An Overview on Micro-Algae Biofuel Production

Dr.Santosh Kumar Singh, Assistant Professor

Department of Health & Allied Science, Arka Jain University, Jamshedpur, Jharkhand, India

Email Id- dr.santosh@arkajainuniversity.ac.in

ABSTRACT: Many experts believe that the most difficult aspect of commercializing microalgal biofuel is effective harvesting. Despite the fact that microalgal biomass may be "energy dense," the algae growth in dilute suspension at approximately 0.02–0.05 percent dry solids presents significant difficulties in establishing a sustainable energy budget in segments and sub biofuel process operations. The tiny size of micro-algal cells, the comparable density of algal cells to the growing medium, the net negative charge on the algae, and the algal growth rates, which need frequent harvesting relative to land plants, all add to the difficulties of micro-algal harvest. Sedimentation, flocculation, flotation, centrifugation, filtration, or a combination of these techniques may all be used to harvest algae. This study examines the different techniques for collecting and dewatering microalgae for biofuel generation. There does not seem to be a single or combination of harvesting techniques that is suitable for all microalgae, and the harvesting method will have a significant effect on the design and management of the both upstream and downstream operations in a microalgal biofuel production process.

KEYWORDS: Centrifugation, Flocculation, Flotation, Filtration, Microalgae, Sedimentation.

1. INTRODUCTION

Despite the fact that algal biomass may be a source of energy, the growth of algae in dilute suspension at approximately 0.02–0.05 percent dry solids presents significant difficulties in establishing a sustainable energy budget in algal process operations. The tiny size of micro-algal cells (most algae are less than 30 lm) the resemblance of algal cell density to the growth medium and the net negative charge on the algae, which ultimately resulted in distributed stable algal suspensions, particularly during in the growth stage. The most difficult aspect of algal biofuel production is cost-effective harvesting of microalgae, which is a major issue restricting the commercial usage of microalgae. Harvesting expenses have been estimated to account for 20–30% of micro-algal biomass costs, while estimations as high as 50% of micro-algal biofuel costs have been provided. Harvesting and drying are expected to account for 90% of the installation costs for algal generation in open systems [1].

Harvesting micro algae is ‘inherently more costly' than harvesting land plants due to the need for constant post - harvest of the water down suspension, and detachment of micro-algae by settlement and centrifugation can require 1 MJ kg^{-1} of dry biomass, which is higher than that of the electricity costs of post - harvest wood at 0.7–0.9 MJ kg^{-1} It is necessary to decrease the cost of collecting microalgae. Unfortunately, a recent study on algae research published by the UK's Bioscience and Biological Sciences Research Council (BBSRC) found that "hardly any economic activity exists in downstream processing". The majority of research on microalgal species selection for biofuel generation has concentrated on yield and yield components rather than recovery ease.

Sedimentation, flocculation, flotation, centrifugation, filtration, or a combination of these techniques may all be used to harvest algae. Despite the significance of harvesting for the economic and energy balance feasibility of micro-algal biofuel, there is no uniform micro-algal biofuel harvesting technique. According to a recent comprehensive study of dewatering microalgal cultures, ‘‘there is presently no better technique of harvesting and dewatering". The benefits and drawbacks of the different microalgae harvesting techniques. The ultimate moisture content of collected algal biomass is a key consideration when choosing a harvesting technique. If the moisture level of microalgal biomass is higher than 85%, it may deteriorate in hours, and high moisture content can have a significant impact on the prices and techniques of further processing and power extraction from the biomass [2].

