A

PROJECT REPORT

ON

"PRODUCTION OF BIOFUEL FROM SEAWEED (SUGAR KELP)"

Submitting in partial fulfilment of the requirement for the B. Tech in Petrochemical Engineering

Submitted by,

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CERTIFICATE

This is to certify that the seminar report, entitled "**PRODUCTION OF BIOFUEL FROM SEAWEED (SUGAR KELP)**" is a bonafide work carried out by **Saloni G Bhosale (10303320181152710009**) of Final Year Bachelor of Technology in Petrochemical Engineering of Dr. Babasaheb Ambedkar Technological University, Lonere in academic year 2021-2022.

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Place: Lonere
Date:

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ABSTRACT

The demand and price of fuel was increasing day by day due to increase in number of vehicles because of continuous increase in population. This is one of the major problems which we are facing in our day to day life. **Marine algae are found to be the good source of hydrocarbons and it can be readily used in the production of liquid bio-fuel**. In this study, Sugar Kelp which was collected from Mumbai, Maharashtra was used for extracting biofuel using hexane as solvent by solvent extraction method and its properties were analyzed. Engine efficiency of pure algal fuel and its blends were also analyzed. Results showed that fuel blend with 80% diesel has good brake thermal efficiency. Key Words: Gracilaria corticata, Biofuel, extraction, Covelong, brake thermal efficiency.

CHAPTER 1

INTRODUCTION

Seaweed (or macroalgae) is a large, diverse group of aquatic plants. Some common species, like sugar kelp, could become a promising source of biofuels, if sustainably produced and used. Compared with, for example soya, which is also used for the production of biofuels, growing seaweed is faster, more space-efficient and does not require the use of fresh water or the addition of fertilizer. Furthermore, seaweed does not compete for land area. On the contrary, seaweed can be grown in exactly the area we have the most of: the sea. Biofuels are considered necessary to decarbonise parts of the economy with no alternatives, notably aviation where electrification is not yet available. Europe today meets 90% of its renewable transport target with land-based biofuels, which in many cases are at least as bad as fossil fuels. Meanwhile, climate science shows that fighting climate change will necessarily involve bioenergy, though the sustainable scale remains one of climate science's most unsure areas. While seaweed for biofuels will see benefits as well as similar and different challenges to landbased biofuels, we need to consider all alternatives to fossil fuels that reduce difficult emissions.

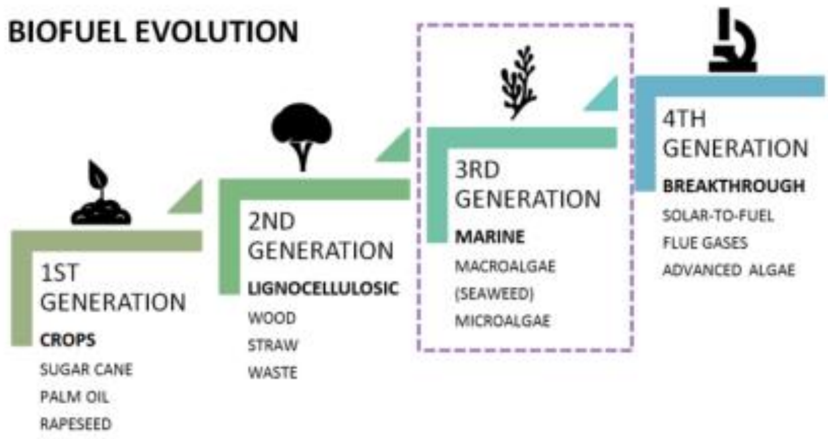

FIG. 1.1: BIOFUEL EVOLUATION

Brown kelp macroalgae — the strange, foul-smelling seaweed so often found washed up on the Pacific Northwest's volcanic sand beaches — could ultimately offer an almost unlimited global supply of commercial-quality ethanol or biomethane.

Fig.1.2 Sugar Kelp Seaweed

Although in the U.S. the idea of macroalgae for energy production is often either confused with microalgae cultivation or dismissed by environmentalists who mistakenly believe “farmed” macroalgae will somehow deplete existing wild seaweed populations, Europe seems to be casting a less jaundiced eye toward cultivated kelp’s renewable possibilities.

“We are convinced there is a potential for seaweed as biomass for ethanol and biomethane,” said Bakken. “We have done cultivation technology development since 2008 and are now scaling up to 100,000 tons of [seaweed] production from about 170 hectares off the coast of Denmark.”

Bakken says Sugar Kelp (laminaria saccharina) can produce about 50 liters of ethanol and 20 cubic meters of biomethane per wet ton. Although SES has produced both ethanol and biomethane gas during testing, it has yet to commercially market any such bioenergy.

While more than 70 percent of earth’s surface is dominated by oceans, they currently only produce a paltry two percent of the globe’s food, feed and biomaterials. In fact, the world only averages a million dry metric tons of seaweed biomass annually, mostly from seaweed crops off the coasts of Asia. However, with cultivation improvements by some estimates annual global seaweed production could be ramped up to 3.5 billion dry metric tons. But at this point, Bakken is simply interested in seeing his own project to fruition.

Bakken says in addition to nearly $20 million already on hand via private investors and project supports from both the European Union and Norwegian government, SES still needs to raise another $10 million to completely fund the company’s next phase of development.

