Microalgae as Third-Generation Biofuel

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Abstract - **Microalgae are an autotrophic type of microorganism that have high levels of nutrition and photosynthetic utilization. They can be used to produce bioenergy like biogas, biodiesel, and biooil. Microalgae are more sustainable than terrestrial crops because of their less complex structure, quick growth, and high oil content. In comparison to other biomass feedstocks, this project reviews the various microalgae cultivation techniques and energy conversion methods. The benefits and drawbacks of microalgae are discussed in detail, including their high lipid content, limited use of cultivated land, and brief life cycle. In order to analyze the viability, dependability, and sustainability of microalgae as a new biomass feedstock, microalgae technologies are investigated as part of this thesis. The SWOT analysis is designed to highlight the microalgae's advantages and disadvantages from a sustainability perspective. The study is based on a review of the literature drawn from various sources, the majority of which were published between 2000 and 2022.**

Index Terms - Microalgae, Biomass Energy, Aquaculture, Renewable Energy

I. INTRODUCTION

Our civilization must solve the petrochemical resource deficit and environmental pollution. Petroleum shortages and rising petrol costs are limiting the global economy due to depleting petroleum resources. According to scientific literature, massive fossil fuel consumption causes environmental damage and climate change calamities. Social and industrial experts are searching for renewable energy options to partially replace fossil fuels to create a more sustainable society and boost global economic recovery. Biomass energy is essential. Air use, and photosynthesis to generate bioenergy. It can be extracted from food crops, crop waste, wood, rubbish, animals, and microbes, manure, algae, etc. Biomass has renewable and low-pollution benefits. Biomass production is now a significant strategy to change energy structure and minimize greenhouse gas emissions for environmental and economic sustainability.

World attention is now on microalgae biofuel development. Microalgae-bioenergy research is starting worldwide. Many countries in the Americas, Asia, and Europe have microalgae bio-energy research initiatives to encourage renewable energy industrialization. Thus, scientists focused on microalgae for sustainable energy extraction. Microalgae are simple, fast-growing, and oil-rich. Algae production requires less area or can be grown directly in shallow seas, sparing us arable land for food production. Microalgae outperform terrestrial crops in sustainability. The initial step of microalgae bio-energy production is cultivation, which depends on climate, water, CO2, and cultivation methods. These factors directly impact microalgae growth. Studying cultivation methods will yield high-quality microalgae feedstocks. Analyze production after cultivation. Harvesting, oil extraction, and energy conversion are the most challenging aspects of microalgae production technology. Most of these technological processes can be utilized to extract algae and agricultural energy, although marine algae and terrestrial crops differ in oil yields, land use, and economic output. The key to large-scale microalgae biofuel production is lowering investment and production costs. Microalgae bioenergy development faced high input costs. Petroleum prices affect microalgae pricing.

Microalgae production technologies are researched for this. Compare microalgae to other biofuel feedstocks. Microalgae energy production requires analysis of microalgae energy industrialization and sustainability. SWOT analysis summarizes microalgae sustainability strengths and vulnerabilities. Life Cycle Assessments of energy balance in microalgae production evaluate energy input and output sustainability. Economic factors such as production cost, biofuel prices, and microalgae development in the US, China, and Sweden are examined. Microalgae bioenergy difficulties and prospects are concluded.

The research is literature-based. This study relied on a literature review. The report is based on mostly 1973–2012 sources. For instance, published books, international association reports, academic theses, and other literature published by institutions or international organizations that have been used in this report provide a basic aid for gaining a general understanding of microalgae and its production technologies, while published literature on oil yield and land use of different biomass feed-stocks can be found.

II. LITERATURE REVIEW

Biomass energy has three generations. First-generation biofuel feedstocks included sugarcane, maize and wheat. Rice straw and switch grass are second-generation biofuel feedstocks. Algae—especially microalgae—is the third-generation biofuel feedstock. Algae may become more important in sustainable energy in the near future. Algae are the oldest plants in fresh, saline, and sewage. 2100 general and 27000 species of algae exist worldwide. Algae have more fat and protein than terrestrial plants. Only sunlight, water, and CO2 produce biomass energy. Algae grow quickly (2-6 days per generation) and photosynthesis efficiently. Algae are classified as mega or micro. Brown, red, and green seaweed are macroalgae. Microalgae include chlorella, spirulina, and green algae. Marine and freshwater microalgae number over 20,000. However, few microalgae have been discovered for bio-energy conversion. Microalgae have simpler structures, faster growth, and higher oil and so on content than macroalgae. Thus, most industrial businesses use microalgae as feedstocks to produce biomass energy.