2. DISCUSSION

2.1. Sedimentation:

Gravitational forces drive liquid bits to separate from a liquid of differing density, although the process may be sluggish, particularly if the pressure gradient or particle size is tiny. Stokes' Law implies that deposition velocity is proportional of the cells' (Stokes') radius and the density differential between both the micro-algal cells as well as the medium. Segments and sub have a density of 1,025 kg m^{-3}, which is similar to that of water and salt water, thus there is minimal density differential driving segments and sub settlement. The density of maritime microalgae cytoplasm ranges from 1,030 to 1,100 kg m^{-3}, cyanobacteria density ranges from 1,082 to 1,104 kg m^{-3}, marine diatom and dinoflagellate density ranges from 1,030 to 1,230 kg m^{-3}, and fresh - water green microalgae (Chlorococcum) density ranges from 1,040 to 1, Micro-algae settlement differs across species, but it may even change in same species. Settlement rates are shown to differ with intensity of light, nutrient deficiency was shown to decrease settlement rate, and sinking rate has been shown to increase in older cells, particularly age - related organisms (non-dividing cells among maturity and death) and spore-producing cells. Carbohydrate has a density of 1,500 kg m^{-3}, protein has a density of 1,300 kg m^{-3}, and lipid has a density of 860 kg m^{-3}, thus microalgae with a high oil content will settle more slowly.[3]

2.2.Flocculation:

Flocculation is often used in combination with other harvesting techniques. The aggregation of algae cells via flocculation may improve the rate of settle or flotation by increasing particle size Flocculation has been proposed as a better technique for separating algae since it can handle huge amounts of microalgal suspension and a broad variety of microalgae. Floc has also been proposed as the most dependable and cost-effective technique, despite the fact that it is still "very costly."Flocculation may happen spontaneously in certain micro-algae, a practice called as auto-flocculation, and micro-algae can also flocculate in response to environmental conditions, such as changes in nitrogen, pH, and chemical oxygen demand.

Auto-flocculation is not seen in all microalgae species, and it may be sluggish and ineffective. Chemicals, both inorganic and organic, and microorganisms may cause flocculation; however, flocculants may be algal species-specific, and recovery and recycling of the flocculants can be difficult. Depending on the microalgal species and flocculant, flocs may have a wide range of form, size, and composition. A good flocculant should be cheap, nontoxic, and effective at low concentrations. It should also be produced from non-fossil fuel sources, be ecological, and renewable.[4]

2.3.Flotation:

For a number of micro-algal species, flotation may be a faster process than sedimentation. Although certain microalgae spontaneously float to the top, adding air bubbles may help them do so. In most instances, flotation requires the addition of flocculants, much as it does with microalgae - based sedimentation. For the isolation of a marine microalga, Isochrysis galbana, floculation flotation was shown to be superior to sedimentation, but only when big, robust flocs were produced by the addition of a variety of organic and artificial polymers. Because micro-algal flocs have a lower density than micro-algal cells, flotation may be preferable to sedimentation for separating flocculated microalgae. The concentration of micro-algae in the separated suspension (7%) from flotation separation is usually greater than the micro-algal suspension from sedimentation. Flotation methods are categorized as dissolved air flotation, electrolytic flotation, or dispersed air flotation, depending on how bubbles are produced. Flocculation and froth flotation have been shown to be successful in the extraction of micro-algae from wastewater when fine air bubbles (no dimensions specified) are produced by a sparger at 3 atmospheres of gas pressure [5]. Flotation, particularly if tiny bubbles are needed, may have significant investment and operating expenses as well as high energy consumption. When the cost of flocculants is considered, it has been claimed that the cost of flotation may be as high as or higher than centrifugation, and a recent study found that there is little proof of the technical or economic viability of flotation [6].

2.4.Filtration:

A variety of filters have been employed to harvest algae, and filtration has been shown to be effective in collecting relatively big algal cells however, poor throughput and fast clogging may be a problem. Despite the vast range of filter designs, membrane filters may be categorized simply by pore or membrane size: macro filtration [10 µm], micro-filtration 0.1–10 µm, ultrafiltration 0.02–0.2 µm, and reverse osmosis 0.001 µm. The pressure needed to push fluid thru a membrane, and therefore the operating energy required, rises when the membrane pore size is reduced. Micro-algae usually vary in size from 2 to 30 micrometers This would indicate that the majority of common species, such as Chlorella and Cyclotella, have the most suitable pore size of 5–6 lm in diameter while flocculated cells and bigger cells need macro filtration. Filtration of galbana revealed that a pore size of less than 1.5 lm is needed to remove 'most' marine micro-algal cells from solution, while flocculation revealed that a pore size of 25 µm is sufficient Micro-filtration has been used to recover micro-algal cells for aquaculture, however membrane filtration has not been extensively utilized to produce micro-algal biomass on a large scale, and it may be less cost-effective than centrifugation on a commercial scale [7].

