**Environment friendly renewable Algae biofuel production and its future prospects**

1aNatarajan Shanthi,1aKotteswari Murugesan2Pillathil Jegan Pillathil Senthil Mani ,2Selvakumar Murugan,PasupathyAllasamy,1Subbiah Murugesan

*1Associate professorPG and Research Department of Botany, Pachaiyappas College, Chennai, 600030, Tamil Nadu, India.*

*1aAssistant professor,**PG and Research Department of Botany, Pachaiyappas College, Chennai, 600030, Tamil Nadu, India.*

*2 Research Scholar,PG and Research Department of Botany, Pachaiyappa's College, Chennai, Tamil Nadu, 600 030, India.*

Corresponding author mail: Email: prithishanthi@gmail.com

**Abstract**

Due to its ability to produce renewable electricity, green energy, biofuels, and thermal energy, biomass has grown-up in reputation lately. The most general type of biomass is algae, which is a type of living biomass. As they increase, they take in carbon dioxide and discharge it when they need it for energy. Many people think biomass is a carbon-neutral energy source because of the carbon cycle. As a result, algae are the ideal contender for biodiesel production since it can minimize greenhouse gas (CO2) emissions while providing more fuel than other bio-oil sources that require less fresh water and fertile land. Lowering greenhouse gas emissions means less environmental effect from climate change and global warming.Adequate biomass resources and a well-functioning biomass market that can ensure stable, sustainable, and long-term biomass supplies are critical prerequisites for achieving such goals. Various countries have extensive experience with developing biomass markets and connecting available resources with market demand.

**Key words:** Biomass, Algae, Carbon di oxide, Greenhouse gas

**Introduction**

Algae can be grown using salt water or brackish water on numerable land as a source of biofuel. The information that algae may be used to produce biofuels without requiring crops for food production is a major benefit. Using light and carbon dioxide (CO2) to produce biomass, algae are organisms that grow in aquatic settings. Macroalgae and microalgae are the two forms of algae. Large, multicellular macroalgae can be seen in ponds. These larger algae have a numeral of strategies to grow. The major multicellular algae are referred to as seaweed; an illustration of this is the massive kelp plant, which may attain lengths of more than 100 feet (Li *et al*., 2008). Microalgae are tremendously tiny organisms that often flourish in ponds or water bodies and are measured in micrometers. In nature, microalgae grow more rapidly than macroalgae and contain more lipids (Lee et al., 2014). Only roughly 30,000 of the more than 50,000 microalgal species have been selected for research (Surendhiran and Vijay, 2012; Richmond and Qiang, 2013; Rajkumar et al., 2014). Algae's key advantage over other conventional crops with annual or biannual harvest cycles is its short harvesting cycle (Chisti, 2007; Schenk et al., 2008). Algal oil can be used as cattle feed, some algae can be harvested daily, algae biofuel is non-toxic, highly biodegradable, and can be produced from leftover algae, which reduces carbon emissions (Demirbas and Demirbas, 2011). Algal biomass has thus received the most awareness due to its potential use in the biofuel industry (Behera et al., 2014).

The biomass of the species and the algal growth rate define the oil productivity, which is the mass of oil produced per unit volume of microalgal broth per day.

