Sustainable Energy: Assessing Biodiesel as a Viable Replacement for Petroleum Fuel

Ashley H. Chon, Delaney G. Faulk, Saron M. Mewa, & Nara D. Poling

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Abstract

Sustainability goals have been at the forefront of political, economic, social, and agricultural discussions since 2015. The fuel industry and its impact on the environment, economy, and society is often the headline within most discussions. The modern century has hosted petroleum fuel as its leader, but with concerning environmental impacts, renewable and sustainable forms of fuel have been proposed. Biodiesel is a renewable fuel extracted from oil in crops. This paper compares and contrasts the potential for biodiesel as a sustainable alternative to petroleum-based fuel through various factors of consideration such as environmental impact, economic impact, yield, feasibility of societal implementation, and the time and labor of extraction and processing. To make biodiesel more competitive within the energy industry, genetically modified crops have been considered leverage for biofuel improvement. After researching and discussing both advantages and disadvantages, the ideas of algae-fueled biodiesel and mixed fuel were proposed to address many of the current drawbacks of biofuel. The possibilities of this new form of production are discussed as a viable solution to the growing fuel issue. This research paper aims to evaluate information on biofuel and petroleum fuel solutions through a comparative analysis to propose a potential solution to help reach UN Sustainability Goal 7, Sustainable Energy.

Introduction

America has always strived to move faster, and petroleum aids that speed but it's not the most practical option. An alternative to mitigate the environmental impacts of petroleum-based fuel has been proposed: biodiesel, a renewable fuel source made from plant-extracted oil. Despite its potential, as of now, biodiesel has yet to meet the capabilities of petroleum such as extraction, efficiency, and cost. Considering various factors of comparison among current studies, research, and expert input, this paper will provide solutions to address biofuel's shortcomings. Throughout history, society has relied on energy and although there have been many advancements in renewable energy discovery and innovation, 80% of the world's energy still originates from petroleum fuel (EESI, 2021).

Petroleum Based Fuel

Petroleum is a fuel extracted from three hundred million-year-old animal fossils submerged in the earth's deepest layers. Due to heat and pressure, the fossils decompose into crude oil or raw petroleum. Refining crude oil involves three processes: separation, conversion, and treatment. The finished products are vital as they provide energy to all aspects of society from businesses to transportation to homes. Due to its abundance, incompressibility, and ability to withstand extended durations in storage, petroleum fuel is critical to the functioning of our society. Despite its success, petroleum is a non-renewable source of energy, and it releases emissions in both mining and use. The carbon dioxide released by emissions is the largest contributing factor to climate change. As these concerns have become more pressing, scientists have been pressured to discover new forms of fuel, one of which has been biodiesel.

Biofuels

Biofuel is a renewable energy source made from processed oil extracted from the refined products of any type of biomass. The crude biofuel extracted from biomass must undergo deconstruction and synthesizing. During deconstruction, biomasses are broken down and then refined in synthesis. One of the two deconstruction processes, High-Temperature Deconstruction (HTD), is dependent on the type of biomass. Pyrolysis is for arboreal biomass which heats the wood in an oxygen-lacking environment. This process separates the produced energy into three outputs: ⅓ heat for the machine, ⅓ biochar, and ⅓ oil. Hydrothermal liquefaction is the HTD for wet biomass, such as algae, seaweed, and sewage. The biomass is subjected to extreme pressure, separating the oil out of the liquid in the substance. Gasification is utilized for fossilized biomass. The process exposes the biomass to intense heat, carbon dioxide, hydrogen, and oxygen. This enables the combustion process to release less harmful emissions by limiting and controlling them. The second method, Low-temperature deconstruction (LTD), uses hydrolysis in which enzymes deconstruct the biomass by breaking down hard sugar chains into glucose and xylose. The bacteria and yeast digest the sugars and create compounds used for biofuels. Since producing biofuel depends on the type of biomass, there are many questions regarding whether the system is efficient, cost-effective, and environmentally safe. To make biofuel competitive against petroleum fuel, scientists have studied genetically modified organisms to increase the yield and efficiency of biofuel crops.

