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Atmospheric CO_2 Capture by Microalgae Culturing: A Critical Review

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Abstract— with rising fuel demands, the carbon which is avowed as inefficient energy sources is continually declining. This method is a promiscuous way not of lowering CO_2 emissions but of producing economic benefits. The physiochemical conversion of carbon dioxide into chemical (energy) goods without contamination. The production of microalgae will thus help to repair CO_2 and biofuels sources. In this present work, we have done a comprehensive reviewed in this paper that carbon dioxide capture mechanism, contribution of microalgae for biomass production. As a result of using microalgae (S. platensis, Salmeriensis, and Scenedesmus dimorphus are capture maximum CO_2 respectively of 1.00 and $0.81gL^{-1}$ d^{-1}, $1.0gL^{-1}day^{-1}$-$2.8gL^{-1}day^{-1}$ and 0.8g CO_2 $L^{-1}d^{-1}$ with the production of microalgae biomass (<0.4g $L^{-1}day^{-1}$, 129.24 $mg^{-1}d^{-1}$, and 0.44gcel $L^{-1}d^{-1}$) in wastewater. The overall cost of the process is considerably reduced when these light conversion and chemical processes are combined, making carbon dioxide collection even more economically viable. Microalgae was used on extensively for biodiesel production and carbon dioxide reduction, and the processes were significantly enhanced with the use of microalgae. To conclude microalgae holds a strong promise in the 21st-century biofuel industry and environmentally friendly by capturing CO_2.

Index Terms— Microalgae, Physiochemical, CO_2 Capture, and Biomass.

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I. Introduction

THE rising world demography and improving living conditions, energy patterns are increasing. In general, the major source of energy has been fossil fuels since ancient times. However, the rapidly increasing requirement for fossil fuels will one day be reduced. Various aquatic algae, organic feedstocks, and including terrestrial are being used to produce green energy for fossil substitution [1]. It is used as a sustainable carbon-neutral type of fuel because of its range and rapid yield [2, 3]. Microalgae are species of microscopic that are guided by the same mechanism and typically suspended as high plants e.g. Chlorophyta [1, 4]. A vascular system to transport nutrients is not required since each cell is phototrophic with nutrients directly absorbed. Solar-powered microalgae cells produce biofuels (such as bi oethanol and biodiesel), animal feed compounds, and bioactive components (such as docosahexaenoic acid) [5-7]. Micrology is also an attractive approach for carbon dioxide sequestration that can be applied more easily to fossil energy flows such as greenhouse gas pollution reduction as shown by their ability to absorb CO_2 [8].

Burning of fossil fuels as a source of electricity in power stations is a significant producer of CO_2 in the atmosphere [9]. The elimination of carbon dioxide emissions from fossil fuels can be done by power plant productivity, the use of other alternative sources of electricity, carbon dioxide trapping, and storage facilities [10]. Although different methods of carbon dioxide capture exist, in particular, is a theoretically promising alternative. By lighting the sunshine as a source of energy, carbon dioxide may be converted to organic matter. While this alternative is useful, it needs further research and development. Terre strial plants can normally consume carbon dioxide and photosynthesize organic matter, but algaes, in particular, can more easily transform carbon dioxide into organic compounds [11]. Studies have recently been underway to evaluate manufacturing processes and methods for the use of microalgaes. The transformation from pilot to industrial scale, however, also plays a negative role for the microalgae cell, resulting in decreased product returns. The microalgae recovery from high thin suspension requires the right steps to lease cells and to decrease the extract yield. It is also difficult to combine the right micro-legiate cells and bioprocessing technology to guarantee cost-effectiveness and environmental sustainability while reducing the number of full-scale tails. Conditions need not be less costly than affordable or fossil fuels for a physically and commercially viable biofuel business, not less land usage, less encouraging improvement of the reduced water usage and quality of air (e.g. CO_2 sequestration) [1]. Micro-based biofuels pose a significant impediment to the commercialization of biofuels' development costs, but in light of competition with fossil fuels, they are promising fuels from microalgae. This paper examines the literature on microalgae grown using CO_2 captured from the atmosphere. In this case, several relevant issues are discussed in this example, including the characteristics of microalgae (e.g., species and composition); Capture of CO_2 via microalgae, and microalgal production.

