Biodiesel Production from Microalgae: A Novel Process

The Influence of Media Portrayal on Emerging Sustainable Technologies

A Thesis Prospectus
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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.

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Introduction

Greenhouse gas emissions continue to reach unprecedented heights, driven by the increasing worldwide demand for energy, resources, and consumer goods to support an ever-growing population. These emissions intensify climate change and contribute to air and water pollution, public health crises, and ecological disruption (Bertrand, 2021). This surge has ignited environmentally friendly innovation to seek renewable substitutes to many contemporary, petrochemical fueled and high emission technologies.

Global energy usage is projected to rise by 15% by 2050 (Energy Demand, 2023). Derived from biomass feedstocks, biofuels serve as a low greenhouse gas emission fuel source in the transportation, electricity generation, and heating industries. In 2021, the United States produced 17.55 billion gallons of biofuels and consumed 16.83 billion gallons (EIA, 2022). However, despite this progress, it is essential to acknowledge the prevailing dominance of fossil fuels. In 2022, the United States primary energy consumption of fossil fuels constituted 79%, while biofuels accounted for only 2.34%, highlighting the ongoing challenge of reducing dependency on traditional, carbon-intensive energy sources (EIA, 2023).

The meat industry stands out as another prominent contributor to climate change, with a projected 9% increase in greenhouse gas emissions by 2031 (OECD & Food and Agriculture Organization of the United Nations, 2022). As a result, it is critical to develop meat alternatives capable of reducing emissions. Cultivated meat, employing tissue-engineering techniques to generate animal fat and tissue cells in laboratory conditions, offers a viable substitute for conventional farming practices (McKinsey & Company, 2023). Estimated to potentially reduce greenhouse gas emissions by 78–96%, cultivated meat also demonstrates reduced water, land, and energy usage compared to traditional meat production methods (Tuomisto & Teixeira de Mattos, 2011).

My technical capstone focuses on algae based biodiesel as a promising energy solution to help fight the global climate crisis. Algae based methods can be more advantageous than first and second generation biofuel sources due to high energy content, rapid growth times, and reduced land and water requirements. However, industrial-scale algal biodiesel production remains constrained by its limited commercial feasibility as it requires significant capital investments (Prommuak et al., 2013). My technical capstone will address these economic deficits. My group is designing the manufacturing process for algae-based biodiesel while offsetting costs through the co-production of lutein, an organic pigment found in algae with anti-inflammatory properties. Lutein is a highly sought after supplement that will generate additional revenue. The economic viability will be determined through a cost-effectiveness analysis.

The implementation of a new technology requires the consideration of the sociotechnical ramifications that ensue. Biofuels and cultivated meat are emerging as sustainable alternatives aimed at accomplishing the same goal: preserving and enhancing existing consumption practices without causing significant disruption or change. These two topics have become the subject of intense controversy, particularly exacerbated through the way they are portrayed in the media. This motivated my STS project, where I will research how news media frames novel sustainable technologies and the impact of this on public perception.

Technical Topic

The objective of my group's technical capstone project is to design a novel method of producing microalgal biodiesel by optimizing previous process strategies while simultaneously subsidizing costs through the co-production of lutein as a high value byproduct in order to improve economic viability. Lutein is widely recognized for its benefits in promoting eye health, particularly in preventing age-related macular degeneration. Additionally, research suggests

potential positive effects in various clinical areas, including cognitive function, cancer risk reduction, and cardiovascular health improvement (Buscemi et al., 2018). The global lutein market was valued at $371 million in 2023 and is projected to reach $488 million in 2028 (*Lutein Market*, n.d.). The overall pathway is outlined in Figure 1.

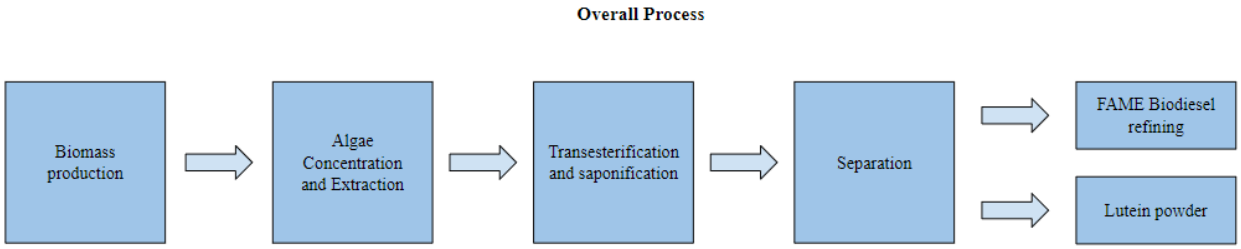

Figure 1. Overall process for FAME biodiesel and lutein.