Genetically Modified Organisms

As the benefits of biofuel have become clearer, scientists have pushed to research ways to improve the yield and efficiency of producing biofuel. Bioengineered crops are genetically modified organisms (GMOs). Researchers are currently attempting to leverage bioengineered crops to increase the production of biodiesel. Scientists will either modify crops by inserting foreign DNA or by changing the organisms existing DNA. More specifically, transgenesis is used to genetically modify biofuel crops. Researchers insert a specific gene, also known as a transgene, that comes from a foreign organism. These modifications are made for size, color, taste, seed content, and various other desirable characteristics. Transgenesis is used because it allows for precision and efficiency that other methods fail to satisfy. Since the introduction of transgenesis in agriculture in 1995, crop production has gone up by 22% (Raman, 2017). Even with the use of GMOs, there are still limitations stunting the success of biofuel. This paper seeks to modify the process of creating biofuel or find another alternative to petroleum fuel to slow down climate change due to petroleum fuel.

Problem Statement

Biofuel has been advertised as the prime alternative to petroleum fuel for its environmental sustainability. However, biofuel has yet to match the price and yield of petroleum fuel. To address these disadvantages, scientists have proposed using genetically modified crops. However, even with crop modifications, the limitations of biofuel are deemed to outweigh its benefits. The UN Sustainable Development Goals directly correlate with this problem. Although the issue touches upon all 17 goals, this paper aims to particularly address Goal 7, Sustainable Energy. Aside from sustainable energy, this also relates to the protection, restoration, and promotion of sustainable use of terrestrial ecosystems. This analyzes the shortcomings and benefits of biofuel but also explores potential solutions to address the lack of a sustainable source of fuel.

Methods

While researching biofuels, we used multiple scholarly databases and search engines to research thoroughly. We began by searching biofuels on a broad spectrum in Google and then chose sources with reliable tags linking to government, organizations, and universities. After establishing a broad description of biofuels, we went to Google Scholar and paired biofuel with more specific, keywords such as “yield”, “extraction”, “time”, “cost”, “emissions”, “water pollution”, “land effects”, “effects on farmers”, “effects on engines” and “employment”. This is how we found data on several factors of comparison such as environmental sustainability, implementation in society, cost, and time and yield effects. After doing a surface search through Google Scholar, we accessed the Virginia Tech Library Database and searched the same comparison points but used quotations to pinpoint more specific information. By using the quotations, we were able to find articles, journals, and research papers that specifically referenced the topics we were searching for. This process helped us understand biofuels on a multi-level scale.

When researching our solutions, we first had to use a variety of phrases to broaden our ideas. To find a few options we looked up “alternatives to biodiesel”, “viable petroleum replacements” and “new renewable energy” in Google and Google Scholar. This gave us a wide range of information and resources that we then refined down to our best choices. Upon establishing our two best options, B20 and algae-based fuel, we scoured the Virginia Tech Library Database searching for more specific information. A few searches we used were “algae biofuel as a viable petroleum replacement”, “B20 emission reduction”, “algae in the biofuel industry”, and “converting to B20 fuel”. Utilizing the same factors of comparison, we equalized our solution studies to our main research. By putting our possible solutions up to the same lens, we prevented bias and made sure all energy sources were compared equally.

Background

Cost

Despite all of the environmental benefits of biofue, cost has stunted the widespread use of biofuel. The Organization of the Petroleum Exporting Countries (OPEC) reports the median rate of crude oil or the basket price from participating countries, including Algeria, Congo, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, UAE, and Venezuela. The price of one barrel of crude oil was $82.95 in 2023 and has grown to $83.64 in 2024 (OPEC, 2024). In contrast, the national average cost of one barrel of biodiesel was $191.94 in April, 2024 (U.S. Department of Energy, 2024). This is a $108.2 difference– a nearly

129.5% increase. This price difference is a result of the accumulation of three distinct expenses: variable costs, fixed costs, capital costs, and transportation costs.

Variable Costs

Variable costs are expenses determined by the amount of oil produced. Chemicals and catalysts used in refineries make up variable costs. The production process of biodiesel uses a process called transesterification which utilizes chemicals and catalysts such as monoglycerides with methanol to increase properties like the reaction rate. (Kandasamy et al., 2020). The combined cost of these chemicals and catalysts sum to $1.37 in contrast to the $1 chemical cost per barrel of petroleum fuel (Illukpitiya & de Kof, 2014).

Fixed Costs

The production of both biodiesel and petroleum concerns the following fixed costs: employee wages, maintenance, and taxes. A petroleum refinery employs 200-1,000 people depending on the complexity of the machinery. Smaller refineries spend around $15 million annually for employee salaries whereas larger refineries dispenses $40 million. Usually, fixed costs equal $2 -$3 per barrel of crude oil (Favennec, 2022). The U.S. biofuel industry employs over 75,200 workers and pays $2.54 billion in annual wages (Tax and Clean Energy Policy, n.d.).

