, S. (2020, May 13). *Could biofuels worsen deforestation? A new report reveals potential harm of 'eco-friendly' alternative*. Green Queen. Retrieved October 28, 2021, from https://www.greenqueen.com.hk/airlines-shifting-to-biofuels-may-lead-to-7-million-hectares-deforestation/.

Pachamama Alliance. (n.d.). *Effects of deforestation: The Pachamama Alliance*. Pachamama Alliance. Retrieved October 28, 2021, from https://www.pachamama.org/effects-of-deforestation.

International Council of Clean Transport. (n.d.). *EU: Fuels: Biofuel policy*. Transport Policy. Retrieved October 28, 2021, from https://www.transportpolicy.net/standard/eu-fuels-biofuel-policy/.

Baier, S., Clements, M., & Griffiths, C. (2009, March). *Board of governors of the Federal Reserve System*. Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet. Retrieved October 28, 2021, from https://www.federalreserve.gov/pubs/ifdp/2009/967/ifdp967.pdf.