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A Review of The Micro-Algae Are Being Harvested to Make Biofuel

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Abstract: *Effective harvesting is seen by many researchers as the main obstacle to the commercialization of microalgal biofuel. The small size of micro-algal cells, the cells' similar density to the growth medium, the algae's negative surface charge, and the algae's faster growth rates than terrestrial plants present additional difficulties for harvesting micro-algae. Sedimentation, flocculation, floatation, centrifugation, filtering, or any combination of these procedures can be used to collect algae. The numerous techniques for gathering and dehydrating microalgae for the creation of biofuel are reviewed in this research.*

Key words: *microalgae, floatation, centrifugation, drying and filtration*.

1. INTRODUCTION

Microalgae are a well-known group of photosynthetic organisms consisting of over 3000 species of aquatic organisms. Most of them are autotrophs, while the rest are heterotrophs. Microalgae grow in a variety of wastewaters and can convert sunlight and atmospheric CO2 into biomass. Cells can convert and store energy instead of using it for growth and development. Wastewater contains several toxic chemicals and pathogens that affect ecosystems. In addition, untreated wastewater causes several problems in irrigation, such as unwanted plant growth leading to several plant diseases and reduced crop quantity and quality (Libutti et al.2018).

Microalgal biomass can therefore be explored as a new biofuel production system that offers a potential alternative to fossil fuels due to its renewability, sustainability and short life cycle of algal growth. Recently, microalgal biomass has been recognized as a carbon-neutral fuel due to the various phytochemical properties of biomass (Arun et al.2021). Additional challenges in algal harvest arise from the small size of microalgal cells (most algae are less than 30 lm) (Molina Grima et al. 2003). It is considered to be the most problematic area of production (Greenwell et al. 2010) and as a key factor limiting commercial exploitation of microalgae (Olgu', 2003). It has been suggested that 20–30% of the cost of microalgal biomass is due to harvesting costs (Mata et al. 2010; Molina Grima et al. 2003; Verma et al. 2010). 50% of the biomass cost of microalgae has been reported (Greenwell et al. 2010). It is estimated that 90% of the capital cost of algal biomass production in open systems comes from harvesting and drainage (Amer et al. 2011). The development of microalgae biorefineries can be effective in reducing fossil fuel needs, reducing greenhouse gas (GHG) emissions, and mitigating problems related to global warming and climate change. Because microalgae can be grown year-round with great productivity, they are regarded as a vital feedstock for the manufacture of biofuels. (Bhatia et al.2021). Photobioreactor (PBR) parameters such as physical parameters (design, volume, volume-to-surface ratio) and operational parameters (temperature, mixing, lighting, CO2 supply) play an important role in the recovery of nutrients from wastewater. (Goswami et al.2020).

Algae can be harvested in a number of ways. Sedimentation, flocculation, flotation, centrifugation and filtration. Despite the importance of harvesting to the economics and energy balance of microalgal biofuels, there is no universal harvesting method for microalgae (Mata et al. 2010; Shen et al. 2009). A recent comprehensive review of dehydration of micro algal cultures concluded that ``no good methods of harvesting and dehydration currently exist'' (Uduman et al. 2010). The final moisture content of harvested algal biomass is an important criterion when choosing a harvesting method (Molina Grima et al. 2003). Microalgal biomass can degrade within hours at moisture contents above 85% (Mata et al. 2010), and high moisture contents can have a significant impact on treatment costs and methods (Molina Grima et al. 2003) and energy production from biomass.