Our long-term goal is seaweed cultivation for energy purposes, says Bakken. But demand for sustainable seaweed-based fish and animal feed and bulk chemical will be important in bridging the gap to full energy production.

However, Bakken hopes that by 2020 SES will be solely focused on producing bioenergy from seaweed.

Meanwhile, although research groups in the U.K, The Netherlands, and Ireland are actively pursuing their own seaweed-based bioenergy projects, private start-ups solely devoted to the idea are hardly plentiful.

Another one of the few such companies is The Bio Architecture Lab (BAL), a five-year old, privately held company headquartered in Berkeley, California, that has spent much of its time pursuing macroalgae production off the coast of Chile. The company garnered headlines early last year when its work on extracting sugars from seaweed feedstock were highlighted in a scientific article that made the cover of *Science* magazine.

BAL CEO Ric Lucien was unavailable for interview regarding the latest status of such efforts, but did provide *Renewable Energy World* with the following statement:

“BAL continues to develop its core intellectual property around unlocking the potential of brown seaweed to be a scalable and sustainable source of sugars for biofuels and other industrial products,” said Lucien. However, Lucien didn’t offer a timetable for doing so.

While Bakken also remains optimistic about the “potential to unlock” seaweed’s bioenergy prowess, he readily admits that his company’s prime focus at the moment is scaling up macroalgae production to commercially acceptable levels. In Europe, that means offshore production of the brown kelp from the top of Norway to southern Portugal.

“The biggest problem is that you need to produce huge quantities at low cost,” said Bakken. “In China, they harvest seaweed in a very labor intensive way, but we are looking at making that process more efficient. To [start producing] bioenergy, you need at least 2 million tons of wet weight seaweed.”

SES has a patent on its seaweed carrier, a “large sail-shaped structure” on which to cultivate large numbers of closely spaced macroalgae plants in the ocean itself. With a seaweed breeding facility in Norway, SES is currently conducting cultivation tests off the coasts of Norway, Denmark and Portugal.

As Bakken explains, with conventional seaweed cultivation, the plants are ready for harvest six to seven months after its spores (attached to ropes) are put out to grow at sea. These spores, in turn, typically spawn three- to four-meter long plants that normally grow from the surface down to depths of a few meters. And unlike terrestrial crops, which are sensitive to the vagaries of the weather, seaweed is generally unperturbed by normal wind, waves and current.

Even so, seaweed still needs waters rich in dissolved nutrients like nitrogen, phosphorus and carbon dioxide that are typically found near coastal areas and in deep ocean water. As a result, macroalgae cultivation for biofuel is going to depend greatly upon geographic location and the development of mariculture facilities says Brandon Yoza, a microbiologist with the Hawaii Natural Energy Institute.

“You’re not going to grow macroalgae in paradisiacal waters around Hawaii,” said Michael Cooney, a chemical engineer at the Hawaii Natural Energy Institute. “When you have crystal clear waters, you have nutrient-deficient waters. That’s why you can see through it.”

Bakken, on the other hand, says that in addition to providing a viable source of bioenergy, seaweed can also be used as a natural ocean filtration system to clean up overly nutrient-rich (read polluted) waters. Seaweed increases biodiversity and oxygen levels, says Bakken, noting ocean pollution is now a huge issue in coastal Europe where he says wild seaweed resources are dying out.

Because the kelp plant is potentially exposed to sunlight filtering beneath the water’s surface, Bakken also notes that seaweed’s photosynthetic efficiency is higher than that for sugar cane.

But despite seaweed’s high marks for the efficient photosynthetic use of incoming solar insolation, Yoza says terrestrial biofuel crops like sugar cane or corn still have significantly higher yields per area. Thus, he notes that profitability from macroalgae is going to depend on a very efficient development process.

Because seaweed is mostly made up of water and salt, Cooney thinks harvesting it efficiently enough to make it viable as a bioenergy alternative will be a major challenge.

“When you harvest the kelp, you have to expend energy to harvest it,” said Cooney. “It’s 60 to 70 percent water; there’s a huge dewatering effort that has to occur. Then you have to get rid of the salt. That takes energy.”

That’s one reason why Yoza says that macroalgae needs to finally be recognized as a distinct biomass resource.

“It’s often [lumped] with terrestrial sources or confused with microalgae,” said Yoza. “Its composition, lifecycle and growth environment is different enough that distinct metrics and evaluation need to be developed. Then [its] research can be better focused.”

CHAPTER 2

LITERATURE SURVEY

A few articles are published on biofuel production from seaweed and it’s analysis. Various available methods and various aspects for the production of biofuel are discussed in several research papers. The following is recap of the relevant literature:

Dr. John Milledge [2014] in this paper, the author sees the potential of algal biomass as a source of liquid and gaseous biofuels is a highly topical theme, but as yet there is no successful economically viable commercial system producing biofuel. However, the majority of the research has focused on producing fuels from microalgae rather than from macroalgae. This article briefly reviews the methods by which useful energy may be extracted from macroalgae biomass including: direct combustion, pyrolysis, gasification, trans-esterification to biodiesel, hydrothermal liquefaction, fermentation to bioethanol, fermentation to biobutanol and anaerobic digestion, and explores technical and engineering difficulties that remain to be resolved. View Full-Text

Rui Jinang [2 January 2016] in this paper, the author has been studying a Marine algal biofuel is considered a promising solution for energy and environmental challenges. Macroalgal biomass has the potential for bypassing the shortcoming of first and second generation of biomass from food crop and lignocellulosic sources. In this review, we summarize the findings in this domain in the past two decades with a focus on the process of saccharification and fermentation of macroalgae for transportation biofuels. In general, macroalgae contains high levels of carbohydrates, almost no or comparatively less lignin than in terrestrial plants, which makes it a very promising source for liquid biofuel production via bioconversion. After harvest, macroalgal biomass goes through several process units, including pre-treatment and/or saccharification and fermentation to be converted to biofuel, e.g., bioethanol. We also propose strategies for further studies to realize macroalgae biomass potential for transportation bioenergy production.

