Teaching Alternative Energy through Biodiesel from Algae

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Abstract:

As the world's energy demands continually increase, the sources of today's energy are drastically depleting and the search for renewable fuel is growing. Biofuels are desirable because the carbon dioxide released when combusted is ultimately captured by photosynthetic plants, thus making the emissions process essentially carbon neutral. The extent to which biofuels can eventually replace fossil fuels as the world's primary source of energy depends on how efficiently they are produced. As research in this field intensifies to optimize these production methods, it is imperative to educate students on the importance of alternative energy.

Biodiesel from algae has great potential because of its high-volume, cost efficient production. Consequently, it is crucial for engineers and scientists to understand how algal growth is affected by parameters such as temperature and carbon dioxide concentration, as well as the methodology on how to extract the necessary oils from these sources. One way to incorporate this topic into the chemical engineering curriculum is to integrate alternative energy research as a six credit sequence. By allowing students to perform independent research, students benefit from a learning experience that allows them to think both critically and creatively. Most importantly, these hands-on projects help increase student interest in the field of renewable energy, which will become important in educating the next generation of engineers.

I. Introduction

The search for renewable fuel is continually growing as the world's energy demands constantly increase. The reserve of non-renewable fuels continues to be exhausted, and as research in this field intensifies, it is imperative to educate students, specifically engineering students, on the importance of alternative energy. At this current pace of consumption, fossil fuel reserves are expected to be completely depleted in the next several decades. As the world technologically advances, this pace will only increase. Additionally, it is expected that the world's oil production rate will radically decline in one to ten years. The combination of both the decline in petroleum production and the increase in consumption creates an urgent need for an alternative type of fuel source. Currently, the most probable candidate for replacing oil as a primary energy source is coal, a non-renewable and environmentally destructive fossil fuel. [1] The dramatic decrease in liquid fuel reserves and the need to eradicate non-renewable and environmentally hazardous energy sources calls for the utilization of alternative renewable energy.

Biodiesel has become one of the leading alternate fuel sources in today's society sometimes utilizing vegetable oil from crops like rapeseed and coconut. The frequent use of these vegetable oils is causing deforestation and affecting food supplies and has become an alarming problem leading researchers to look elsewhere for sources for biodiesel. Multiple sources have been researched and algae have become a primary topic of discussion. There are thousands of strains of algae that can be used to produce biodiesel, which allows for different research projects that can be incorporated at the undergraduate level. The benefit of using biodiesel over fossil fuels is an important question for students to ask, as it may become problematic for them as they look to careers and to their futures.

It is crucial for engineers and scientists to understand the details involved in biodiesel production. It is imperative that researchers are aware of these details; from the different types of algae to how algal growth is affected by many parameters, including temperature and carbon dioxide concentration, to the methodology on how to extract the necessary oils from these sources. It is possible to incorporate this topic into chemical engineering curriculum by integrating alternative energy research as a six credit course, over two semesters. Performing independent research at the undergraduate level allows students to benefit from a learning experience that is not typical and advocates both critical and creative thinking. More importantly, these hands-on projects help increase student interest in the field of renewable energy, which will become important in educating the next generation of engineers.

II. Alternative Energy: Biodiesel

There is no question that the future of the world's energy sources is unknown. It is imperative, though, that countries progress away from the current use of fossil fuels. The existing sources of the world's energy have deleterious environmental consequences on the Earth. In the last century, worldwide energy consumption has increased almost twenty-fold, resulting from the rapid growth in technology and the necessity of oil and fuel to power these twentieth century innovations. [2] Compared to fossil fuel, biofuels are extremely desirable because of their environmental benefits and the fact that they are derived from renewable resources. There are many types of biofuels, including, but not limited to, biodiesel, one of the most dominant sources being researched worldwide. The extent to which biofuels can eventually replace fossil fuels as the world's primary source of energy depends on the efficiency of their production, and fortunately research has intensified to address this.

Biodiesel is an energy source derived from animal or plant lipids and is a biofuel that is biodegradable and nontoxic with low emission profiles, thus, making it environmentally friendly. It has great potential for high-volume, cost efficient production. It is comparable to petroleum diesel and can be produced in relatively small areas. Table 1 shows that the future of biofuels, focusing on biodiesel, is excellent; while the world's current sources may be in jeopardy.