**Algal biomass**

Algal biomass is currently documented as a third-generation biomass feedstock with a number of benefits, including less cultivation and higher yield (Khoo et al., 2019). Algae biomass has been widely researched over the past ten years. Algae lipids are a immense source of raw materials for bioenergy products like jet fuel, biodiesel, and gasoline (Khoo
*et al*., 2019). Algal biomass comprises microalgae, macroalgae, and cyanobacteria (Voloshin et al., 2016). In the past, freshwater microalgae have been used to feed both people and animals. These microbes could easily absorb nutrients from the liquid phase and flourish there. The significant capacity of freshwater microalgae in biomass for bio-based energy production has been shown in numerous research, including *Chlorella vulgaris* (Al-Lwayzy *et al.* 2014), *Chlorella pyrenoidosa* (Yang *et al.* 2015), *Muriellopsis* sp. and *Scenedesmus subpicatus* (Gómez-Serrano *et al.* 2015), *Ankistrodes musfalcatus* (George et al. *Coelastrella* sp. (Narayanan *et al.* 2018), *Asterarcys quadricellulare* (Sangapillai and Marimuthu, 2019), *Scenedesmus obliquus* (Liu *et al.* 2013 and *Tribonema* sp. (Wang *et al.*2014). According to Tumuluru *et al*. (2012) and Grayburn *et al* (2013), freshwater macroalgae have the capacity to produce liquid and solid biofuels that can be used independently of or in combination with more conventional energy sources. Additionally, dewatering similar biomass of suspended microalgae is considerably more difficult and expensive than harvesting biomass as thick floating mats (Hillebrand 1983; Grayburn *et al*. 2013). *Oedogonium, Rhizoclonium, Ulothrix*, and *Microspora* are a few common freshwater macroalgal taxa that have been recognized (Kebede Westhead *et al*. 2003; Pizarro *et al*. 2006; Adey *et al* 2011). The biomass of the species and the algal growth rate are what define the oil productivity, which is the mass of oil produced per unit volume of algal broth each day.

**Cultivation**

Algae can be grown in closed or open systems, and since open systems, like lakes or ponds, are less technologically higher than closed systems, they can be used to scale up production more rapidly. All algae cells should effectively receive solar radiation through the cultivation system (Ho *et al.,* 2011). The location of open systems is a crucial parameter to consider, bearing in mind the availability of sunshine and the requirements of the algae to be cultivated. The oval channel or racing track channel can be found in raceway ponds. They are typically constructed of concrete.

Raceway ponds continuously supply carbon dioxide and fertilizer to recirculate algal cultures. To keep away from sedimentation, they contain a paddle wheel that provides mild mixing. To increase air flow rate and hence CO2 usage, an aerator can be used (Brennan and Owende, 2010). According to Dragone *et al.* (2010), the single-channel raceway pond was exceeded by the cascade system in terms of retention time. Sapphire Energy's Columbus Algal Biomass Farm in Columbus, Ohio, has effectively generated 520 metric tonnes of dried microalgae biomass during its two years of operation without experiencing any technical problems. This is one of the successful raceway pond cultivations (White and Ryan, 2015). In spite of having a superior production capacity, open ponds are less productive than closed systems due to the higher water temperature, vapour losses, atmospheric CO2 diffusion, and potential for contamination.

Photo bioreactors (PBRs) are designed to provide for increased light accessibility for optimal algae development. Additionally, PBRs allow for correct mixing, which raises the light to a level that is ideal for cell growth and improved gas exchange (Kunjapur and Eldridge, 2010). PBRs can be made in the shape of towers, tanks, or bags. Glass or plastic can be used to make plates or tubular PBRs. Additionally potential choices include bubble columns and airlift PBRs because they produce a significant amount of algal biomass. (Ugwu et al., 2008). Photobioreactors, which are closed systems, provide a regulated and controlled cultivation environment with a lower chance of contamination. Due to improved mixing capabilities, the effectiveness of CO2 fixation in a photobioreactor exceeds that of an open system.

**Harvesting of microalgae**

Biomass has been harvested using a variety of methods, including filtering, centrifuging, flocculation, and flotation (Singh and Patidar, 2018). To raise harvesting efficiency, two or more approaches may occasionally be combined.

A semi permeable membrane is used in the filtration process, allowing the liquid medium to pass through while holding onto the microalgae so that they may be collected
(Al Hattab et al., 2015). Because the pore diameters of the filter membrane vary, this method can adapt to the needs of different microalgae and handle the more delicate species that are susceptible to shearing damage. It can also extract a high concentration of cells from the medium. Bejor et al. (2013) created a stretch cotton-based filter membrane with a 66-93% harvesting efficiency.