II. CO_2 CAPTURE VIA MICROALGAE

Although several solutions for reducing CO_2 emissions are being investigated, no one mitigation technology has yet to provide an optimal answer. Carbon dioxide capture and storage (CCS) is a technique that involves extracting CO_2 from its industrial and energy-related sources and moving it to a storage facility for long-term isolation. Chemical absorption, that is used to capture carbon dioxide, comprises cyclical carbonation/decarbonation events in which gaseous CO_2 reacts with a solid metal oxide to produce metal carbonate. When the metal carbonate is heated above its calcination temperature, the metal oxide is regenerated. The monoethanolamine (MEA) solvent is widely used as a carbon dioxide chemical absorption technology. The desorption of greenhouse gases into an aquatic MEA-solution, which, when heated, regenerates the MEA in a reversible process. Urbanization is anticipated to be a significant source of CO_2 and contribute to greenhouse gases as one of the most significant atmospheric contaminants. As per Kyoto Protocol (1997), which was agreed by over 170 countries, greenhouse gas emissions in 1990 were supposed to be decreased by 5.2 percent based on emissions in 1990 [12]. Since then, different research and innovation projects have been done across the world in order to accomplish CO_2 reduction. Chemical, Physical, and biological approaches have been widely studied [13-16]. Among these attempts, a successful approach to biological CO_2 fixation is believed to be the biological process using microalgal photosynthesis [17]. Microalgal feedstock provides nearly 50% carbon by dry weight [18]. Usually, much of this biomass is extracted from carbon dioxide. During daylight hours, carbon dioxide must be nourished continuously. The pH values can help with carbon dioxide supply control. The pH calculations minimize carbon dioxide leakage. This will minimized the global effect of the combustion of fossil fuels by generating biodiesel by microalgae cultivation with carbon dioxide emitted from power plants [19].

III. CO_2 FIXATION

The flue gases produced by various companies are responsible for the majority of the greenhouse gas emissions. Carbon dioxide can only be attached to algae during the day. Microalgae, like other plant, will eventually produce CO_2 overnight. There is, however, net positive absorption of CO_2 as a consequence. An additional amount of flue gas supply is needed in outdoor culture systems or open systems to provide the necessary amount of carbon dioxide. Microalgal growth is restricted by outdoor culture [11].These processes are not easily regulated and demonstrate poor performance due to the variations of the following: (a) system ventilation, (b) ambient temperatures, and (c) light usage. Compared with open culture structures, a closed photobioreactor is simple to track and can reach fast growth rates [20]. A closed photobioreactor may be considered a bio scrubber for waste gas therapy. The microalgal cells cultivated in this photobioreactor convert CO_2 from waste gas into biomass in an energy-efficient and economical manner [20]. The carbon dioxide fixation rate is closely connected to the efficiency of light consumption and the cell density of microalgae. Photoautotrophic growth requires microalgal carbon dioxide fixation in which anthropogenically derived may be used as a source of carbon. Therefore, evaluating the capacity of a microalgal culture system for direct CO_2 removal, biomass measurements, or growth rate assessments are important [21, 22]. In many studies of photobioreactors, the effects of CO_2 concentrations in the air on microalgae growth have been evaluated. The aim was to propose trapping carbon dioxide at high CO_2 concentrations from waste gases [23-29]. To this end, the photobioreactor was fed with various air and CO_2 feed compositions. This study has allowed microalgal growth and carbon dioxide fixation to be studied, with this knowledge being useful for determining the efficiency of CO_2 removal. Despite this, there is still a lack of consensus between the different algal species on the optimum carbon dioxide concentration.

The consequences of carbon dioxide content in the atmosphere on microalgae development have been studied extensively in photobioreactor investigations. The aim was to propose trapping carbon dioxide at high concentrations from waste gases [28, 29]. To this end, the photobioreactor was fed with various air and CO_2 feed compositions. This study has allowed microalgal growth and carbon dioxide fixation to be studied, with this knowledge being useful for determining the efficiency of carbon dioxide removal. Despite this, there is still a lack of consensus on the optimal concentration of CO_2 for different species of algae. The difference in carbon dioxide levels of entering and departing effluents in a photobioreactor with microalgal culture may be used to calculate the carbon dioxide removal efficiency. The efficiency of CO_2 removal (η) can thus be calculated using the formula below [30].