2. SEDIMENTATION

In sedimentation, gravity separates liquid or solid particles from liquids of different densities, but the process can be very slow, especially if the density difference or particle size is small. The density of microalgae is 1,025 kg m-3, which is close to that of water and salt water (Millero and Lepple 1973), with only a small density difference to facilitate microalgal colonization. The density of the cytoplasm of marine microalgae is between 1030 and 1100 kg m-3 (Smayda 1970), the density of cyanobacteria is between 1082 and 1104 kg m-3 (Kromkamp and Walsby 1990), and the density of marine diatoms and dinoflagellates is between 1030 and 1100 kg m-3. Densities of freshwater green microalgae (Chlorococcum) between 1230 kg m-3 and 1,040 to 1,140 kg m-3 (Van Lerland and Peperzak 1984). A sedimentation velocity of 0.1 m day-1 can be calculated. Calculated using Stokes' law (equation 1) for the common spherical microalgae chlorella [density 1,070 kg m-3, average cell diameter 5 lm (Edzwald 1993)]. m day-1 (Collet et al. 2011), but chlorella usually does not colonize easily (Nurdogan and Oswald 1996). Cyclotella, an alga similar in size to chlorella, has a calculated colonization rate of 0.04 m day-1, but the observed colonization rate was higher at 0.16 m day-1 (Smayda 1970). Observed microalgal subsidence rates have been found to deviate from calculated rates and be several times higher or lower than calculated rates (Reynolds 1984; Smayda 1970). Sedimentation velocities are highly dependent on the type of microalgae present, with average sedimentation velocities of 0.2 mday-1 for diatoms, 0.1 mday-1 for green microalgae, and 0.0–0.05 mday-1 for cyanobacteria. Recommended for water quality. model (Cole and Wells 1995).

Microalgae colonization varies between species, but can vary within the same species. Colonization rates have been shown to vary with light intensity (Waite et al. Production cells (Bienfang 1981). Sedimentation has not been widely used for microalgae removal (Uduman et al. 2010) and has been demonstrated in pilot-scale wastewater treatment plants (Lundquist et al. 2010), but has not yet been applied. reach large scale. The settling rate of microalgae as small as 4–5 lm in the open ocean is 'negligible' (Waite et al. 1992). Microalgal colonies have low cell recovery and solids concentration (Mata et al. 2010; Shen et al. 2009), with 60–65% cell recovery (Collet et al. 2011) and suspension Solids concentration of total solids up to 1.5%. (Wudman et al. 2010). The energy consumption of colony harvesting is generally low, with lamellar separators using 0.1 kWh m to achieve initial concentrations of 0.1–1.5% dry microalgal biomass (Uduman et al. 2010).

3. FLOCCULATION

Flakes are typically used in combination with other harvesting methods (Brennan and Owende 2010). An increase in particle size due to flocculation of algal cells by flocculation can increase sedimentation or flotation velocity (Mata et al. 2010). Agglomeration has been proposed as an excellent method for algae separation because it can process large volumes of microalgal suspensions and a wide range of microalgae (Uduman et al. 2010). Flocculation has been suggested as the most reliable and also the cheapest method, but unfortunately it remains 'pretty expensive' (Benemann et al. 1980). Aggregation, a process known as autoaggregation, can occur naturally in certain microalgae, and microalgae can aggregate in response to environmental stress. Changes in nitrogen, pH and dissolved oxygen (Uduman et al. 2010). Self-aggregation does not occur in all microalgal species and can be slow and unreliable (Schenk et al. 2008). Agglomeration can be caused by both inorganic and organic chemicals, or microorganisms. However, flocculants may be specific to algal species, and collection and recycling of flocculants can be problematic (Molina Grima et al. 2003). The shape, size and composition of flakes vary greatly depending on the type of microalgae and flocculant (Jago et al. 2007). An ideal flocculant should be cheap, non-toxic, effective at low concentrations (Molina Grima et al. 2003), preferably derived from non-fossil energy sources, sustainable and renewable. .