We are drawing upon the insights presented by Tabernero et al. (2012) as inspiration for the development of our overall process. The first stage begins with the cultivation of *Chlorella vulgaris,* a commonly used algae species in biodiesel production, in raceway ponds. Raceways offer an affordable and low maintenance method for growing algae (Griffiths et al., 2021). Agricultural waste will provide an inexpensive source of carbon and nitrogen. Paddles and spargers will be utilized to ensure complete mixing of nutrients and adequate aeration, therefore promoting a high rate of algae growth. Algae harvested at the end of the raceway will undergo a dewatering process to increase its concentration for further processing. This will involve a combination of mechanical centrifugation and a flocculation process assisted by nanomagnetites described by Patel et al. to increase efficiency.

The downstream steps are modeled after the methodology outlined by Prommuak et al. but will be augmented to accommodate industrial scale production. Triglycerides and lutein fatty acid ester, crude forms of the desired products, will be removed from harvested algae via cell disruption. A scaled-up version of a Soxhlet extraction employs methanol and chloroform as

solvents to extract the lipids and dissolved lutein from the algal biomass (Wang et al., 2023). The remaining algae residue will be recycled back into the raceway as an additional carbon source. The chloroform and methanol will subsequently be removed to isolate the crude lipids, where they will then be converted to biodiesel and lutein through a coupled transesterification and saponification process. This process as well as the following separation processes to derive the final biodiesel and lutein powder products are demonstrated in Figure 2. Further refining of the biodiesel with a fractional distillation column may be able to achieve higher purity and thus increase the value of this product. The ultimate goal following the process design is to perform an economic analysis to determine the viability of microalgae biodiesel production alongside lutein co-production.

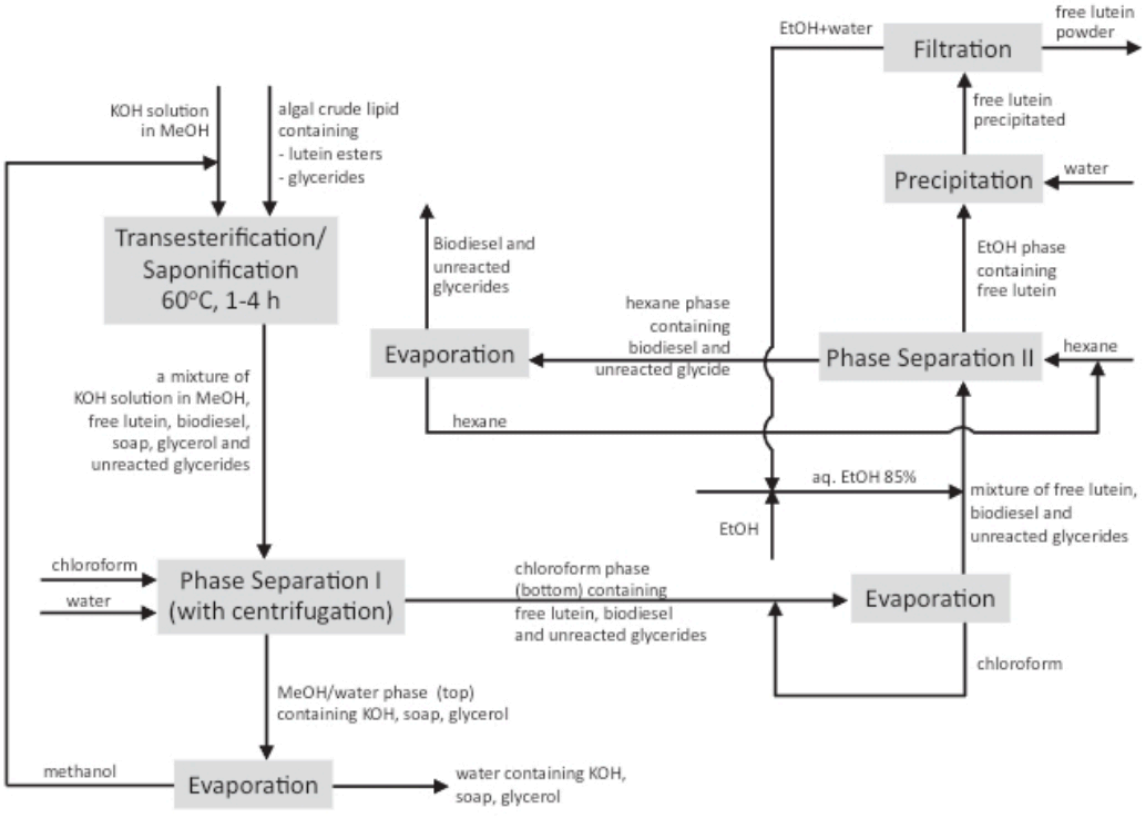

Figure 2: Reaction and separation to produce lutein and FAME biodiesel (Prommuak et al., 2013).

This project will be completed over the course of two semesters by our 5 person group. Certain aspects, including biodiesel refining and phase separation, will be modeled using the chemical process simulation software Aspen Plus. Since lutein and lipid production are well-established processes, we have access to an abundance of papers to reference and will utilize more specialized sources for each unit operation. To ensure an even distribution of work and timely completion of the project, we will assign team leaders to each process defined in Figure 1. Team leaders will oversee and delegate tasks like selection and calculations on specific operation units, ensuring a balanced workload and schedule flexibility. This approach ensures team members gain familiarity with all process aspects.