Capital Costs

Capital costs happen when refineries invest in new equipment or facilities with the goal to regain that money over time through production. For biofuels, U.S. capital costs can be difficult to determine. However, every year in New Zealand, capital expenses can add up to $3-$4 million for a plant that produces 30,000 gallons of biodiesel a day (Duncan, 2003). In comparison, $8-$9 per barrel of crude oil is used for capital costs (Favennec, 2022). For a plant that produces 30,000 gallons of petroleum, the sum of capital costs would be $2.1 million yearly. ***Transportation Cost***

After the refinery, the finished products are sent through a mode of transportation called pipelines. It takes around $0.06 per gallon of finished petroleum to ship from a terminal to retailers to then be sold to consumers (Lenard, 2021). Comparatively, transportation costs of ethanol (biofuel primarily made from corn) range around $0.13-$0.18 per gallon (NADO, 2007). Biofuels prove to be more costly because they must be transported by different means, due to the fact that they cause more harm to pipelines. (Ethanol, Biofuels, and Pipeline Transportation, n.d.).

Consumer Costs

Gas companies purchase petroleum goods at around $3 per gallon (considering previous costs) and as of July 2024, the United States average diesel price is $3.88 (AAA, n.d) meaning the average profit is around $0.20-$0.80 per gallon. At the same time, biodiesel prices for buyers are $4.08 per gallon (CARD, 2023). When considering all other expenses in producing biodiesel, it costs $5.53-$6.38 a gallon (Illukpitiya & de Kof, 2014), essentially, resulting in a $1.45-$2.30 per gallon loss. To conclude, every year, the United States processes over 306.6

billion gallons of petroleum (EIA, 2023) in contrast to the mere 2.1 billion gallons of biodiesel produced yearly (CARD, 2024).

GMO Cost

Much of this cost of producing biofuels is attributed to the cost of feedstock (Gebremariam & Marchetti, 2018). To create 70,000 tonnes of biodiesel, over $20-$30 million is spent on feedstock. Since the feedstock is so expensive, GMO-induced crops have been considered as a method to eradicate the cost issue while producing more oil at the same time. However, farmers must pay $761.80 per acre to grow GMO corn in contrast to the $680.95 per acre of non-GMO corn (Jennings, 2014). It can also cost $136 million to create a new GMO crop (Zhou, 2015). Many companies and farmers are uninterested in risking failure investing in biofuels or GMOs because of the lack of guarantee.

When weighing the overall costs and profits of both biodiesel and petroleum, we were able to conclude that biodiesel is not the best alternative to petroleum on an economic scale. Biodiesel costs more per barrel due to the increased variable, fixed, consumer and transportation costs. Furthermore, it's hard to determine how GMOs could improve biodiesel costs due to companies refusing to invest because of the heightened expenses.

Implementation in Society

When evaluating biodiesel's implementation into society, we found that biodiesel has the largest impacts on engines, farmers, and employment.

Engines

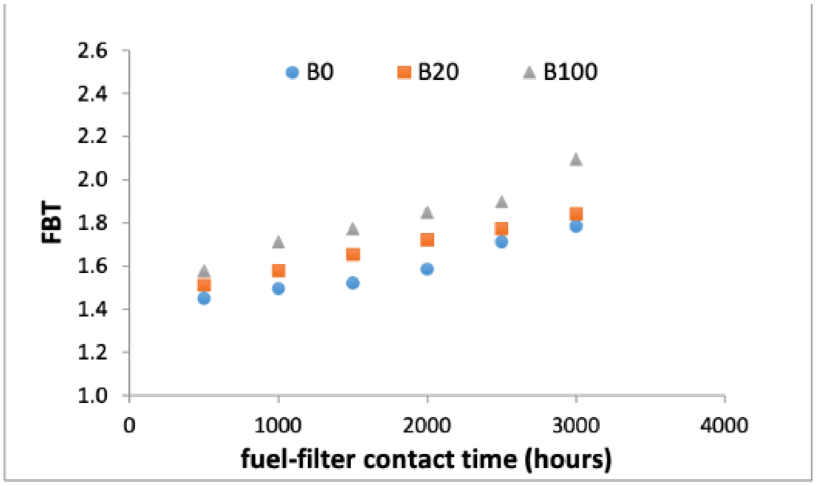
Biodiesel is hygroscopic, meaning that it absorbs more water than diesel due to its polar chemical structure. When fuel blends, the water content will increase which causes risks of higher water solubility in biodiesel which causes the risk of micro-organism activity. A 2022 report found that the quantity of colony-forming units [CFUs] in biodiesel was 22% higher than in petroleum-based fuel when placed in an outdoor tank for 60 days. This hygroscopic quality of biodiesel makes it 3.5-5 times more corrosive to copper and brass (Sterpu et al., 2024) raising concern for the corrosion of engines which mainly consist of copper and brass. Furthermore, the CFUs will increase the Fuel Blocking Tendency [FBT] of an engine. As shown in Figure 1, the use of B100 exhibits a FBT of 2.0-2.2 in a contact period of 3000 hours, while B0 only shows 1.6-1.8 in a contact period of 3000 hours, proving that the higher the biodiesel content in fuel, the higher the fuel-blocking tendency. (Komariah et al., 2018).