Microalgae are minuscule, microscopic algae. Aquatic ecosystems depend on microalgae (Becker, 2004). Microalgae sources are chlorella, spirulina, and Nitzschia. (Christi, 2007). They are single-cell organisms with excellent photosynthesis. Microalgae develop quickly and double every 1-4 days. Biofuel can be made from microalgae with at least 30% lipids. Microalgae use photosynthesis to make carbohydrates and oxygen. Photosynthesis reaction: $6CO_2 + 6H_2O$ + sunshine energy $\rightarrow C_6H_{12}O_6$ (sugars) + $6O_2$. Sugars can be transformed into biofuels by converting to lipids, proteins, and carbohydrates

To conclude, microalgae's energy production benefits are: Microalgae photosynthesis using chlorophyll and other photosynthetic components. Microalgae converts organic molecules into biofuel using sunshine, H2O, and CO2 from the air, Split-type breeding and a short cell cycle make large-scale culture of microalgae easy and Microalgae may be grown in seawater, alkaline water, and wastewater, making it an important bioenergy source in freshwater-poor and desolate locations. Microalgae culture begins with energy production. Cultivation focuses on producing high-quality microalgae feedstocks. The properties and functions of microalgae have led to some scientific growing approaches. Microalgae production methods are currently these two: The open-pond and close-photo bioreactor systems Microalgae energy development is hampered by the production method. It has harvesting and oil extraction and energy conversion parts. Microalgae cells have small diameters (3-30 μm) and high-water content, making harvesting and oil extraction difficult. So, collecting microalgae from cultivation equipment is tough. The high harvesting cost, which accounts for 20%–30% of microalgae production costs, is the main issue. Thus, future microalgae technology development will prioritize cost-effective methods. Energy conversion is crucial to microalgae bio-energy production. Energy conversion technologies determine whether microalgae can efficiently produce biofuel.

III. METHODS FOR MICROALGAE

Harvesting of Microalgae

Not only are the techniques of harvesting dependent on the species of microalgae and the cell density of the microalgae, but they also depend on the many variables that are present during cultivation. The climatic circumstances and the cultivating conditions are inextricably linked to one another. According to Demirbas (2010), microalgae can be harvested using a variety of practical methods, including flocculation, flocculation with froth, flocculation with membranes, and centrifugation. The two techniques that are utilized the most frequently are centrifugation and flocculation.

Microalgae oil extraction

After harvesting, the subsequent step is to extract the oil from the microalgae. After drying, oil from the microalgae is still present in the cells of the microalgae. Both the cell wall and the cell membrane are responsible for keeping the microalgae oil inside the cell. The microalgae cells need to have their cell walls and membranes broken in order to successfully extract the oil, which must then be allowed to escape from the ruptured cells. There are a number of different ways to extract the oil from microalgae. In the process of microalgae oil extraction, the most common extraction methods are the chemical cool press method, enzymatic extraction, and supercritical fluid extraction.

Energy conversion from microalgae to bio energy

The conversion of biomass resources into bio fuel energy can be accomplished using either chemical or biological processes; this is the fundamental idea behind the microalgae energy conversion process. Thermochemical conversion and biochemical conversion are the two primary forms of energy conversion that are typically utilised in the majority of laboratory research as well as some industrial manufacturing processes.

Microalgae can be used in a variety of ways to generate various forms of bioenergy using a variety of strategies that are involved in the process of energy conversion. Energy conversion is something that needs to be researched in order to gain an understanding of the most appropriate approach of technically converting microalgae. Gasification, liquefaction, pyrolysis, fermentation, and trans esterification are the five processes that are most frequently utilized. These methods can be applied to the cultivation of microalgae in order to generate biogas, bio-oil, bio-diesel, and bio-ethanol.

Transformation into thermochemical form

The term "thermo-chemical conversion" describes a process that involves the use of chemical processes in order to convert biomass-based resources into biofuel while the environment is heated. Gasification, pyrolysis, and liquefaction are all a part of this process.

Biochemical

The term "biochemical process" refers to a procedure in which the biochemical properties of biomass raw materials and the metabolic processes of microorganisms are utilized in order to generate petrol fuel and liquid fuel. Fermentation and trans-esterification are two major metabolic conversion techniques that are utilised in the production of energy from microalgae.

IV. BIOFUELS

Biofuel is centuries old. Original biofuel feedstocks were wood and straws. They merely heat and cook. Technology allows maize and wheat to create oil. These crops are first-generation biofuel. After that, scientists discovered that lignocellulose materials can also produce bioethanol and biome thane. Second-generation biofuel appeared since then. People are recognizing microalgae as the basic material for third-generation biofuel.

Food crops are the most common first-generation biofuel used in industrial manufacturing. Sugar crops—sugar cane and beets—are the primary components. Third-generation biofuels are aquatic microorganisms. Microalgae are pioneering third-generation biofuel. Microalgae have high carbon adsorption, high lipid content, simple growth conditions, and quick growth. Microalgae have 25–200 times more lipids than soybeans. Microalgae oil may be turned into biodiesel, its carbohydrate into alcohol, and its nitrogen and phosphorus into fertilizers. sugar, starch, and oil crops (rapeseed, soyabean, and sunflower). Different methods can convert all these feedstocks to biofuel. Corn, grown in the U.S. and Brazil, is a common feedstock. Sims & Taylor (2008) Biomethanol can replace some petrol worldwide. However, some issues limit first-generation biofuel development. Planting crops takes longer and requires 30 huge arable acres. The first-generation bio-fuel was generated on a big scale, occupying a lot of arable land and reducing food production. Thus, treating the "Energy Crisis" with food crops will worsen "Food Crisis". Second-generation biofuels use lignocellulose crops. All timbers and crop wastes (switch grass) contain lignocellulose. Since the production feasibility of the second-generation People think new bio-fuel feed-stocks will alleviate food shortages and land reclamation. Even lignocellulose feedstock can replace food crops. Even though the second-generation biofuel has lower raw material prices and greater cellulose content, its manufacturing costs are substantially higher than those of the first-generation. Second-generation biofuel is not yet commercially produced.