Polyvalent metal salts, ferric chloride, ferrous sulfate, and aluminum chloride (alum) are commonly used in wastewater treatment to remove algae, and alum is effective in flocculating chlorella and synedesmus. has been shown (Molina Grima et al. 2003). Aluminum salts have been shown to be more effective than ferric salts in chlorella aggregation (Papazi et al. 2010). Flocculants derived from renewable plant and animal materials may have environmental advantages over both inorganic and polyelectrolyte flocculants derived from fossil fuels. Chitosan, a cationic inorganic polymer derived from crustacean shells, has been used for wastewater treatment in the food industry (Harith et al. 2009). Chitosan has been shown to be effective against a variety of freshwater microalgae, although at dosages significantly higher than synthetic organic flocculants 20–150 mg l-1 (Harith et al. 2009; Molina Grima et al. 2003). No efficient flocculation with chitosan was observed with Phaeodactylum alone, but when the pH was increased to 9.9, a dose of 20 mg l-1 of chitosan gave "satisfactory" flocculation results (S¸irin et al. 2012). Although chitosan is considered non-toxic (Vandamme et al. 2010), the survival rate of oyster larvae fed with chitosan flake microalgae was reported to be reduced (Molina Grima et al. 2003). Harvesting microalgae for biofuel production does not appear to be economical due to the cost of chitosan and the high dosage compared to synthetic polyelectrolytes (Vandamme et al. 2010).

Starches and modified starches can colonize microalgae (Mohn 1988). Cationic starch, which is increasingly used as an alternative to inorganic and synthetic organic flocculants in the wastewater and paper industry, has been found to flocculate

scenedesmus and parachlorella, but at higher doses than chitosan and with lower efficacy. has a large variability. tested (Vandamme et al. 2010). Starches and modified starches do not appear to affect microalgal viability and are used in drinking water treatment (Vandamme et al. 2010). Modified starches may be cheaper than both inorganic and synthetic organic flocculants (Vandamme et al. 2010; Mohn 1988), but current cationic starches are not specifically designed for microalgae. , their modification to improve microalgal performance can dramatically increase costs (Vandamme et al. 2010).

4. FLOTATION

For many microalgal species, flotation can proceed relatively rapidly compared to sedimentation (Edzwald 1993). Some microalgae naturally float on surfaces, but the addition of air bubbles can enhance levitation (Singh et al. 2011). As with microalgae sedimentation, in most cases the addition of flocculants is required for effective flotation (Edzwald 1993; Mohn 1988). Flotation processes are classified according to the method by which air bubbles are generated. Dissolved air flotation, electrolytic flotation, dispersed flotation (Shelef et al. 1984a). Flocculation and froth flotation have been shown to be effective in removing microalgae from wastewater using microscopic air bubbles (dimensions not shown) generated by a 3 atm gas pressure sprinkler. shown (Moraine et al. 1979). Microbubble generation by fluid vibration is a method of generating small bubbles with less energy than conventional methods, and was developed at the University of Sheffield (Zimmerman et al. 2009). Recently, microbubbles generated by fluidic vibration were shown to be effective in harvesting algal biomass from growth media (Hanotu et al. 2012). However, more research is needed to determine whether an energy-efficient large-scale fluid oscillatory microbubble method for harvesting microalgae is viable. If so, capital and operating costs are high and energy consumption can be high (Mohn 1988). Including flocculant costs, it has been suggested that flotation costs may be as high as or higher than centrifugation (Mohn 1988), and a recent review suggests that flotation may be technically or economically costly. It was concluded that there was little evidence for the feasibility of the proposed approach (Brennan et al Owende 2010).

5. FILTRATION

During centrifugation, gravity is replaced by a much larger force as the separating force. Almost all types of microalgae can be reliably and easily separated by centrifugation (Mohn 1988). For plate stack centrifuges, the force applied can be 4,000 to 14,000 times greater than gravity (Perry and Chilton 1973), greatly reducing separation times. Plate stack centrifuges are the most common industrial centrifuges and are widely used in commercial plants for high-value algal products and pilot plants for algal biofuels (Molina Grima et al. 2003). A disc stack centrifuge consists of a relatively shallow cylindrical bowl containing a num- ber (stack) of closely spaced metal cones (discs) that rotate. The mixture to be separated is fed to the centre of the stack of discs and the dense phase travels outwards on the underside of the discs while the lighter phase is displaced to the centre. Materials of different densities are thus separated into thin layers, and the narrow flow channel of 0.4–3 mm between the closely-spaced discs means that the distance materials must travel for this separation to occur is small (Perry and Chilton 1973). They can separate not only solid/liquid, but also liquid/liquid or liquid/ liquid/solid on a continuous basis.The energetic position of using centrifugation for the production of biofuel could be improved by the use of the entire algal biomass (Milledge 2010a) A kilogram of dry algal biomass containing 20 % oil would yield around 1.9 kWh of biodiesel, but the calorific value of the entire biomass is around 6 kWh (Milledge 2010b) and the exploitation of the entire biomass could thus be a key factor in a positive energy balance in the production of biofuel (Milledge 2010a).