Another downside of biodiesel is its high viscosity. Viscosity is a fluid's thickness and resistance to flow. This can cause damage to a vehicle because it requires more energy to flow lowering the energy yield per gallon. Biodiesel tends to have a higher viscosity rate due to the higher fat content from organic materials. In fact, biodiesel made from soybeans has been shown to have a viscosity between 3.5-5.0 mm2/s while diesel fuel has a viscosity in the range of 2.0-4.5 mm2.s at 40°C (Ferreira et al., 2021).

Although the increase in fat content means biodiesel has a higher viscosity than diesel, it is what makes biodiesel an excellent lubricant. Lubricant allows for less friction and drag in the engine. After a 20-hour study that investigated oil effects on engines, it was determined that metal wear is 30% lower as a result of the engine using biodiesel fuel compared to an engine with diesel fuel (Temizer & Eskici, 2020). This shows that despite the potential for corrosion of brass and copper, considering metal wear as a whole, the overall effect of biodiesel on engines has an overarching benefit rather than a drawback.

Figure 1.

Fuel blocking tendency for various biodiesel blends (Komariah et al., 2018).



Ultimately, despite the overall benefit of using biodiesel, industries will often be reluctant to use it due to the other factors such as corrosion and fuel blocking tendency.

Farmers

Biodiesel takes up a lot of land which will affect small farmers. The Renewable Fuel Standard, a program that enforces biofuels to be blended with petroleum fuels in the U.S, causes 26% more conversion of natural land to cropland nationally than would have occurred without such a policy. Converting natural lands and croplands displaces local farmers. A survey was conducted in Yeji, Ghana, in July 2014 regarding the production of biofuel crops. The survey found that 72% of farmers were displaced from their land due to biofuel projects. 43% of the farmers were natives of the land. Furthermore, only 93% of the dispossessed farmers indicated they were not consulted before the leasing of their lands to the biofuel companies and only 57% were paid compensation (Aha & Ayitey, 2017).

Furthermore, if farmers convert to using biofuel to run farm equipment instead of oil, food prices will spike even more, allowing for farmers to compensate for the higher fuel costs. In fact, studies have shown that a 1% increase in oil price is associated with a 0.347% increase in food price (Zmami & Ben-Salha, 2019).

Employment

Although U.S. employment rates can easily be affected by the influx of jobs from the biofuel industry, this comes at the cost of the jobs in the fossil fuel industry. Employment in the renewable energy industry in the United States reached 769,000 direct and indirect jobs in 2015, a 6% increase from the previous year (Kattumuri & Kruse, 2017). In 2022, the biodiesel sector introduced 75,200 jobs and paid $3.6 billion in annual wages in the United States (LMC International, 2022). However, there is an estimated net job loss of 1.2 million by 2035 across the fossil fuels sector with the implementation of renewable energy sources (Saha et al., 2022). Although biodiesel would generate jobs, it would result in the loss of jobs in the fossil fuel industry which would negatively affect America's employment status.

Time and Yield

Time

Another factor to consider is extraction time and labor. On one hand, petroleum processing takes about 2 days from extraction to use. (Schwab et al., 1999). On the other hand, depending on the form of raw material, biofuel processing can take as long as one year. As far as machines go, both forms of fuel produce significant levels of emissions simply through production. Ultimately, petroleum emits a considerable amount more than biofuel. In comparison to the machines that constantly run to extract oil from the ground, machines harvesting and synthesizing biomass products only run during harvest time.