2.5. Centrifugation:

In centrifugation, gravity is replaced with a considerably stronger force that drives separation. By centrifugation, almost all kinds of microalgae can be consistently and easily separated. The force used in disc stack centrifuges may range from 4,000 to 14,000 times that of gravity. significantly decreasing separation time. The most popular industrial centrifuge is the disc stack centrifuge, which is extensively employed in commercial facilities for high-value algae byproducts and in bioenergy pilot plants. A disc stack centrifuge is made up of a shallow cylindrical bowl with a number (stack) of tightly packed rotating metal cones (discs). The divided mixture is injected into the center of the stack of discs, where the dense phase moves outwards on the discs' undersides while the lighter phases is displaced to the center. Different densities of materials are therefore divided into thin layers, and the small flow channel of 0.4–3 mm between the closely spaced discs ensures that the distance between materials is kept to a minimum. disc stack centrifuges are suitable for separating particles of the size (3–30 µm) and concentrations (0.02–0.05%) of algal cells in a growing medium. They can continuously separate not just solid/liquid, but also liquid/liquid or liquid/liquid/solid. Disc stack centrifuges are notorious for using a lot of energy.

A Westfalia HSB400 disc-bowl centrifugal with intermittent self-cleaning bowl centrifugal clarifier, for example, has a maximum capacity of 95 m^3 h^{-1} but is only capable of 35 m^3 h^{-1} for algae collection. The motor's maximum power is 75 kW, while typical running demand is likely around 50 kW, resulting in a separation energy cost of 1.4 kWh m^{-3}A value of 1 kWh m-3 was reported for concentrating Scenedesmus from 0.1 to 12 percent using a Westfalia soul disk stack centrifuge, and a value of 1.4 kWh m^{-3} was reported for harvesting micro-algae grown on pig waste using a disc bowl centrifuge.. If an HSB400 centrifuge is supplied with a solution of 0.02 percent dry weight of microalgae with a 20% oil content, it will produce 7 kg of dry algal materials and 1.4 kilogram of algal oil every hour. 1.26 kg of methyl ester biodiesel with a calorific value of 13 kWh is generated if 90% of the algal oil is converted to methyl ester biodiesel, assuming a net calorific value of 10.33 kWh kg^{-1}. As a result, the operational energy for centrifugation is about four times that of the algal biodiesel. Although this estimate is based on data from a single manufacturer, comparable data for Alfa-Laval models also suggests that centrifugation consumes more energy than the biodiesel produced.[8]

2.6. Material management:

The harvest of micro-algae is one step in the process of producing micro-algal biofuel, and it must be connected to a growing system as well as a means of extracting energy from the micro-algal organic matter. Moving material between process operations may be expensive, particularly when it comes to removing the dilute micro-algal solution from the growing system and recycling the growth medium after harvesting.

The energy required for material movement and recycling between major unit operations was estimated to be equal to or greater than the operational energy for mixing and gasses transfer in micro-algal raceway growth ponds in an outline design developed for Superheated Plasma Fuels for the production of micro-algal biodiesel. The physical characteristics of the micro-algal solution change with concentration, and this may affect how it is treated and handled. A milk-like suspension is 1–2%, a cream-like suspension is 10–12%, and a cheese-like suspension is 15–20%. Micro-algal solutions become non-Newtonian at concentrations over 7%, possibly exacerbating handling issues; and at 15–20%, the micro-algal solution may no longer be fluid, further complicating handling.[9]

2.7. Drying:

Prior to energy extraction, drying may be needed in addition to harvesting. Evaporation may be a highly energy-intensive process for removing water from algal biomass. Because the enthalpy of water at 20 C is 84 kJ kg^{-1} and the enthalpy of vapor at 100 C is 2,676 kJ kg^{-1} it takes around 2.6 MJ kg^{-1} or about 700 kWh m^{-3} to heat and drain water at atmospheric pressure from a temperature of 20 ºC. Solar drying, roller drying, spray drying, and freeze drying have all been employed to dry microalgae before further processing or energy extraction. Sun drying does not need the use of fossil fuels, although it is weather-dependent and may result in significant denaturation of organic molecules.