Microalgae cells are separated from the culture media by centrifugation operation based on the density and particle size of each component (Soomro *et al.,* 2016). In spite of the method's outstanding efficiency at harvesting cells, the method requires a lot of time and energy (Rawat *et al*., 2013).

Free floating unicellular microalgae cells unite to form a larger particle known as a floc by adding a flocculating chemical to lower the surface charge of the cells (Muylaert et al., 2017). For instance, iron and aluminum salts have been widely used in industry as inexpensive and accessible chemical flocculants (Bracharz et al., 2018). The majority of the bioflocculants used, according to Pugazhendhi et al. (2019), are biopolymers such acrylic acid and chitosan that are either created naturally or artificially. When compared to their chemical counterparts, bio-flocculants are far safer, more affordable, and environmentally friendly. In order to allow microalgae cells to float on the surface of the culture fluid for straight forward harvesting, flotation, according to Zhu and Hiltunen (2018), uses small bubbles that stick to microalgae cells.

**Extraction Methods**

Algal oil is extracted using a variety of techniques, including mechanical extraction and chemical extraction (Barnwal, and Sharma, 2005). The oil press is the easiest and most used technique. Up to 75% of the oil from the pressing algae can be extracted using this method. Up to 95% of the oil is extracted from algae using the hexane solvent method, which is essentially a two-step procedure that also involves pressing the algae(Santos et al., 2009). The press first presses the oil out. The remaining algae are then combined with hexane, washed, and filtered to ensure that no chemicals are left in the oil.Hexane is the preferred chemical for solvent extraction since it is less expensive and risky than other solvents like benzene and di-ethyl ether(Kumar et al., 2017)

**Refinery**

The fields of hydrogen and biogas production and biomass conversion are related. The primary resource is changed into a hydrogen-containing gas at high temperatures without burning, which is similar to coal gasification. Biomass can be used to create bioproducts, which are carbon-based compounds, in addition to energy and fuel. Glycerin, sugars and sugar alcohols, furfurals, cellulose fiber and derivatives, carbonaceous materials, resins, bioplastics, and other items are some of these products (Godula *et al.*., 2010; Ramesh
*et al.,*2015).

**Global energy demand**

Global energy consumption is steadily increasing, forcing the cost of petroleum-based fuels to rise and motivating research into fresh techniques and sustainable biofuel production technologies. Annual consumption is expected to reach around 778 Etta Joule by 2035, according to global energy demand predictions(Suresh Kumar Krishnan et al 2021). Around 30% of the world's total final energy demand and around 25% of the CO2 emissions connected to energy were attributed to transportation in 2017. From 2000 to 2017, the world's transport emissions grew by 2% year, totaling 8 Gt CO2 (IEA, 2019). Road transportation, which is mostly used for passenger travel, was the mode with the biggest absolute rise (+ 1.7 GtCO2), accounting for three-quarters of all transport emissions. With approximately two-thirds of the world's oil final energy demand going toward transportation, which accounts for more than 90% of the total final energy demand, transportation is the energy end-use sector with the least variety (IEA, 2017).

The World Alternative Policy Scenario, which was included in the World Energy Outlook 2006 (IEA, 2006), illustrates how the global energy market may alter if all nations implemented the policies and measures now in place for lowering carbon dioxide emissions and enhancing the security of the energy supply. In the scenario, traditional biomass decreases but the proportion of renewable energy in total energy consumption essentially stays the same. While other renewable energy sources (such as geothermal, solar, and wind) will develop the fastest but from such a low base that they will remain the lowest component of renewable energy in 2030, hydropower production will rise but its percentage will remain unchanged (FP-154-E-final).