Pablo G. del Río [2019] in this paper, the author has been studying Concerns about fossil fuels depletion has led to seek for new sources of energy. The use of marine biomass (seaweed) to produce biofuels presents widely recognized advantages over terrestrial biomasses such as higher production ratio, higher photosynthetic efficiency or carbon-neutral emissions. In here, interesting seaweed sources as a whole or as a residue from seaweed processing industries for biofuel production were identified and their diverse composition and availability compiled. In addition, the pretreatments used for seaweed fractionation were thoroughly revised as this step is pivotal in a seaweed biorefinery for integral biomass valorization and for enabling biomass-to-biofuel economic feasibility processes. Traditional and emerging technologies were revised, with particular emphasis on green technologies, relating pretreatment not only with the type of biomass but also with the final target product(s) and yields.

Izabela Michalak in this paper, the author has been studying the following paper provides an overview of the potential uses of seaweeds derived both from artificial cultivation as well as from eutrophic reservoirs as the feedstock for biofuels production. This review presents biochemical (anaerobic digestion [AD] and fermentation), chemical (extraction and transesterification) and thermochemical conversions (combustion, liquefaction, gasification and pyrolysis) of seaweeds for biofuels with special attention being paid to seaweeds processing such as pretreatment techniques, production methods and experimental conditions, and so forth. Seaweeds are considered as a suitable source for biogas and bioethanol production due to their high carbohydrate content. This review explores also the possibility of the application of oil extracted from seaweeds for biodiesel production. Since the chemical composition of seaweeds significantly differs from land biomass, a new comprehensive approach is required. Many macroalgal components are recalcitrant to bioconversion and pose microbiological challenges. The text deals with advantages and disadvantages of seaweeds as a feedstock for biofuels. Since macroalgae exploitation only for energy production is too expensive, seaweed integrated biorefineries were proposed as a solution which enables a development of high-value algal bioproducts. Algae appear to be a promising source of biofuels. Utilization of waste algal biomass constitutes a link between the pollution abatement and energy production.

This article is categorized under:

Bioenergy > Science and Materials

CHAPTER 3

MACROALGAE – FEEDSTOCK FOR BIOFUEL PRODUCTION, CULTIVATION METHODS, AND ITS ENVIRONMENTAL IMPACT

Macroalgae is a diverse and non-phylogenetic macroscopic aquatic eukaryote that belongs to Rhodophyta (red algae), phaeophyta (green algae), and Phaeophyceae (brown algae) [2]. Algae can be cultivated in almost all types of water including wastewater [12]. Moreover, the algal growth rate is about 20–30 times quicker than fodder crops and the oil content present in macroalgae is around 30 times more than the conventional feedstocks [13]. The algal source is completely biodegradable and sulfur free, the oil derived from algae has better quality [14]. Further, the absence of lignin makes the macroalgae easy to digest by microbes in the biorefinery process [15] and makes it easier to convert into a biofuel than land-based plants [16]. Biomass residues after the conversion processes can be used for heating purposes, fertilizers, and other types of fuel production [17]. Macroalgae have water content with rich carbohydrates (25% – 50%), protein (7% – 15%), and lipid (1% – 5%) [18] which makes macroalgae a promising feedstock for biodiesel production, bioethanol and biohydrogen production [19]. Similarly, macroalgae can also be used as food supplements [20], hydrocolloids, healing materials, fertilizer, and animal feed. In the food industry, macroalgae account for $5 billion worldwide on an annual basis, which is 83% – 90% of the total seaweed industry. Many researchers have studied about the usage of macroalgae as a feedstock for biofuel production such as biodiesel [21,22], bioethanol [23–25], biohydrogen [26–28], biomethane [29–31] and bio-oil [32,33]. Most of the results showed a positive review about the production of biofuels from macroalgae.

The macroalgae biomass market is expanding both in market capitalization on an annualized basis, with statistical information from the Food and Agriculture Organization of the United Nations (FAO) indicating that global macroalgal biomass production in 2016 amounted to approximately 30 million tonnes at a value of USD$ 11.6 billion. Asia is the world’s greatest producer of macroalgae, with China leading the way with 14 million tonnes valued at USD$ 8.6 billion, followed by Africa with roughly 140,000 tonnes and the Americas with 15,634 tonnes. A variety of macroalgal species, including Laminaria japonica, Eucheuma spp., Kappaphycusalverezii, Pyropiayezoensis, Undaria pinnatifida, and Graciliariaverrucosea, have already been mass cultured in Asia [34]. Europe, on the other hand, still has a limited aquaculture industry, and cultivation methods are lagging. Nonetheless, the effort to stimulate the European macroalgae market and aquaculture industry is in its early stages, and both academic and commercial interests have propelled strategies to farm macroalgae on a bigger scale.