Yield

Along with the emissions comes the actual product yield. For every unit of fossil fuel used in production, biodiesel yields 4.5 units of fuel. Petroleum, however, produces .83 units of fuel for every unit of fossil fuel (Traviss et al., 2018). To address this deficit, genetic engineering has been leveraged to increase yield. A few of these modifications include an increase in starch content, insect and herbicide resistance, stress tolerance, and strong cell walls. Starch can be extracted to create biofuel and glucose can also be extracted from starch to be synthesized into biofuel. To mitigate economic and labor inefficiency, herbicide resistance allows for crops to withstand harsh conditions, resulting in higher rates of crop survival. To further address environmental conditions, crops have also been selected for stress tolerance. These stresses include drought, salinity, and soil issues. By engineering crops to be stronger, farmers can use less arable land for the non-consumption tracked crops and utilize marginalized land for biofuel crop production instead. Lastly, scientists are breeding plants with stronger cell walls to increase yield and create a better energy balance within the cells. In 2014, genetically modified plants were increasing yields by 22% and profits by 68%. In 2018, new studies showed a 25% increase in yield based on new research and data collection (Norero, 2018). Furthermore, biofuel energy production is superior to petroleum fuel because of its higher sulfur and aromatic content as well as its lower flash point, which is the point at which the fuel combusts to create energy.

Despite this, the time and resources to produce biofuel holding biodiesel back from being commercialized. Therefore, as of now, the U.S. is only able to meet 12% of the 19.84 million barrels of biodiesel per day the country's population demands (EIA, 2024). Because of this, the country instead produces 12.933 million barrels of petroleum fuel every day (EIA, 2024).

Another aspect of time and resources limiting the production of biofuel is the strict 6:1 molar ratio that is initiated during transesterification. This is the process by which biofuels are extracted through chemical reactions using enzymes to separate products from the material. The molar ratio compares the methanol to oil that is used to extract these products. The most efficient ratio is a 6:1 methanol to oil, producing biofuel yields of 87%-89% of petroleum fuels used during production (Farokhnia et al., 2022). The molar ratio makes the extraction process hard because it's difficult to achieve the exact 6:1 environment and it takes extra time and resources to guarantee the perfect ratio.

A final factor that drives yield is the fact that petroleum is easily extractable from a non-renewable source of fossil fuels while biofuels are extracted from a renewable energy source. Petroleum fuels are limited to fossil fuel products, but biofuels are open to any biomasses and a vast variety of renewable crops. Each of these factors plays a significant role in yield, yet it truly comes down to which one produces the most yield in the least amount of time regardless of resource use or environmental impact. Considering all of biofuel's advantages, petroleum fuel is superior simply because it can be produced abundantly and efficiently. With or without GMOs, biofuels have yet to match the yield and efficiency of petroleum fuel.

Environmental Impact

Petroleum fuel has been notorious for its horrific environmental impact. It has been the biggest contributor to greenhouse gasses and, thus, climate change. The comparison of the environmental impact of petroleum and biodiesel can be separated into three key components: air, land, and water pollution.

Air Pollution

It is well known that, in the scope of the environmental harm, diesel most contributes to this through emissions, particularly CO_2 emissions. Although biodiesel does still release CO_2, various studies prove that it is nowhere near the amount released by conventional diesel.

Some studies show that the CO_2 intake of biofuel crops offset the CO_2 emissions from the use of biofuel. Regarding the direct emissions of biofuel, biofuel also decreases the life cycle of CO_2 emissions by 50%-75% (Schröder et al., 2013), resulting in an overall net decrease of CO_2 emissions by 78.45% compared to conventional diesel (Sheehan et al., 1998b).

Beyond CO_2, biodiesel can help mitigate other pollutants. Soybean oil-based biodiesel reduces life-cycle methane emissions by an average of 2.25% compared to petroleum diesel (Sheehan et al., 1998a). Other such pollutants include sulfur, hydrocarbons, and carbon monoxide (Earley et al., 2005). Overall, emissions of these particles from the use of biodiesel are 40% lower than petroleum-based diesel (McCormick, 2007).

Land Pollution

With the growing demand for biodiesel, more land has been used to grow biofuel crops, causing potential habitat and biodiversity loss. According to a 2019 study, more than 90% of biofuel farms considered in the study deemed the relative species loss due to the farm to be greater than that of fossil fuel production (Elshout et al., 2019). Recently, the U.S. Court of Appeals for the District of Columbia said that the production of renewable biomass to satisfy the renewable fuel standard poses a real danger to threatened and endangered species (Lehn et al., 1032).

To maximize crop growth, farmers growing biofuel crops implement intense farming techniques, dousing crops in chemical fertilizers, cramming many crops per plot, and draining the soil of all nutrients. Over the last few years, more land has been converted to growing energy crops. In just the United States alone, between 2006 and 2007, the area planted with corn increased by 6.2 million ha (Fargione et al., 2009). Such land use has resulted in a 60% reduction in animal diversity. Part of this is because studies have shown that birds of conservation concern are more threatened by conversion to row crops like those that are grown for biofuel (Fargione et al., 2009).