**Environment friendly reduce GHG**

When the fuel is consumed, the amount of CO2 emitted is exactly the same as the amount of CO2 needed for the algae to grow and produce the fuel. As a result, there is no net CO2 emission, the same as there would have been if the algae had never been grown. Algae-based biodiesel may be a sustainable fuel source that doesn't hurt the environment. It can be grown in places where other types of agriculture are ineffective. The ecosystem is essentially unaffected by algae biofuel(Spring power and Gas, 2009). We don't need to be concerned about the ecosystem being negatively impacted significantly or permanently in the event of a spill. The single method of creating algae-based biodiesel that has been explored up to this point, fatty acid methyl transesterification, claims to be able to reduce greenhouse gas emissions by more than 60% when compared to petroleum diesel (Biofuels: The Promise of Algae). If produced in installations that start operations on January 1, 2021, kerosene made from microalgae biomass must attain a reduction in GHG emissions of at least 65% in contrast to the reference values in order to meet the GHG emissions minimum saving criteria (Marie Holzleitner *et al*., 2020).

**Fuel in future**

The usage of algae offers a number of benefits over competing biofuel systems. According to IEA predictions, biofuels might supply 27% of the world's transport fuel by 2050. When compared to other renewable energy sources like solar and wind energy, the expanding potential for using algae-based airplane fuel shows how quickly present petroleum fuels may be replaced (Kumar, 2012). Only by ongoing study and development will the idea of using this unusual critter as a readily available, affordable, renewable fuel source within the next ten years be achieved. For instance, the International Energy Outlook 2016 report from the United States Department of Energy predicted that 99% of new cars would likely have internal combustion engines by 2040 (Gul, 2016). As a result, biofuel derived from algae presents a promising option to fossil fuels and has the potential to lower harmful carbon emissions. However, commercial, low-cost production is not potential given the state of technology today. Even though biofuels generated from algae are getting more and more well-liked on a worldwide scale, oil will probably continue to be the primary source of energy in the world (The Future of Algae Biofuel).

**Conclusion**

Modern biofuels have the potential to restore fossil fuels while avoiding unfavorable effects like food instability and biodiversity loss, particularly those made from algae. The world economy and efforts to slow climate change are predictable to boost from increased production of these fuels.