6. MATERIALS HANDLING

The harvesting of micro-algae is one stage in the process of the production of micro-algal biofuel and the harvesting operation must be linked to both a growth system and a method of exploiting the energy within the micro-algal organic matter. The energy costs of moving materials between process operations could be considerable, especially for the flow of the dilute micro-algal suspension from the growth system and for the recycling of the growth media after harvesting. In an outline design developed for Pure Energy Fuels for the production of micro-algal biodiesel the energy required for the movement and recycling of material between major unit operations was estimated to be as great as or greater than the operational energy for the mixing and gaseous transfer in micro-algal raceway growth ponds.The physical properties of the micro-algal suspen- sion vary with concentration and may influence subsequent treatment and handling. A 1–2 % suspen- sion is milk-like, a 10–12 % suspension cream like and a 15–20 % cheese. At concentrations above 7 % the micro-algal suspensions become non-Newtonian, potentially increasing han- dling problems; and at 15–20 % the micro-algal suspension may no longer be fluid further increasing handling difficulties (Greenwell et al. 2010) 。

7. DRYING

In addition to harvesting, drying may be required prior to energy generation. Removal of water from algal biomass by

evaporation can be very energy intensive. The enthalpy of water at 20 °C is 84 kJ kg-1 (Weast 1985) and the enthalpy of steam at 100 °C is 2,676 kJ kg-1 (Mayhew and Rogers 1972). Therefore, to heat and evaporate water from a temperature of 20 °C at atmospheric pressure requires an energy input of about 2.6 MJ kg-1 or over 700 kWh m-3. Various methods have been used to dry microalgae for further processing or energy generation. Sun drying, roller drying, spray drying, freeze drying. Although solar drying does not require fossil fuel energy, it is weather dependent and can cause significant denaturation of organic compounds. Sun drying is the most cost-effective drying method (Brennan and Owende 2010). Drum, spray and freeze dryers are widely used in the food industry, and Dunaliella drying has all produced satisfactory results. (Molina Grima et al. 2003). Spray drying has been the preferred method for drying high-quality microalgal products, but it is expensive (Brennan and Owende 2010; Molina Grima et al. 2003) and probably not economical for microalgal biofuel production. is not. Spray drying can produce a dark green powder, but can cause significant degradation of microalgal pigments (Brennan and Owende 2010; Molina Grima et al. 2003). Freeze-drying tends to be less damaging to organic material than spray-drying, but it is more expensive (Brennan et al. 1969), and premium instant coffee is usually used to achieve a better flavor than spray-drying. used for products such as the use of freeze-drying is considered too expensive for large-scale commercial microalgae production and its use is limited to research (Molina Grima et al. 2003). Dehydration at harvest uses less energy than evaporation to remove water, thus minimizing the moisture content of harvested microalgae prior to drying, energy extraction that does not require drying of microalgae It seems preferable to choose a method.

8. CONCLUSIONS

Sedimentation and flocculation may provide the lowest energy expenditure for harvesting microalgae, but no single method or combination of harvesting methods seems to work for all microalgae. The concentration of microalgae can vary between 0.5-27% of dry weight, and further dehydration or drying may be required before the microalgae can be used as energy. The required concentration level depends on the method used to extract usable energy from the microalgae. The most energy-efficient microalgal biofuel process may consist of a growth system that does not provide maximum yields but yields easy-to-harvest microalgal biomass, and an energy extraction process that requires minimal concentrations from microalgal harvesting methods. there is. If efficient harvesting is a major challenge in the commercialization of microalgal biofuels, as suggested by many researchers, the design and operation of both upstream and downstream processes of the entire microalgal biofuel production process should be considered. It will have a big impact.

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