Solar drying is the most cost-effective drying method but it requires a wide area since only around 100 g of dry matter can be generated per sq meter of sun-drier surface. In the food sector, roller, spray, and freeze driers have all achieved acceptable results when it comes to drying Dunaliella. Spray drying has long been the favored technique for drying high-value microalgal materials, but it is costly and likely uneconomic for microalgal biofuel production. Spray drying may result in a dark green powder. It can also cause micro-algal pigments to deteriorate significantly. Freeze drying is less damaging to organic compounds than spray drying, but it is more costly and is usually employed for premium instant coffee to provide a superior flavor than spray dried coffee. Freeze death is too costly for large-scale commercial micro-algae recovery, therefore it's only used for research. Dewatering during harvesting requires less energy than evaporating to remove water, thus it would seem desirable to reduce the water content of the collected micro-algae drying and use energy extraction techniques that do not need drying [10].

3. CONCLUSION

Although sedimentation and flocculation may have the least energy inputs for micro-algal harvesting, no one technique or combination of methods seems to be suitable for all micro-algae. The concentration of micro-algae obtained via different harvesting techniques may range from 0.5 to 27 percent dry weight, indicating that further dehydration or drying may be needed before extracting energy from the microalgae. The concentration needed will vary depending on the technique utilized to extract usable energy from microalgae. The most energy-efficient technique of collecting or generating usable energy from microalgae may not be included in the most energy-efficient microalgal biofuel manufacturing process. The most energy efficient micro-algal biofuel process may include a growing system that doesn't provide the highest yield but produces easier-to-harvest micro-algal biomass, and an energetic extraction process that needs the least concentration by the microalgal harvesting technique. If effective harvesting is the main obstacle of commercializing microalgal biofuel, as many experts believe, it will have a significant impact on the design and management of both downstream and upstream processes in the entire microalgal biofuel production process.

REFERENCES

[1] J. J. Milledge and S. Heaven, "A review of the harvesting of micro-algae for biofuel production," *Reviews in Environmental Science and Biotechnology*. 2013, doi: 10.1007/s11157-012-9301-z.

[2] J. Ranjitha and S. Vijayalakshmi, "Micro-algae as a substrate for biofuel production - A review," *Research Journal of Biotechnology*. 2015.

[3] R. Slade and A. Bauen, "Micro-algae cultivation for biofuels : cost , energy balance , environmental impacts and future prospects – Supplementary Information Life Cycle assessment meta-model approach and assumptions," *Biomass and Bioenergy*, 2013.

[4] R. Rajkumar, Z. Yaakob, and M. S. Takriff, "Potential of the micro and macro algae for biofuel production: A brief review," *BioResources*. 2014, doi: 10.15376/biores.9.1.1606-1633.

[5] R. Dineshkumar, R. Narendran, and P. Sampathkumar, "Cultivation and harvesting of micro-algae for bio-fuel production – a review," *Indian Journal of Geo-Marine Sciences*. 2017.

[6] A. Jacob, A. Xia, and J. D. Murphy, "A perspective on gaseous biofuel production from micro-algae generated from CO2 from a coal-fired power plant," *Appl. Energy*, 2015, doi: 10.1016/j.apenergy.2015.03.077.

[7] F. Alam, S. Mobin, and H. Chowdhury, "Third generation biofuel from Algae," in *Procedia Engineering*, 2015, doi: 10.1016/j.proeng.2015.05.068.

[8] Y. P. Nagaraja, C. Biradar, K. S. Manasa, and H. S. Venkatesh, "Production of biofuel by using micro algae (Botryococcus braunii) Sample collection," *Internatational J. Curr. Micobiology Appl. Sci.*, 2014.

[9] M. Habib, I. Ul Haq, P. Mustafa, H. Rehman, R. Khan, and A. U. Khan, "Production of biofuels from micro ALGAE and green wastes through Anaerobic Digestion," in *2015 Power Generation Systems and Renewable Energy Technologies, PGSRET 2015*, 2015, doi: 10.1109/PGSRET.2015.7312230.

[10] A. Kumar, S. Kaushal, S. A. Saraf, and J. S. Singh, "Microbial bio-fuels: A solution to carbon emissions and energy crisis," *Front. Biosci. - Landmark*, 2018, doi: 10.2741/4673.