**References**

1. Adey Walter H., Patrick C. Kangas, Walter Mulbry. Algal turf scrubbing: cleaning surface waters with solar energy while producing a biofuel. Bioscience. 2011; 61(6):434–441.
2. Al Hattab M, Ghaly A, Hammoud A. Microalgae harvestingmethods for industrial production of biodiesel:critical review and comparative analysis. J FundamRenewable Energy Appl. 2015; 5(2):1000154.
3. [Al-Lwayzy](https://sciprofiles.com/profile/42117) Saddam H., [Talal Yusaf](https://sciprofiles.com/profile/1097588) and [Raed A. Al-Juboori](https://sciprofiles.com/profile/763323). Biofuels from the fresh water microalgae Chlorella vulgaris (FWM-CV) for diesel engines. Energies. 2014; 7(3):1829–1851.
4. Barnwal, B.K. and M.P. Sharma, Prospects of biodiesel production from vegetable oils in India. Renewable and Sustainable Energy Reviews, 2005; 9(4): p. 363-378.
5. Bejor ES, Mota C, Ogarekpe NM, Low-cost harvesting of microalgae biomass from water. Int J DevSustain. 2013; 2(1):1–11.
6. Behera,S., Mohanty,R.C.,andRay,R.C. Batch ethanol production from cassava (Manihot esculenta Crantz.) flour using Saccharomyces cerevisiae cells immobilized in calcium alginate. Ann.Microbiol. 2014. doi:10.1007/s13213-014- 0918-8.
7. Bracharz F, Helmdach D, Aschenbrenner I, Harvest of the oleaginous microalgae Scenedesmus obtusiusculus by flocculation from culture based onnatural water sources. Front Bioeng Biotechnol.2018; 6:200.
8. Brennan,L and Owende,P. Biofuels from microalgae-a review of technologies for production, processing, and extractions of biofuels and co-products. Renew. Sustain. Energ. Rev. 2010; 14, 557–577.
9. Chisti,Y. Biodiesel from microalgae. Biotechnol. Adv. 25, 294–306.doi:10. 1016/j.biotechadv.2007.02.001.
10. Demirbas,A.Oily products from mosses and algae via pyrolysis. Energy Source. 2006;28, 933–940.doi:10.1080/009083190910389.
11. Dragone,G.,Fernandes, B.,Vicente,A.A.,andTeixeira,J.A.“Third generation biofuels from microalgae,” in Current Research, Technology and Education Topics in Applied Microbiology and Microbial Biotechnology, ed. A. Mendez-Vilas (Madrid: Formatex), 2010; 1315–1366.
12. Godula, K. Bertozzi, C.R. Synthesis of glycopolymers for microarray applications via ligation of reducing sugars to a poly(acryloyl hydrazide) scaffold. J. Am. Chem. Soc. 2010; 132, 9963–9965.
13. [Gómez-Serrano](https://link.springer.com/article/10.1007/s00253-015-6694-y#auth-C_-G_mez_Serrano-Aff1), C,  [Morales-Amaral](https://link.springer.com/article/10.1007/s00253-015-6694-y#auth-M__M_-Morales_Amaral-Aff1), M.M. [Acién](https://link.springer.com/article/10.1007/s00253-015-6694-y#auth-F__G_-Aci_n-Aff1), F. G.[R. Escudero](https://link.springer.com/article/10.1007/s00253-015-6694-y#auth-R_-Escudero-Aff1), [J. M. Fernández-Sevilla](https://link.springer.com/article/10.1007/s00253-015-6694-y#auth-J__M_-Fern_ndez_Sevilla-Aff1) and [E. Molina-Grima](https://link.springer.com/article/10.1007/s00253-015-6694-y#auth-E_-Molina_Grima-Aff1). Utilization of secondary-treated wastewater for the production of freshwater microalgae. Appl MicrobiolBiotechnol. 2015; 99(16):6931–6944.
14. Grayburn, W.S., Holbrook, G.P, Tatara, [K.A. Rosentrater](https://scholar.google.com/citations?user=XQ5TKnsAAAAJ&hl=en&oi=sra). Harvesting, oil extraction, and conversion of local filamentous algae growing in wastewater into biodiesel. Int J Energy Environ. 2013. 4(2):185.
15. Gul, T. Renewable Transport Fuel Obligation Statistics. Period 9 2016/17: Department for Transport; 2016. p. 1-6.
16. Hillebrand, H. Development and dynamics of floating clusters of filamentous algae. In: Periphyton of freshwater ecosystems, Springer. 1983; pp 31–39.
17. Ho, S.H, Chen, C.Y, Lee, D.J, Chang, J.S. Perspectives on microalgal CO2 emission mitigation systems - A review. Biotechnology Advances 2011; 29:189–98.
18. IEA, 2019. CO2 emissions from fuel combustion 2019, Statistics. International Energy Agency, France.
19. IEA, 2017. Technology Roadmap - Delivering Sustainable Bioenergy. International Energy Agency, Paris, France.; IPCC, 2018. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, IPCC Special Report. Intergovernmental Panel on Climate Change.
20. IEA,2006. Energy Technology Perspectives.The world’s guidebook on clean energy technologies.
21. [Kebede-westhead](https://onlinelibrary.wiley.com/authored-by/Kebede%E2%80%90westhead/Elizabeth) Elizabeth, [Carolina Pizarro](https://onlinelibrary.wiley.com/authored-by/Pizarro/Carolina), [Walter W. Mulbry](https://onlinelibrary.wiley.com/authored-by/Mulbry/Walter%2BW.), [Ann C. Wilkie](https://onlinelibrary.wiley.com/authored-by/Wilkie/Ann%2BC.). Production and nutrient removal by periphyton grown under different loading rates of anaerobically digested flushed dairy manure. J Phycol. 2003; 39(6):1275–1282.
22. Khoo Choon Gek, Yaleeni Kanna Dasan, [Man Kee Lam,](https://www.sciencedirect.com/author/57194113699/man-kee-lam) Keat Teong Lee. Algae biorefinery: Review on a broad spectrum of downstream processes and products. [Bioresource Technology](https://www.sciencedirect.com/journal/bioresource-technology). 2019; [Volume 292](https://www.sciencedirect.com/journal/bioresource-technology/vol/292/suppl/C), 121964.