The macroalgal can be cultivated both in offshore and onshore in various methods. The offshore cultivation includes kelp growth, raft cultivation, and floating cultivation [30] which is shown in Figure 1. Due to less consumption of cost for installation and maintenance, cultivation using ropes or nets is considered to be a prevalent cultivation technique. Lagoons are used for culturing macroalgae in which the nutrients are available from seawater. Fixed off bottom, long lines and rock-based farming are the other methods used in macroalgae cultivation. Transplantation is another cultivation method in which species saplings are allowed to be grown indoor, later they are cultured in the tanks and finally transplanted into the sea using ropes [35].

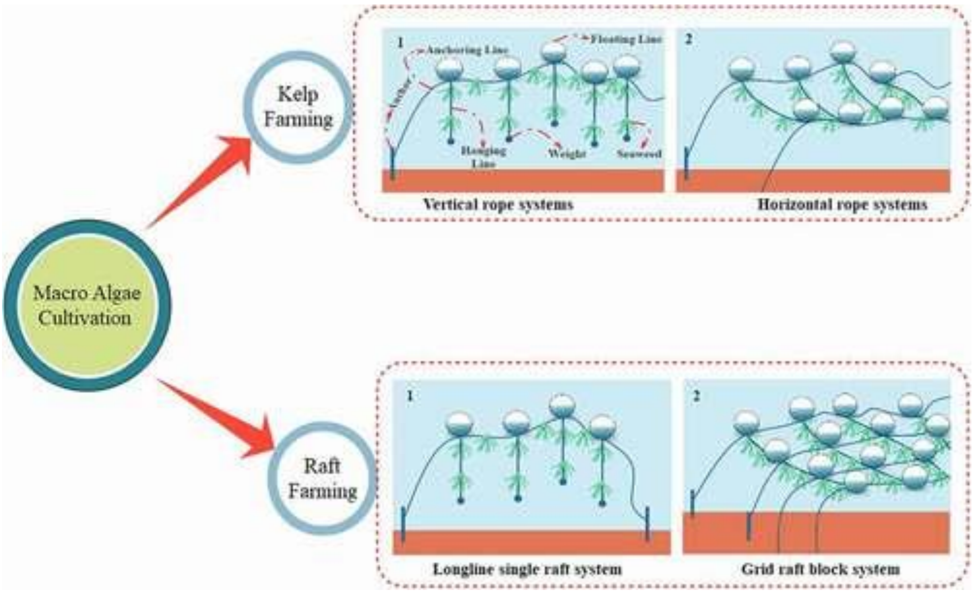

Figure 3.1. VARIOUS METHODS OF MACROALGAE CULTIVATION SYSTEM

In Onshore cultivation techniques, seawater has been extensively used for cultivation and has the advantage of prohibitive extend of control over safety and high product yield. It offers high adaptability for a wider range of macroalgae and is more sustainable than offshore cultivation since marine species are not affected by onshore cultivation. In addition, mixing is a potential factor that promotes better algal growth in this type of cultivation. Proper agitation or circulation have been preferred to mix algal cultures effectively but consume more cost. So far, this onshore cultivation lacks a sustainable low-cost innovative approach for implementation on large scale. It is also possible that a biotic and abiotic ecosystem could get intruded upon by open farming. This reduces the grade of the algae, making it unsuitable for use in the pharmaceutical, chemical, and cosmetic industries [36]. A ring-shaped culture technique for algal cultivation on land was developed by Sebok et al. [37]. Through this strategy, expenses were drastically decreased by lowering the level of cultivation medium required [38]. In addition to supplying CO_2 and nutrients individually, this method also absorbs the heat during agitation, leading to a more efficient growth phase. Moreover, the growth rate of the cultivated algal biomass is important that shows the impact of the cultivation methods. Yong et al. [39] determined the standard formula for calculating the growth rate of the algae, then the formula as follows:

Growth rate $(G)=[(W_f/W_i)^{1/T}-1] \times 100\%$

(1)

Where,

W_i – Initial weight of algal biomass,

W_f – Final weight of algal biomass and

T – Number of days in culture

The growth rate of the algal biomass was helpful in the assessment of better and essential nutrient-rich algae which promotes better biofuels generation. To cope with this high rate of growth, the biofuel industry and governments are constantly exploring new biofuel feedstocks, processing technologies, and policy mechanisms in order to ensure that future expansion is achievable and sustainable. Grown algae are measured by weighing the drained algae thalli at the beginning and at the end of the test.