The final product of this design project will be a technical report containing material and energy balances, equipment designs, and an evaluation of the proposed process on economic, environmental, and safety grounds. This report will be produced in CHE 4476 in the spring of 2024. This project will align technology, innovation, and environmental responsibility in the pursuit of developing sustainable energy solutions.

STS Topic

Technologies designed to mitigate environmental issues are often propelled into the center of current social and political discourse. Understanding the factors that contribute to public perception of technologies is essential as it plays a pivotal role in guiding policies and consumer choices. Media has always been a powerful influencer of public opinion. By carefully curating and presenting articles and stories, news media-including print, TV, and online sources-actively pursues its agenda in shaping the salience and persuasiveness of information (McCombs & Valenzuela, 2020). This selective version of reality has been further amplified in the digital age, where media and information are readily accessible through the internet. How biofuels and

cultivated meat are presented in the media, whether as revolutionary solutions to environmental challenges or as contentious and potentially risky discoveries, has the ability to sway not only individual beliefs but also collective attitudes. This has significant repercussions, as public opinion impacts policy and industry adoption (Burstein, 2003).

Public opinion of biofuels exhibits notable variation in the United States, driven in large part by the difference in media consumption along political party lines. Media outlets are known to have political biases, and individuals may deliberately choose media that resonates with their partisan leanings. This contrast in media consumption results in distinct reactions among Democrats and Republicans when exposed to media related to biofuels. For Democrats, increased interactions with political media content tends to enhance their positive views of the technology, but for Republicans, greater attention has a negative effect (Cacciatore et al., 2012).

In this context it is important to understand the intricate connection between biofuels and politics. When forming opinions regarding science, individuals often turn to their political beliefs as guiding principles (Nisbet & Goidel, 2007). Opinion of biofuels may be a product of political ideology due to the polarized views on climate change and energy resources in the United States. Biofuels have become embedded within the larger societal debate on environmentalism and sustainable development (Dragojlovic & Einsiedel, 2014). They are also divisive in discussions concerning government involvement in the economy, impact on food prices, and global leadership in science and technology (Mitchell, 2009). Furthermore, opinions are often molded under the influence of persuasive appeals originating from political elites (Brulle et al., 2012). Analyzing the political nature of biofuels provides insight into the dynamics of public acceptance and decision making. In my thesis, I plan to investigate the extent of the impact of political media engagement on the perception of biofuels.

By contrast, the perception of cultivated meat seems to transcend political boundaries and appears to be governed by knowledge levels and rhetoric employed by the media. The general population has a limited understanding of what cultivated meat is and as a result are often swayed in the direction of information they are exposed to (Bekker et al., 2017). More specifically, individuals tend to be susceptible to the language utilized by the media. The use of less technical terms such as "fake meat" can contribute to the development of more negative consumer opinions (Chriki et. al, 2020). Cultivated meat is also associated with sustainability yet public discourse varies when compared to biofuels. As both biofuels and cultivated meat are striving to be adopted into the market and subject to regulatory measures, they share common challenges and objectives. This will serve as an interesting contrast to the impact of media portrayal on biofuels.

In order to study the intricate relationships and interactions among various actors that shape how media influences public perception of biofuels and cultivated meat, I will utilize Actor-Network Theory as my STS framework. ANT will provide me with the ability to explore complex networks and hybrid interactions between human and non-human elements to allow for a comprehensive understanding of how media, technology, politics, and societal values intersect and unite to shape public opinion. My research will delve into the collaborative efforts of these actors to discern the strategies that contribute to achieving economic and regulatory success.

Research and Methods

The question I plan to research is: How does news media framing of novel sustainable technologies such as biofuels and cultivated meat influence public perception? To address this question, I will employ a multifaceted research approach, including discourse analysis and an extensive review of relevant literature. The data collection process will encompass news articles

spanning from the year 2000 to the present. These materials will provide valuable insights into how biofuels and cultivated meat are presented in the media, with a specific focus on language, narratives, and frames. My goal is to not only analyze the existing media landscape but also contribute to a deeper understanding of how these portrayals impact public perceptions of eco-friendly alternatives.

Conclusion

Escalating levels of greenhouse gas emissions illuminate the urgency of finding solutions to global environmental challenges. The technical part of my project aims to investigate an avenue of producing cost effective microalgal biofuels that can be utilized by engineers in industry. Through my STS project, I hope to gain a better understanding of how media coverage can affect public attitudes and acceptance of biofuels and cultivated meat. This research will identify strategies to be used by media outlets and policymakers to promote widespread adoption and regulation of new environmentally conscious technologies. Learning how to effectively develop and implement sustainable innovations will contribute to the transition towards a net-zero emissions future by providing clean energy and low impact resources to support rising global demand.

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