23. Kumar, S.J., Kumar, G.V., Dash, A., Scholz, P. and Banerjee, R. Sustainable green solvents and techniques for lipid extraction from microalgae: A review. Algal Research, 2017; 21: p. 138-147.
24. Kumar, S "[Algae Fuels,](http://large.stanford.edu/courses/2012/ph240/kumar2/)" Stanford University, Fall. Physics. 2012; 240.
25. Kunjapur, A.M., & Eldridge, R.B . Photobioreactor Design for Commercial Biofuel Production from Microalgae. Industrial & Engineering Chemistry Research, 2010; 49(8), 3516–3526.
26. Lee,K., Eisterhold, M.L., Rindi, F., Palanisami,S and Nam,P.K. Isolation and screening of microalgae from natural habitats in the Mid western United States of America for biomass and biodiesel sources. J. Nat.Sci.Biol.Med.2014; 5, 333–339. doi:10.4103/0976-9668.136178.
27. Li, Y., Horsman, M.,Wu, N., Lan,C.Q., and Dubois-Calero, N. Biofuels frommicroalgae. Biotechnol.Progr.2008; 24, 815–820.doi:10.1021/bp070371k.
28. Marie Holzleitner, Simon Moser, Stefan Puschnigg. Evaluation of the impact of the new Renewable Energy Directive 2018/2001 on third-party access to district heating networks to enforce the feed-in of industrial waste heat,Utilities Policy, 2018; Volume 66,2020,
29. Muylaert K, Bastiaens L, Vandamme D, Microalgae-based biofuels and bioproducts. In:Gonzalez-Fernandez C, Muñoz R, editors. Harvestingof microalgae: overview of process options and their strengths and drawbacks. Woodhead Publishing; 2017.p. 113–132.
30. Pizarro, C. W. Mulbry, D. Blersch, P. Kangas. An economic assessment of algal turf scrubber technology for treatment of dairy manure effluent. Ecol Eng. 2006; 26(4):321–327.
31. Pugazhendhi A, Shobana S, Bakonyi P. A reviewon chemical mechanism of microalgae flocculation viapolymers. Biotechnol Reports. 2019;21:e00302.
32. Rajkumar, R.,Yaakob,Z., and Takriff, M.S. Potential of the micro and macroalgae for biofuel production: a brief review. Bioresour.2014; 9, 1606–1633. doi:10.15376/biores.9.1.
33. Ramesh, T.; Rajalakshmi, N.; Dhathathreyan, K. S. Activated carbons derived from tamarindseeds for hydrogen storage. J. Energy Storage 2015, 4, 89–95.
34. Rawat I, Ranjith Kumar R, Mutanda T, Biodieselfrom microalgae: a critical evaluation from laboratory tolarge scale production. Appl Energy. 2013;103:444–467.
35. Richmond,A.,and Qiang, H. Hand book of Microalgal Culture: Applied Phycology and Biotechnology, 2013; Second Edn. Hoboken, NJ: Wiley-Blackwell.
36. Sangapillai, K, Marimuthu, T. Isolation and selection of growth medium for freshwater microalgae Asterarcysquadricellulare for maximum biomass production. Water Sci Technol. 2019; 80(11):2027–2036.
37. Santos, F.F.P., S. Rodrigues, and F.A.N Fernandes, 2009. Optimization of the production of biodiesel from sobean oil by ultrasound assisted methanolysis. Fuel Processing Technology, 90(2): p. 312- 316.
38. Schenk,P.,Thomas-Hall,S.,Stephens,E.,Marx,U.,Mussgnug,J.,Posten,C. Second generation biofuels: high efficiency microalgae for biodiesel production. Bioenergy Res. 2008. 1,20–43.doi:10.1007/s12155-008-9008-8.
39. Singh G, Patidar S. Microalgae harvesting techniques: areview. J Environ Manage. 2018; 217:499–508.
40. Soomro RR, Ndikubwimana T, Zeng X, Development of a two-stage microalgae dewatering process–a life cycle assessment approach. Front PlantSci. 2016;7:113.
41. Spring power and Gas October 16th, 2019.
42. Surendhiran,D.,and Vijay, M. Microalgal biodiesel –a comprehensive review on the potential and alternative biofuel. Res.J.Chem.Sci.2012; 2, 71–82.
43. Suresh Kumar Krishnan, Senthilkumar Kandasamy, Kavitha Subbiah .Nanomaterials.Application in Biofuels and Bioenergy Production Systems. Book.2021; 677-687 (FP-154-E-finalEnergy supply and demand: trends and prospect.5-19).
44. The Future of Algae Biofuel, Alyssa Noll, November 25, 2015,Submitted as coursework for PH240, Stanford University, Fall 2015.
45. Tianzhong Liu, Junfeng Wang, [Qiang Hu](https://www.sciencedirect.com/author/57190021592/qiang-hu), Pengfei Cheng, Bei Ji, Jinli Liu, Yu Chen, Wei Zhang, Xiaoling Chen, Lin Chen, Lili Gao, [Chunli Ji](https://www.sciencedirect.com/author/55443124500/chunli-ji), Hui Wang. Attached cultiion technology of microalgae for efficient biomass feedstock production. Bioresour Technol. 2013; 127:216–222.
46. [Tumuluru](https://onlinelibrary.wiley.com/authored-by/Tumuluru/Jaya%2BShankar) Jaya Shankar, [Christopher T. Wright](https://onlinelibrary.wiley.com/authored-by/Wright/Christopher%2BT.), [J. Richard Hess](https://onlinelibrary.wiley.com/authored-by/Hess/J.%2BRichard), [Kevin L. Kenney](https://onlinelibrary.wiley.com/authored-by/Kenney/Kevin%2BL.). A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application. Biofuels Bioproducts Biorefining. 2011; 5(6):683–707.
47. Ugwu, C.U. Aoyagi, H. Uchiyama, H. Photobioreactors for mass cultivation of algae. Bioresour Technol. 2008; 99(10):4021–4028.