Macroalgae offer a good unique atmosphere for marine organisms to sustains and fosters ecosystems [40]. Light intensity, turbidity, water temperature, nutrient concentrations, pH, and salinity are all factors that affect algae growth. But, algal harvesting causes damage to the ecosystem and becomes an issue [41]. In addition, Inorganic fertilizers like nitrogen and phosphorus has been used to flourish the growth of macroalgae. This nutrient enrichment induces algal blooming which could be seen in coastline which disrupts the ecosystems of its surroundings and probably results in hypoxia [42]. However, in the deep sea, this consequence is decreased. In addition, a substantial percentage of inorganic carbon is captured by macroalgae during photosynthesis and will be first metabolized as carbon dioxide and then as $HCO_3^-$and again to carbon dioxide. Using the process such as carbon trapping, photorespiration, and respiration, carbon will indeed be returned to saltwater. Through biological degradation, a component of the carbon is converted to carbon dioxide, while the residue persists as particulate organic carbon in the ocean, where it eventually settles on the bottom. Macroalgae have the last opportunity to capture phosphate until it gets diluted in deep waters. Seaweed farming has been progressively used as a promising nutrient removal technology [43]. Furthermore, a reduction in irradiance throughout the aquatic environment beneath macroalgae culture sites may have a deleterious influence on other marine creatures in shallow areas. Macroalgae in integrated multitrophic aquaculture can employ nutrients for fish farming as fertilizers in algae grown both in land-based and offshore marine culture systems

CHAPTER 4
BIOFUEL PRODUCTION

Biofuels are any solid, liquid, or gaseous fuels that are obtained from biological matter. These biofuels are capable of being used in automobiles and a variety of industrial activities. First, second, and third-generation biofuels are dependent upon the type of biomass. Biofuels can be derived from macroalgae through various biochemical and thermochemical methods which are shown in Figure 2. The most commonly used processes for the production of biofuels are transesterification, liquefaction, fermentation, anaerobic digestion, and pyrolysis. However, the complex structure of the algal biomass may affect the hydrolysis process which is a rate-limiting step that consumes more time. This affects the biofuel yields; hence it can be reduced by introducing suitable pretreatment [44]. Pretreatments break the bond of molecules and depolymerize the complex structure, thus increasing the solubilization [45]. The solubilized samples can be easily used in the conversion process and also enhance biofuel production. Various pretreatment methods such as physical, chemical, biological, mechanical, and combinative methods are used for solubilization of the complex substrate in macroalgae. Biofuel production from various macroalgal species.

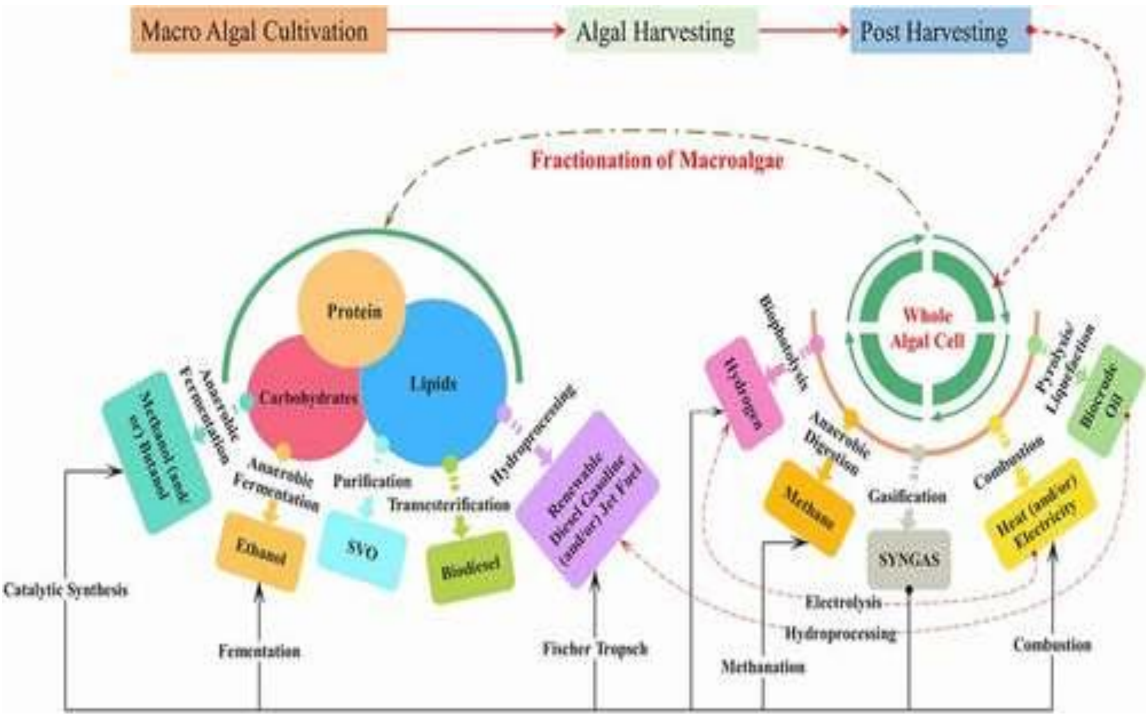

Figure 4.1 MACROALGAL BIOFUEL REFINERY

3.1. Biodiesel generation

A mixture of monoalkyl esters of long-chain fatty acids extracted from algal biomass is biodiesel. Comparing biodiesel to fossil fuels, it has exceptional ignition properties and lowers fumes and carbon dioxide emission levels by 78% [46]. Osman et al. [47] studied biodiesel production from Ulva intestinalis and recovered a yield of 32.3 mg/g dw. Sharmila et al. [48] studied biodiesel production from Chaetomorphaantennina and Gracilariacorticata, achieving a biodiesel content of 2.4 mL and 2 mL per 10 grams of algal biomass. Tamilarasan [49] esterified the FFAs of Enteromorpha compressa algal oil from 6.3% to 0.34%, and then two steps are developed for biodiesel production. During the first step, the FFAs were established with an acid catalyst, and then the oil is turned into biodiesel in the second step. Another attempt used Cladophora glomerata to produce glucose and then converted glucose to free fatty acids for biodiesel. Recently, Xu [50] attempted using macroalgae as a carbon source of oleaginous yeast to produce biodiesel, and the maximum lipid content was 48.30% meanwhile the by-product FFAs accompany mannitol can be used to culture the oleaginous yeast.