Water Pollution

When making biofuel, water pollution is of most concern when it comes to the growing of crops, in particular, fertilizer and water usage. According to a study by the National Renewable Energy Laboratory (NREL), the production of biodiesel from soybean oil generates less carbon dioxide, wastewater, and hazardous waste than the production of low-sulfur diesel from crude oil (Sheehan et al., 1998b). However, growing crops for biofuel involves high levels of fertilizer. These fertilizers ultimately reach local runoff, causing eutrophication and potentially causing great environmental harm. Even worse, however, is that biodiesel is highly toxic because of all the different chemicals and catalysts mixed in from production. Even so, in comparison to diesel, biodiesel is less toxic to aquatic life (Khan et al., 2007). Biodiesel also degrades faster than diesel. A study comparing the degradability of conventional diesel and biodiesel over 50 days showed that the fatty acid methyl esters were degraded to 10% of their original content within 3 weeks (DeMello et al., 2007).

Another characteristic of biodiesel is its solubility. Biodiesel is 15-25 times more soluble than diesel (He et al., 2007). This makes biodiesel more prone to microbial growth during long-term storage and faster at contaminating waterways. However, because it is less toxic than diesel, ultimately, aquatic life is more likely to survive a biodiesel spill than a diesel spill. The contamination of water remains similar throughout all types of biofuel, but water usage is highly dependent on crop and irrigation. For example, on average, each gallon of corn ethanol uses 115 gallons of irrigation water. (Fargione et al., 2009). Producing one gallon of petroleum takes about 3-6 gallons of water (Schwab et al., 1999) while producing one gallon of biodiesel takes between 10-324 gallons of water (Cho, 2011).

Ultimately, biofuel is not entirely environmentally friendly. However, in comparison to conventional fuel, it is far less detrimental.

Solutions

Algae Based Biofuels

The varying avenues of biofuel production include biofuel by crops, GMO-grown crops, and other biomass materials. Petroleum has a large emissions output as well as an unstable resource bank. After researching these varying proposed solutions we have seen that scientists deemed algae as one of the most qualified sources to replace petroleum fuel.

A few advantages of algae include its short harvesting cycle of 10 days from start to fuel (Vassilev & Vassileva, 2016). This process creates higher yields and increased productivity since the algae takes less time to accumulate extractable levels of triglycerides. A few extraction processes include biochemical conversions such as fermentation, aerobic digestion, and photobiological hydrogen. Thermochemical extraction processes include gasification, pyrolysis, and liquefaction. Chemical reactions such as transesterification, which is another use of enzymes, are also used for extraction. All of these processes are similar to that of regular biofuel production. Along with creating a more sustainable fuel source, the process captures the carbon dioxide and reduces the amount of greenhouse gasses emitted. Another benefit comes in lower resource and product use considering that there is no high-quality land needed, less water, and no herbicides or pesticides. The microalgae field also has a broader range of diversity with more than 300,000 different species. Since there are so many species, both freshwater and saltwater can be used and reused. Scientists have begun applying the GMO technology used in more conventional forms of biofuel to algae.

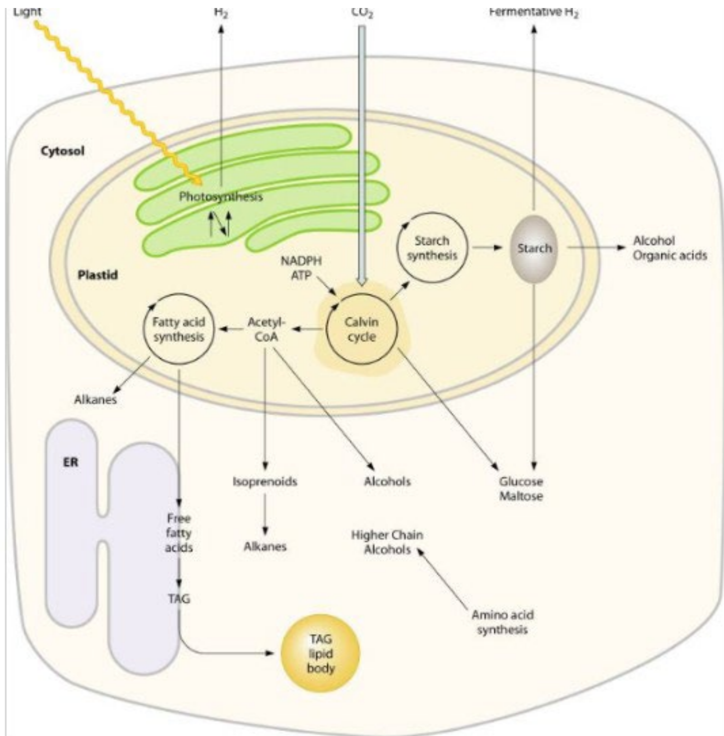
The biggest and virtually single drawback is the expense of production. The strict climate needs of specific water, carbon dioxide, and light levels make the process painstakingly intricate. Although the economic factor can easily deter the public, one way to fix this is by educating the population and working to make it reasonable to the people by endorsing this process. Scientists are saying “Biofuels can be a viable alternative to fossil fuels on short and medium terms. Additionally, advanced biofuels made from residues or waste have the potential to reduce CO2 emissions by 90% compared to petrol/diesel.” (Alam et al., 2012). This shows that society needs to be driving this method to the forefront of our agricultural priorities to reach our sustainability goals.