$$\eta = \frac{(Influent - Effluent)\ of\ CO2 \times 100}{Influent\ of\ CO2}$$

The effectiveness of carbon dioxide removal or fixation in a closed culture system is determined by (a) CO_2 concentration, (b) microalgae species, (c) operation parameters, and (d) photobioreactor arrangement. In a membrane photobioreactor, Cheng et al. recorded a maximum carbon dioxide removal efficiency of 55.3 percent at 0.15 percent CO_2, with a decrease of 80 mg / L h at 1 percent CO_2 [21]. The world of vulgarism. (27 to 38)% and (7 to 13)% of carbon dioxide are fixed by Spirulina sp. in a three serial tubular photobioreactor. Carbon dioxide fixation performance in treatments with 12 percent CO_2 aeration, from the other side, was only (7-17) percent for Spirulina sp. [23]. In other ways, a species is reliant on the efficient removal or fixation of carbon dioxide. This might be attributed to microalgae's physiological circumstances, such as metabolism of CO2and cell growth potential.

IV. Improvement and Application of the CO_2 Fixation Process

Carbon dioxide fixation by microalgae, energy consumption, and biomass production, have all made significant advances in laboratory-scale study [31-33]. To more effectively guarantee carbon dioxide fixation and biomass production, process improvement as a middle measurement is important. Whether for pilot-scale application or laboratory-scale research, the effectiveness of CO_2 fixation and biomass generation is largely reliant on the parameters and process conditions. Microalgae culture, selection, and promotion to get high-performance microalgae species might be key variables for laboratory-scale research [34, 51]. It is also important to assess the efficiency of microalgae extreme conditions and environmental factors such as high carbon dioxide concentrations, high temperatures, and toxic flue gas pollutants. For pilot-scale use, microalgal culture is primarily impacted by light exposure, cultivation temperature, and hydrodynamic conditions [35]. Open cultivation is more impacted by intensity of light (day and night), external temperature, and season than closed cultivation (affecting microalgal growth. Advancements to the process variables for carbon dioxide fixation include mostly physicochemical characteristics, such as light exposure, closed systems, nutritional circumstances, and hydrodynamic parameters, whereas scale-up is a contentious issue [36]. Biomass production can be boosted by using a high carbon dioxide mass transfer rate, a high aeration rate, and a high removal rate of excess oxygen in the culture medium [37]. Nonetheless, high microalgal cell stress and high operating costs also face major challenges [34]. As a consequence, different variables, such as microalgal species, hydrodynamic conditions, and physicochemical are affected by carbon dioxide fixation via microalgae and biomass development in practical usage. Process parameter and synergistic impact adjustment are critical for improving carbon dioxide fixation and biomass production efficiency [35].

V. Method and Result

Carbon dioxide fixation biotechnologies are used to minimize emissions of greenhouse gas (CO_2). These methods are based on the employment of reactors to produce photosynthetic actions in which microgreens are utilized as biocatalysts in a sequence of biochemical processes to convert CO_2 to photosynthetic metabolic products [38]. Mainly carbon dioxide fixations are conducted by the Photosynthetic method. Carbon-capture rates are also dependent on medium or species of microalgae which also promoted the production microalgal biomass. Different species of microalgal are used for CO_2 capture from the environment and production of microalgal for energy conversion. Such as, S. platensis, N. oleoabundans, Chlorella vulgaris, S.almeriensis, Scenedesmus dimorphus, Scenedesmus obliquus, Gleocystis ampula etc. [39, 35, 40, 41]. The productions are promoted mainly different agents like alkali compound (bicarbonate, sulfonate), light intensity, wavelength, photoperiod etc. By the use of Chlorella vulgaris and S. platensis species of microalgal captured a maximum fixation rate of CO_2 about (1.45 g L^{-1} d^{-1} and 6.24 g L^{-1} d^{-1}) and (1.00 and 0.81gL^{-1} d^{-1}) respectively [42-44]. Bicarbonate compound as a promoted agent which influences the maximum production of microalgal about (<0.4g L^{-1} day^{-1}) [42]. Many researchers worked on the production of microalgal with different carbon fixation rates by used of microalgae species, Table 1.