3.2. Bioethanol production

Bioethanol production from Sargassum spp. was carried out by Borines et al. [51] with a conversion yield rate of 89%. Using fermentation, Gracilariaverrucosa, red seaweed is used to produce bioethanol production with a yield of 0.43 g/g sugars was achieved [52]. Yoza and Masutani [53], experimented with the bioethanol production from macroalgae biomass, Ulva reticulate in which 0.37% v/v concentration of bioethanol is produced from 1 gram of sample. The authors also reported the above results to correspond to approximate 90 liters of ethanol yielded per dry tonne of macroalgae. A study by Osman et al. [47] on bioethanol production from Ulva intestinalis recovered a yield of 0.081 g/g dw. Bioethanol conversion yield of 90.9% was obtained through saccharification and fermentation methods by treating seaweed waste [54]. In a batch reactor, anaerobic fermentation using B. Custersii generated 11.8 g/L ethanol from 90 g/L sugar whereas about 27.6 g/L ethanol from 72.2 g/L sugar in a continuous reactor [55]. Also, results from Offei et al [22] concluded that E. Cottonii could be a potential feedstock for bioethanol production. Red algae, Palmariapalmata, mainly containing carrageenan, released glucose, galactose, and sugars by acid hydrolysis (0.4 M H_2SO_4 at 125°C for 25 min) and then were fermented to ethanol [56]. Kappaphycusalvarezii [57] biomass was saccharified at 100°C in 0.9 M H_2SO_4 and the best yields for saccharification were 26.2% and 30.6% (w/w) at the laboratory (250 g) and bench (16 kg) scales, respectively. Stefan Kraan et al. [58] reported that washing macroalgae in acidic water (0.09 M HCl in H2O) at 65°C enhanced hydrolysis of laminarin.

3.3. Biohydrogen production

Biohydrogen is considered as a clean sustainable energy with a high-energy yield and it is the main source of future fuel. Hydrogen yield of 109.6 mL/g COD (Chemical Oxygen Demand) was achieved by treating Laminaria japonica using heat treatment at 170°C [59]. Yin et al. [60] experimented with microwave pretreatment for treating macroalgae Laminaria japonica at temperature 160°C for 30 min and obtained a hydrogen yield of 15.8 mL/g TS. Using disperser treatment, Kumar et al. [24] achieved biohydrogen production of 45.5 mL by treating algal biomass, Ulva reticulate. Algae Laminaria japonica is treated using an alkaline treatment which yielded 15 mL/g of biohydrogen [61]. Also, biohydrogen yield of 63 dm3/kg VS was obtained by treating the macroalgae using hydrogen peroxide chemical [62]. Yin and Wang [63], studied the combined microwave and acid pretreatment method to Laminaria japonica and achieved biohydrogen production of 28 mL/g TS at 140°C with 1% H2SO4 in 15 min.

3.4. Biomethane production

Biomethane production of 47.25 mL/g COD was obtained by treating the algal biomass, Chaetomorphaantennina, through chemo disperser treatment [64]. Jard et al. [65] studied biomethane production by treating Palmaria palmate a red macroalgae, and achieved high biomethane production of 308 ± 9 mL/gVS. Gurung et al. [66] studied the biomethane production from green and brown algae and obtained 256 ± 28 and 179 ± 35 mL/g VS biomethane as yield respectively. Biomethane yield of 70% was achieved by treating Laminaria hyperborean using anaerobic digestion [67]. Marine biomass has shown promise for stable methane production, yielding between 140 mL and 280 mL of methane per g volatile solids (VS) for green and brown algae genera, such as Sargassum, Gracilaria, Laminaria, Ascophyllum, and Ulva. Some studies even suggest biomethane recovery of 260–500 mL methane per g VS for Laminaria sp., Macrocystis sp., and Gracilaria sp.

3.5. Bio-Oil production

Bio-oil can be directly used for fuel internal combustion engines and also used as a chemical. Pyrolysis is considered to be one of the most possible conversion processes to produce bio-oil by heating algal biomass in absence of oxygen. The Hydrothermal liquefaction of the green macroalgal species Enteromorpha prolifera yielded of bio-oil of 23.0% dw (energy density of 29.89 MJ/kg) at 300°C, 30 min in the presence of Na2CO3 as catalyst. Similarly, Anastasakis and Ross [68] investigated the same liquefaction in brown macroalgae Laminaria saccharina which infiuences reaction parameters and yielded the highest bio-crude of 19.3% having algal/water ratio as 1:10 at 350°C and a residence time of 15 min without catalyst. Dong et al. [69] investigated bio-oil production from macroalgae using a fixed-bed reactor and yielded 47% with 33% of biochar as its co-product. Wang et al. [70] reported bio-oil production from macroalgae using microwave treatment and achieved a maximum yield of 18.4 wt.%.