Table 1
Availability of modern transportation fuels [3]

Fuel type	Availability	
	Current	Future
Gasoline	Excellent	Moderate-poor
Bioethanol	Moderate	Excellent
Biodiesel	Moderate	Excellent
Compressed Natural Gas (CNG)	Excellent	Moderate
Hydrogen for fuel cells	Poor	Excellent

Biodiesel has been used in some countries but the potential for its production and future application is much more. Even though biodiesel can be produced from numerous sources including multiple forms of vegetable oils (edible and waste oils) and animal fats, it can also be produced by algae. Algae have a number of unique benefits in the production of biodiesel. Notably, it is an aquatic species and does not require arable land for cultivation and thus does not compete with the agricultural market. [1] Many microalgae are rich in oil and can be converted to biodiesel using existing technologies, which is extremely beneficial. It can be used directly as fuel, with some engine modifications, or blended with petroleum diesel and used in diesel engines with few or no modifications. It is an environmentally friendly fuel and these environmental benefits of biodiesel make it extremely attractive. Table 2 shows these among its many other benefits.

Table 2
Major benefits of biodiesel [3]

Economic impacts	Sustainability
	Fuel diversity
	Increased number of rural manufacturing jobs
	Increased income taxes
	Increased investments in plant and equipment
	Agricultural development
	International competitiveness
	Reduced dependency on imported petroleum
	Inherent lubricity
	Higher cetan number
Environmental impacts	Greenhouse gas reductions
	Reduced air pollution
	Biodegradability
	Higher combustion efficiency
	Improved land and water use
	Carbon sequestration
	Lower sulfur content
	Lower aromatic content
	Less toxicity

Energy security	Domestic targets
	Supply reliability
	Higher flash point
	Reduced use of fossil fuels
	Ready availability
	Domestic distribution
	Renewability

The increasing competitive advantages of biodiesel are raising interest among investors, consumers, and students who can learn more about biodiesel through the proposed research.

III. Integration of Alternative Energy in Engineering Education

Hands-on experience is extremely beneficial for students in order for them to understand the importance alternative energy has for the future. Independent research is a great opportunity for undergraduates to not only apply what they have learned but to learn new skills and techniques that are seen in industry today. By implementing alternative energy research as a six-credit sequence, students will begin to think both critically and creatively on how alternative energy can be our future. They will begin to understand the importance of renewable energy to our world as a whole.

There are multiple steps to integrating alternative energy projects at the undergraduate level and this should all begin during the students' junior year. Students ought to form their teams if they wish to work in a group and begin research on alternative energies that they are interested in. If students decide what topic they want to pursue, i.e., what type of alternative energy, they will be more interested, as it will not be something they are assigned to do. The research will likely be more thorough and all around a better project because the students will be invested in what they are learning and researching. After they have chosen a topic, they are to write a proposal that is to be handed into their advisor before the year's end. The proposal will include what alternative energy they are researching; what is the purpose of the research; what are they trying to conclude; and how they are performing the experiment. Once the proposal is accepted, the group should have several meetings with their advisor to start planning their research and to develop a timeline of their project. At this point, materials should be ordered that may be needed in the upcoming semester. Once this has been completed the students will begin their six-credit sequence during their senior year.

During their senior year, the students should be required to write a literature review on research projects similar to their own. Making the students research other projects exposes them to other possibilities they can try to experiment with - to see if they can change a few parameters within their experiment to compare their results to those of other research experiments. When beginning their experiment, the student's first semester tends to be a trial and error period. They encounter bumps and problems making them start to think creatively and find new ways to perform the experiment they started with. The students may even have to fall back to a Plan B in case their experiment does not work the way they planned it. This teaches the students that everything does not work out the way they planned initially. In the real world, companies may

have to run through several ideas before they find the right one which is something that students cannot experience and see in a classroom.

The second semester is used to perfect the experiment and to make a conclusion based on the results they recorded during their months of researching and experimenting. From all the information they have learned, researched and concluded, a paper, for possible publication, should be written and handed in for a final grade. The paper should explain why they chose their type of alternative energy, the procedure and experiment the students came up with, the results that were recorded, and what their results mean now, and possibly for the future. A timeline is shown in Figure 1 to depict the sequence of events that should be incorporated for this type of project.