Table 1: Microalgae conduct CO_2 capture by the photosynthetic method.

Microalgal species	**Promoting agent/ Remark**	**Maximum CO_2 uptake rate ($gL^{-1}d^{-1}$)**	**Production of microalgal biomass ($g L^{-1} day^{-1}$)**
S. platensis [42]	bicarbonate	1.00 - 0.81	<0.4
N. oleoabundans [46]	light intensity, wavelength, and photoperiod	11.4×10^{-3}	$(14 \pm 4) \times 10^{-3}$
Chlorella vulgaris [40]	centrifugation and vacuum filtration	102.13 tons of CO_2/year	12.7 g/m^2/day
S.almeriensis [43]	Carbonate and bicarbonate compound	1.0- 2.8	129.24×10^{-3}
Scenedesmus dimorphus [48]	Carbonate and sulfonate compound around pH-7.4	0.8	0.44
Chlorella sp. AG10002 [34]	-	0.282–0.510	-
Scenedesmus obliquus [34]	Alkali media	$(327–547) \times 10^{-3}$	$213–358 \times 10^{-3}$
Chlorella pyrenoidosa SJTU-2 [42]	-	0.026	1.55
Chlorella sp. BTA 9031 [43]	suitable strain for biomass and lipid production using CO_2	0.235	1.42
Chlorella sp. GD [44]	-	2.333	1.296
Heynigia riparia [45]	-	0.71 ± 0.01	3.28 ± 0.01
C. sorokiniana UKM3 [46]	-	0.273	-
Monoraphidium contortum [47]	-	529.26×10^{-3}	1.698
Oscillatoria sp. [48]	-	0.156 ± 0.004	-
Chlorella sp. [49]	-	98.89×10^{-3}	56.22
Chlorella vulgaris [49]	-	gas superficial velocity of 7.458×10^{-3} m/s.	1.6×10^{-3} m/s
Chlorella sp. WT [50]	-	0.266–0.376	-

VI. FUTURE PROSPECT OF MICROALGAE

Since a microalga is capable of photosynthesis, it is therefore important for life on Earth and it also produces oxygen and aids in the absorption of carbon dioxide. Thus extensive research on microalgae will serve as a positive supportive role in the future. Currently, the world's climate is being adversely affected by rising levels of carbon dioxide, which is very important for the future as it can be absorbed and removed by microalgae. This is because the greenhouse gas effect caused by carbon dioxide reduces the absorption of microalgae by absorbing it through the production of bioenergy, which will help reduce the additional pressure on the fuel in the future. The next important issue is wastewater treatment through microalgae, because one of the causes of environmental pollution is water pollution.

For the future treatment of wastewater through microalgae, reduction of both chemical and biochemical oxygen, further research on coliform bacteria, phosphorus, heavy metal needs, and removal of nitrogen to be made more effective. Conventional water treatment of microalgae should be carried out comprehensively, taking into account the safety of the animals living in the water and the ecosystem. Biofuel production from microalgae will lead to more efficient and efficient biofuel production in the future, which will reduce costs and adverse effects on the environment, such as reducing the harmful effects of eliminating toxic pollutants, greenhouse gases, and gradually reducing emissions. Above all, microalgae need to be economically important in the future, such as low operating cost, recyclable biomass production, limited elimination through hybrid system innovation, measures taken for large-scale microalgae cultivation, control of optimum production, and growth parameters to reach.

VII. CONCLUSION

This short review explains carbon dioxide fixation in wastewater. Microalgae plants can soak up carbon dioxide and turn it into a feedstock for biomass. In the instance of photobioreactors for carbon dioxide capture with algae culture, diligent implementation of physicochemical principles can result in cost-effective designs with high utilization of solar energy. The importance of microalgae is the absorption of carbon-di-oxide and its conversion into biomass feedstock, as well as the possibility of microalgae production as a valuable source of energy due to the potential to produce various valuable fuels and non-fuels. Microalgal biomass can generate a number of non-fuel products and essential fuels for chemical feedstock. Cultivation of microalgae in drainage media also enables the elimination of significant wastewater contaminants. Microalgae, balances the effects of greenhouse gases by absorbing and eliminating carbon dioxide and plays a important role in sustaining the economy as well as the environment and biodiversity.

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