CHAPTER 5
MATERIALS AND METHODS

Collection of seaweed

Seaweed Sugar Kelp was collected from Mubai, Maharashtra and were thoroughly washed with water remove sand other particles. Then were dried under sun light and were powdered.

Fig. 5.1 DRIED SEAWEED POWDER

Extraction of algal oil

The extraction was carried out in a Soxhlet apparatus for 4 hrs with solute that is 15 gram of seaweed powder and 175 ml solvent hexane in order to determine the algae oil content. The amount of final oil content was 50ml oil.

Fig**.** 5.2 SOXHELET APPRATUS

Fig 5.3 COLLECTION OF OIL

Transesterification process

The algal oil was reacted with mixture of potassium hhydroxide and ethanol for transesterification for 12 hrs. Then biofuel and glycerin were separated using separating funnel (Fig.2). The extracted Biofuel was washed with water many times to remove residual solvent present in it.

The result and brief discussion about the project is still in progress.

CHAPTER 6
FUTURE SCOPE

- First and second generation biofuels cannot meet global demands in sustainable way.
- Artificial photobioreactors are most effective in terms of high production volume.
- Fuel blends with algal biofuels give positive results on combustion and emission.
- Commercialization of algae production can redefine the future of global energy.
- Government emission policies combined with research will fast-track algae biofuel.

Considering the enormous prospects for sustainable energy from this macroalgae, pretreatment enables satisfactory phase separation of the entire coastal growth must be recommended, mostly for biofuels production and for use as a food fixer, additional content, restorative, manure, and medication, boosting the biorefinery's financial viability. Biorefinery development is based on the consistent providence and high-volume output of a suitable species of macroalgae as feedstock. But, the most significant obstacles to biorefinery advancement are the macroalgal cultivation process. Life cycle analyses and techno-economic assessments of such technologies have frequently revealed that the culture aspect of the system is perhaps the most expensive and energy-intensive, requiring further research and innovation to render macroalgal biorefineries commercially feasible. For effective development, improvements in awareness and acceptance of macroalgal development cycles, and the invention of novel efficient and suitable growing technologies (primarily for offshore cultivation) for each species of macroalgae, are critical. For each species, the energetic balance or recovery rate of the process is also necessary. It comprises reduced operational and investment expenses (such as labor, technology, and energy inputs) while enhancing and growing biomass yields and the value of potential biofuels. About 447 algae and Spirulina spp. production units currently exist in Europe. A variety of species, production methods and commercial applications have been identified throughout the European countries.In Europe, the harvesting of wild stocks is the predominant production system for macroalgae (68% of the production units mapped). In the case of microalgae, photobioreactors are the main production method (71%) while for Spirulina spp., the open ponds prevail (83%) [102]. total of 309 permits for macroalgae cultivation in Norway, of which roughly half were awarded for kelp cultivation (S. latissima, L. digitata, A. esculenta) with S. latissimaat present being the commercially most important species. The total kelp production for 2017 amounted to

145 tons with a sales value of approximately 74,000 Euro [103]. International collaboration would be required to promote and develop the agricultural technology and experience of the East Asian nations (i.e., China, Korea, Japan, Indonesia, and the Philippines), which are the primary producers of macroalgal biomass for biorefinery [104] focussed to improve the macroalgal biorefinery. In 2010, these countries supplied 95% of the world’s supply. Owing to ecological circumstances such as climate, the dominant species produced in the countries differ. China and Korea cultivated 85% and 30% of the entire world production of L. japonica and U. pinnatifida, respectively [105]. Porphyra sp. was mostly grown in Japan, while other red algae were primarily grown in Indonesia and the Philippines [106]. East Asian countries would play a key role in expanding the amount of macroalgae produced globally for biorefinery feedstock, thanks to their decades of farming technique and experience. Various types of sensors for predicting temperature, pH etc., can be preferred in future which led to the emergence of integrated electronic technologies and the Internet for the control, monitoring, and analysis of difficulty in macroalgal growth systems. This type of technology has been implemented in microalgal cultivation system now-a-days [107]. To fractionate the ocean growing biomass, innovative and environmentally sustainable cycles are critical. According to the data gathered for this study, the most efficient and practical method for obtaining fermentable sugars is a weak corrosive pretreatment. The requirement for more eco-friendly measures brings research into pretreatments utilizing green solvents (such as water, deep eutectic solvents, and so on that when combined with effective warming frameworks, could improve the suitability of these integrated ocean growth biorefineries. There is also a demand for low-cost, earth-friendly solutions for saccharification of non-cellulosic polysaccharides. One of the most crucial obstacles is the availability of catalyst mixed drinks for particular hydrolysis of ocean growth polysaccharides. In this regard, the use of deposits from phycocolloids businesses is suggested as a feasible option, given that cellulolytic chemicals used in lignocellulosic biomass saccharification can be used. Disengagement and presentation of novel compounds from marine microbes, on the other hand, is a novel pattern that could lead to the discovery of effective proteins for saccharification of non-cellulosic kelp polysaccharides. As a result, it’s only reasonable that biotechnology improvements enable the development of microorganisms capable of hydrolyzing and aging these sugars in a combined bioprocessing setting, employing genetic modifications and metabolic designing apparatuses. The development of kelp

biomass-to-biofuels measures could be aided by proper fractionated pretreatment and solidified bioprocessing.