Furthermore, new advancements have been made in algae production as far as GMO technologies. The overall goal is to increase the production of raw materials through the metabolic pathways of the algae cells. A few of these materials include lipids, alcohols, hydrocarbons, polysaccharides, starches, and triacylglycerol. Each of these materials are produced through the various cell functions. Figure 2 displays the map of an algal cell and shows the inputs of light and other necessities and how they contribute to the outputs of material (Radakovits et al., 2010). This goal is achieved through genetic insertions and the reliance on transgene expression.

The exogenous genes must be expressed properly in the proteins to ensure those superior genes can be integrated into the host. This produces qualities such as higher chlorophyll content, higher hydrogen content, and more condensed lipids for carbohydrates, alcohol and organic acids, sugars, and other raw materials. This diversity is very advantageous because each of these extracts can go into a different form of fuel which broadens its applications. Lipids can be used for renewable diesel and other renewable forms of energy. Triacylglycerols can fabricate fatty acids to produce biofuel by processing and secreting the oils out of those acids and refining them into biofuels. Straight-chain alkanes, hydrocarbons connected in a chain, can be used directly as a transportation fuel because these specific carbons alone have a flash point high enough to produce energy for a vehicle. Along with being chemically deconstructed in the biofuel process, starches and sugars can be excreted from algal blooms and synthesized into fuel.

Figure 2.

Process of cell intake and excretion of extractable components (Radakovits et al., 2010).



To help speed this process even more, scientists have been experimenting with increased light intensity to aid the photosynthetic process. Algae is fueled by the sun which makes it easy to grow and even easier to manipulate its growth. By increasing the light intensity, the cells can perform more processes through the added energy produced through the photosynthesis increase. This helps the metabolic pathways that create each of these raw materials to perform more efficiently and produce higher-quality products. By genetically modifying algae, we are catalyzing these production processes; causing higher yields in record times.

The algae-based fuel industry has seen lots of research and development over the years. The production process is significantly more efficient and environmentally safe than petroleum fuels and it uses overall resources than biofuels. Further developing the algae production, GMO initiatives are also on the uptick as we fight for faster, more healthy, fuel. The microalgae engineering field is helping to increase the efficiency, production, and quality of algae and biofuels in general. Scientists are saying, "The application of these modern metabolic engineering tools in photosynthetic microalgae has the potential to create important sources of renewable fuel that will not compete with food production or require fresh water and arable land" (Radakovits et al., 2010). Although the process of producing biofuels, especially algae-based, is extremely expensive it is also extremely important. We must work to bring it to the front burner of our decisions to secure futures for succeeding generations.

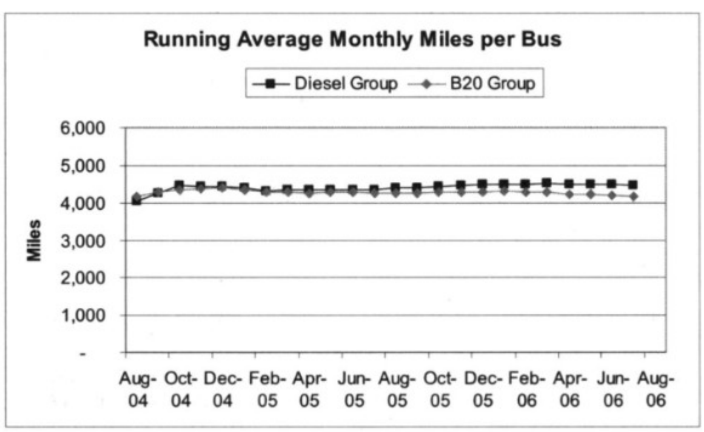
Implementing a B20 Mandate in the U.S.