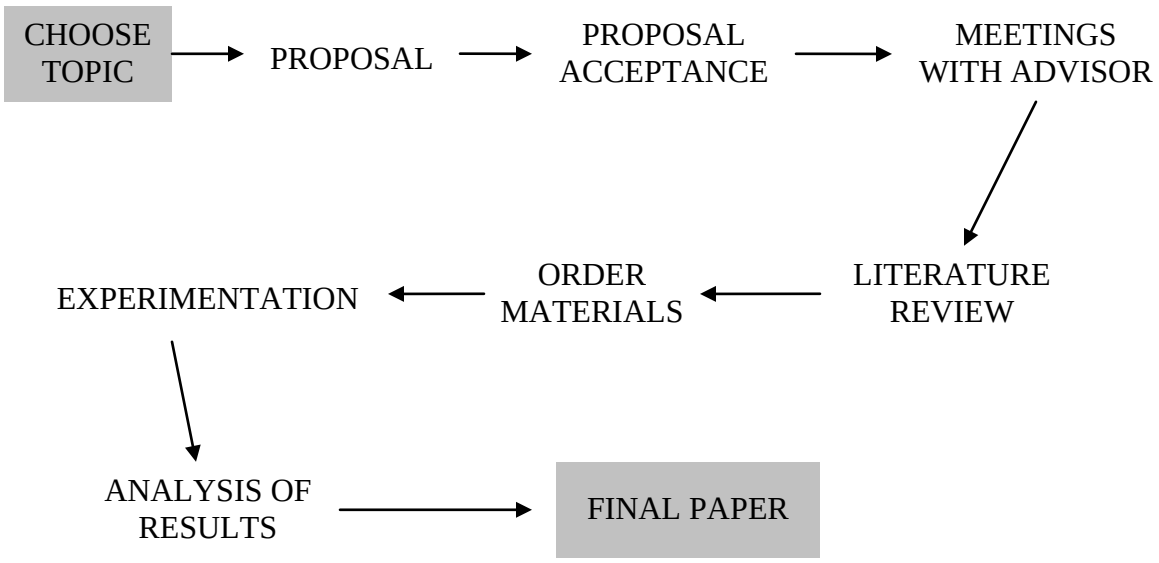

Figure 1. Timeline of Research Project

There are many potential hazards for our future if we keep employing all of our usable oil reserves rather than finding new ways to fuel our cars, industries and homes. Giving undergraduates the full knowledge of these hazards and what can be done to prevent them during their education increases awareness for engineers in the future. Having students learn that there are other sources of energy out there and giving them the opportunity to research them will increase their interest. Hopefully students will understand that they are our future when it comes to alternative energy and they can be the difference.

IV. Our Research: Biodiesel from Algae

An independent project is a six credit elective sequence for the graduate students at Manhattan College. Our group felt it would be a new learning experience for us to tackle research in an area not specifically taught to us as undergraduate and graduate students. In choosing a topic, alternative energy seemed to be important to each of the group members.

Simply, as college students and as drivers in New York State, the rising price of gas affected us. While alternative energy is not going to affect gas prices any time soon, we felt we wanted to know more about what can be done in the future. With this in mind, we chose to look into biodiesel, and eventually chose to study algae.

After writing a proposal the summer before our graduate year, we began literature research in order to see what others have done and what could be done in a college laboratory to understand how to obtain biodiesel from algae. At this point we also chose a strain of algae to grow and eventually extract the necessary components to make our own biodiesel. The strain chosen was Neochloris oleoabundans, a freshwater microalga.

Through our literature research, we were able to understand the process behind obtaining biodiesel from algae, and it is not a simple one. The production of biodiesel starts with the extraction of fatty acids and two of the more popular methods, involving an external energy source, are ultrasound-assisted extraction and microwave-assisted extraction. Research has been done that concludes microwave-assisted extraction is the best method to extract fatty acids from algae; thus we chose that when the time came, we would further investigate this method for possible use. [4] The next step in the process is transesterfication, to convert the fatty acids to esters. In industrial settings, the resulting biodiesel is often tested against standards that are accepted by the United States government as a way of quality control.

Part of the learning experience in independent projects and research is adapting to changes and dealing with unexpected results. This was a cause of some discomfort in our project. The algae that we were observing did not follow the expected growth pattern, that is, it did not grow in the first semester of our project. We consistently tried different methods to increase its growth rate and subjected it to different amounts of glucose and light and kept it in a constant temperature bath. Fortunately, the algae did not die, so while we changed its environment, we shifted our focus to study how and why the algae would not grow. We observed the dissolved oxygen content in the system and tried different light intensities and bath temperatures. Our efforts proved futile in our first semester of study and we decided to start anew in the next.

During the second semester, we have obtained a new sample of algae, choosing to study the same strain, Neochloris oleoabundans, and we have made our own growth medium. We have decided to focus on the growth of the algae in this medium and have set up nine different samples, examining if the head space is a factor in its growth. Half the samples are open to the atmosphere while the other half are sealed and we will observe any effects this may have on the algae growth.

This independent project is a learning experience that allows us to adapt to constant changes in the results and focus of our experiment. While time will not allow us to extract the fatty acids from the algae that we grow, one of the benefits of research is that a system is now in place where a group of students can examine alternative energy over a six credit sequence in a topic of their choice or the topic of past students.

V. Conclusion

The search for new renewable fuel is growing as the world's energy demands continually increase. Biofuels are a desirable alternative that is currently being researched but the lack of knowledge in this area is the cause for its inefficient production. Therefore, it is crucial to educate students about the importance of alternative energy and one way to do this is by implementing a six-credit sequence in the undergraduate curriculum on this subject. Giving students the power to learn, independently explore and be part of this change could influence them to go forth in this area that needs as much research and help as possible. By giving students hands-on learning experience in and awareness of alternative energy, they may be able to educate and influence their own generation of engineers, as well as the next.

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