## Voloshin Roman A, Margarita V. Rodionova, Sergey K. Zharmukhamedov, T. Nejat Veziroglu, Suleyman I. Allakhverdiev. Review: Biofuel production from plant and algal biomass. [International Journal of Hydrogen Energy](https://www.sciencedirect.com/journal/international-journal-of-hydrogen-energy). 2016, 41:39, Pages 17257-17273.

1. Wang Hui , [Chunli Ji](https://www.sciencedirect.com/author/55443124500/chunli-ji), Shenglei Bi, Peng Zhou, Lin Chen, Tianzhong Liu. Joint production of biodiesel and bioethanol from filamentous oleaginous microalgae Tribonema sp. Bioresour Technol. 2014a; 172: 169–173.
2. White, R.L, Ryan, R.A. Long-term cultivation of algae in open-raceway ponds: lessons from the field. Ind Biotechnol. 2015;11(4):213–220.
3. Yang Libin,, Xiaobo Tan, Deyi Li, Huaqiang Chu, Xuefei Zhou, Yalei Zhang, Hong Yu. Nutrients removal and lipids production by *Chlorella pyrenoidosa* cultivation using anaerobic digested starch wastewater and alcohol wastewater. BioresourTechnol 181:54–61
4. Zhu L, Li Z, Hiltunen E. Microalgae Chlorella vulgarisbiomass harvesting by natural flocculant: effects onbiomass sedimentation, spent medium recycling andlipid extraction. Biotechnol Biofuels. 2018;11(1):183.