After researching the advantages and disadvantages of biodiesel, and how GMOs can help the production of biodiesel, we have found that implementing a policy of B20 in the U.S. could also be an effective solution. B20 is a fuel that contains 20% biodiesel and 80% petroleum. Using a blend of biodiesel and petroleum will allow for the country to ease its way into the ultimate future of completely switching to a renewable form of energy. It has been found to substantially lower carbon emissions and has been implemented in various states in the U.S. Furthermore, it has less engine wear than biodiesel and has been found to have similar energy content to diesel. The policy has been proven to be effective in various states.

The Renewable Fuel Standard (RFS) is a federal program that requires fuel to contain a minimum volume of renewable fuels. This has helped the U.S.'s renewable energy progress because the RFS increases the biofuel amounts each year. By 2022, the RFS had increased biofuels to 36 billion gallons (*Alternative Fuels Data Center: Renewable Fuel Standard (RFS) Program*, n.d.). In contrast to biodiesel, B20 has also been shown to be extremely efficient in energy content. Studies have shown that B20's efficiency is slightly higher than diesel at a higher speed. At 2200 Revolutions Per Minute (RPM), B20s efficiency improvement was around 0.8% compared to diesel. However, when 100% biodiesel was used at the same speed, the efficiency was 5% lower than diesel (Bari, 2014). Furthermore, a similar study showed that B20 has little effect on vehicle mileage compared to diesel. In 2 years, 100,000 miles were driven by test vehicles. One group of the vehicles used B20 while the other used diesel. The study found that both groups averaged over 4,000 miles per bus per month (Proc et al., 2006).

Figure 3.

Running average monthly miles (Proc et al., 2006)



B20 has been proven to be effective in Minnesota. Since Minnesota has established a policy requiring the use of B20, its GHG emissions from transportation have fallen by 18% from 2005 to 2020 (Claflin et al., 2005). This is extremely productive considering the population growth in Minnesota has increased, but the GHG emissions are decreasing. This puts Minnesota on the right track toward renewable resources.

Although B20 has shown to be productive as a source of energy, it does have some disadvantages. Biodiesel has been found to be more expensive than diesel. When 2 groups of test vehicles were tested with B20 and diesel, it was found that the B20 group cost was $0.07 per mile compared to the diesel group of $0.05 per mile. However, a $0.02 per mile average difference is not statistically significant compared to the higher costs of 100% biodiesel. However, the cost of replacing a B20s engine is quite higher than a diesel engine. The study found that over 2 years, the maintenance costs of the B20 group were $6,293 while the maintenance costs of the diesel group were $1,763 (Proc et al., 2006).

High costs could be discouraging but it’s important to consider the benefits as well as the disadvantages. Although B20 might be expensive, it’s still less expensive than pure biodiesel and has greater efficiency when used. Furthermore, the cost difference is not significantly high when evaluating cost per mile. Some industries might be swayed by B20 while others might worry about the maintenance costs. Regardless of the disadvantages, B20 will still reduce emissions and bring the U.S. on the right track toward improving upon the climate crisis. B20 is a good baseline for beginning to move towards renewable resources because it allows for slow progress. This would give the U.S. Government more time to prepare farmlands, spending, and other policies so it can align with replacing petroleum with biofuels.

Conclusion

Society can not rely on petroleum fuel forever, therefore, we need to expand our horizons and find an alternative. Based on the comprehensive analysis of biodiesel as a sustainable alternative, several key facts can be found. While biodiesel is promising in terms of mitigating the environmental impacts of petroleum fuel, it faces challenges when it comes to economics and societal implementation. Ultimately, the comparison between biodiesel and petroleum fuel considering many factors proves that biodiesel has the potential to address the UN’s Sustainability Goal of Sustainable Energy. Algae addresses many of the challenges petroleum presents but is not a cure-all. Future research may explore ways to further cultivate algae using different methods or to try cultivating an entirely different genetically modified crop. In the meantime we can focus on implementing B20 as a temporary solution.

As the world grapples with the urgent challenges of climate change and environmental degradation, transitioning from petroleum to biodiesel represents a critical pathway forward. This transition not only addresses immediate environmental concerns but also fosters a resilient energy economy that supports both ecological health and societal well-being. By continuing to explore innovative solutions and fostering collaborative efforts across scientific, economic, and policy domains, we can pave the way toward a greener and more sustainable energy landscape for future generations.

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