Despite the numerous benefits, commercialization of microalgae bio-fuel faces a number of obstacles.

V. CHALLENGES

The primary difficulty in developing microalgae as a bio-energy source is reducing the production cost of microalgae culture. From planting to harvesting, the process of microalgae cultivation is plagued by high production costs. The initial investment required to construct a pond and stock it with fish, for example, might be quite substantial. Due to the high level of cultivation conditions required for microalgae growth, the production cost of microalgae culture will rise. This is because CO_2 and fertilizer, which feed nutrients to microalgae, are required requirements. In addition, moist algal feed-stocks must be dried off before they can be used in a microalgae energy conversion process. Certain pieces of machinery might be quite pricey. Algae harvesting, as already established, is the costliest part of the production process. The question of whether or not harvesting costs can be reduced at all is crucial.

Another two major obstacles are the environmental implications of microalgae production and waste management. There are environmental effects of using microalgae as a renewable bioenergy feed supply. In the case of microalgae bio-fuel's pyrolysis process, for instance, the technology for recycling and reusing solid, liquid, and gas is not yet sufficiently developed. Cultivation water, which already includes nitrogen and phosphate, is discarded after fertilizers are applied to the pond where microalgae are grown. That necessitate treatment following algae harvesting. So far, there is no best way to recycle this surplus of water. The volume of waste water discharged into the environment could have major consequences if microalgae are produced on a huge scale.

Other technological hurdles, like the microalgae seed selection issue, boosting microalgal oil content, and developing effective oil extraction techniques, remain to be conquered. Microalgae bio-energy has the potential to provide future benefits, such as a replacement for fossil fuel, if these challenges can be overcome.

To encourage the growth of microalgae energy, governments should implement new policies. Policies will need to be revised in the future to make it easier for microalgae businesses to flourish and to promote the development of biomass energy in coastal areas.

This review examines the research on the practicability, dependability, and sustainability of microalgae as biofuels.

VI. CONCLUSION

The work is complete on a type of bio-energy feedstock that has broad commercial applications. This study demonstrates the potential advantages of using microalgae as a novel biomass feedstock for bio-energy generation. Microalgae's key benefits are their high oil output and low land usage. Unfortunately, there are a lot of thorny issues that need fixing before massive industrial manufacturing can be realized. Producing microalgae requires a very sophisticated technical system, requiring input from experts in a wide variety of fields and a substantial financial commitment. Large-scale production has not been realized, and the cost of producing it is substantially higher than that of petroleum. There are several technical issues that need to be resolved, such as the proper selection of microalgae species, harvesting techniques, microalgae concentration, microalgae cell wall cracking, and oil extraction. Reducing equipment investment and production costs while finding effective solutions to these production technique difficulties is often regarded as the greatest challenge facing the manufacturing industry today. Biofuels rely on microalgae cultivation as their foundation; nevertheless, in order to solve issues like microalgae oil content and growth rate, genetic engineering must be established.

Development of algae energy is required for both technical advances and cost savings in manufacturing operations. This is the only way to maximize the benefits of microalgae energy over petroleum. There are strategic and environmental concerns at play in today's widespread support for research into and use of alternative energy sources.
The presence of petroleum crude oil in the Middle East contributed to the escalation of numerous wars (the Gulf War and both of the subsequent Iraq Wars). Oceans disputes (the South China sea dispute between China and the Philippines, the Diaoyu Islands dispute between China and Japan, and the Four Northern Islands dispute between Japan and Russia) have emerged all around the world as a result of the successive development of undersea energy by many countries (including Japan, China, the United States, Russia, and Southeast Asia, etc.).
These issues can be mitigated by the development of renewable energy sources that can be produced at home.

VII. FUTURE WORK

Growing microalgae in sewage sludge eliminates the need to use agricultural land. The facts about algae's qualities inspire us to practice domestic self-production in nearly every nation. With less demand for imported petroleum oil, the likelihood of a global conflict over natural resources is less.

There are unquestionably bottleneck issues that need investigating with regards to algal energy. The extent to which microalgae production affects the environment is unknown because it is not yet done on a massive scale. Food shortages, oil shortages, and conflicts over scarce energy sources might all be mitigated with the help of microalgae. Microalgae energy, as the third generation of bio-fuel, will contribute its own strength to relieve the difficult situation of resources as the technology advances and algae production in industrialization continues to be improved.

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