For each macroalgae variety, which can be grown sustainably, it is necessary to determine the range of possible bioproducts and biofuels, and also the optimum, holistic, and integrated bioprocessing pathways. Such information will be essential for the bioeconomy’s long-term viability and economic benefit. Each bioprocessing step, as well as the variety of potential bioproducts, should be stored in a central database that is accessible worldwide, as this will allow the macroalgal sector to flourish.

Even if it may appear to be unduly hopeful, it is possible with strong collaboration linkages between academics and industry, as well as multidisciplinary organizations made up of cultivation experts, bioscientists, marine biologists, engineers, and social scientists. Proper Collaborations are crucial for advancement in this field. It is also critical that the bioprocessing of every macroalgal species features must be analyzed precisely for better sustainability using various innovative eco-friendly evaluation techniques once the ideal bioprocessing routes have been recognized and recorded. Some of these include life cycle assessment, energy, and energy-based models, all of which may assist progress in macroalgal biorefinery.

In offshore cultivation, proper regulation and licensing of farming in each country must be fulfilled to harvest the native macroalgal species and its affordability in order to yield better biofuels through various bioprocessing technologies. Furthermore, bio-refineries would use local species in coastal water, which have an impact on bioproducts that may vary by country. Also, the biochemical contents of macroalgae affect the potential bioproducts by creating fluctuation by taxonomic group [31]. This could have a greater impact on the bioeconomy of each country or coastal region. Furthermore, with rules varying between nations, procurement of planning authorization toward developing a biorefinery in a coastal environment may be difficult.

Due to the effects of global warming, the bioeconomy organization in a single country may alter theatrically in the coming decades. Consequently, the increased temperatures caused by climate change, studies have shown possible variations in geographical distribution and huge macroalgae in various coastline surroundings. Macroalgal distribution shifts will have an impact on macroalgal biorefinery infrastructures, their locations, jobs, and general viability in bioeconomy [108]. As a result, it is critical in the distribution of species to simulate and project the commercially important macroalgal species transition in climate change. In the decades ahead, a continued study in the development of novel macroalgal biorefineries is required mainly in the farming areas which may oppose the source of reduced feedstock or invasion of new species due to alteration in distribution [109].

In addition to the acceptability of macroalgal biorefinery by broader population and local authority, it is also important to consider the economic implications too. There might be some governmental and community groups opposition to the building of vast biorefineries at shorelines (and off-shore macroalgae growing schemes that might preferably be within close vicinity) [110]. For bio-refineries accepted by the general population, sustainable innovative strategies have been examined as well as implemented. Biotechnologies and their effects could’ve been conveyed to coastal communities prior to the biorefinery’s development [111]. Participants from academia, funders, sponsors, and the citizens could still be included in focus group meetings and/or workshops that have been accessible to all. Hence, the macroalgal sustainable biorefineries addresses the following:

Waste biorefinery incorporated with circular bioeconomy represents a low carbon economy by involving CO2 sequestration which can resolve the global issues.

Macroalgae and agriculture is additionally an expanding area of research of multi-feedstock culturing techniques focussing on the scalability of macroalgal cultivation.

Large-scale biorefineries at coastal sites will undoubtedly provide societal benefits, including job creation, energy security, and economic development through employment

The development of biofuels has both direct and indirect social impacts, including job creation (quality and permanence), social responsibility, and social equity, including issues such as wealth distribution to rural communities

CONCLUSION

In the future, a huge potential for demonstrating an integrated pattern of biofuel generation from macroalgae would be a great option. For the development of bio-fuels, bioproducts, and high-value biochemicals, research investigations have identified potential biochemical processing processes including a variety of distinct macroalgae species from all three taxonomic groupings. Its innovative potential to make a contribution to the bioeconomy and provide a sustainable renewable energy source is outlined by the intense trend in implementations of macroalgal property rights, and perhaps a rising demand of funded research projects encompasses the entire macroalgal biorefinery route. Many problems exist mostly in process of using macroalgae for producing fuels and chemicals, namely macroalgae availability and huge seasonal patterns in macroalgae biochemical and nutrient value. Certain limitations remain, such as insufficient technology and the unpredictability of the volume and quality of macroalgae biomass. The biomass of macroalgae differs by species, geographical region, and season, as well as the yields and product types generated, which are significantly reliant on processing technology. The technologies used to treat terrestrial-based biomass are generally suitable, and indeed the technique of emerging technologies or the development of new technology could well be beneficial. It’s also crucial to highlight that macroalgal biorefineries are obviously in the development stage in promoting the lab-scale techniques to an industrial scale. But, bioenergy and other macroalgal products still have the ability to impact the government’s legal and regulatory framework. These enabling states to focus on developing bioeconomic schemes and accelerate the urgency ought to prevent utilizing scarce non – renewable sources. Commercialization of such biorefineries will be possible with effective knowledge transfer and transparency between stakeholders, industry, academia, the general public, and the government. Identification of new microorganisms, technology development for genetic transformation and metabolic engineering, and process development and optimization for yield enhancement should all be prioritized to make macroalgae more effective and efficient in future. Thus, macroalgae could significantly contribute to a low-carbon economy and become the most promising biomass in future.

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