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Review

Effects of water culture medium, cultivation systems and growth modes for microalgae cultivation: A review

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ABSTRACT

As the world's natural fuel sources continue to deplete, the search for alternative fuel sources intensifies. A promising fuel source alternative is biofuels from microalgae, due to it being a renewable source, its wide availability, and also its high production rate. This paper reviews recent developments in microalgae culture medium, cultivation systems and growth modes. The importance of identifying the type of medium suitable for microalgae cultivation is highlighted along with descriptions and comparison of the medium types that include freshwater, saltwater and wastewater. The different cultivation systems such as open system, closed system, dark system and offshore cultivation used for cultivating microalgae are discussed, along with a study on the impact of large scale cultivation using these systems. Besides that, various growth modes for microalgae cultivation like phototrophic, heterotrophic, mixotrophic, photoheterotophic modes are reviewed.

Contents

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1. Introduction

There is a rise in demand for liquid fuels nowadays as the world population increases. This leads to increased reliability onto natural gas and petroleum as they are cheap and easy to extract. However, fossil fuels are non-renewable energy and will run out quickly within 50 years. There is much intensive research ongoing to replace the usage of fossil fuels. One branch of research with the highest potential to replace fossil fuels is microalgae research. Microalgae have the potential to produce biodiesel due to its high photosynthetic rate and ability to store huge amounts of lipid [1]. High growth rates and productivity can allow for the production of a sustainable fuel source.

The benefits of microalgae over fossil fuels and field crops are that it can produce a greater oil yield per hectare of land, and it can be cultivated in different environments such as sea water, fresh water or even polluted water [2]. Wastewater contains high amount of nutrients, phosphorus and nitrates that can promote the growth of microalgae, resulting in its usage for water purification and remediation along with reduction of global greenhouse gases. The growth of microalgae requires high amount of CO_2, 1 kg of dry algal requires approximately 1.8 kg of CO_2 for survival. However, there are some limitations for this technology. Among them includes the need to select the best strain that possesses all the desired characteristics. So far, there are no strains that have all the desired traits. A proper strain selection is necessary as it brings about different effects to the later stages of the production, cultivation, harvesting and oil extraction [3]. Currently there is a wide variety of algae that can be used, making diversity a slight issue in relation to scaling up. This in combination with the large volume of wastewater to be treated makes overall scale up process rather difficult. Strain selection here is of utmost importance considering that wastewater is not a simple environment to survive in [4]. Wastewater colour is also one of the limiting factors here that can justify this statement. The species selected needs to survive under limited light conditions while being able to degrade the compounds responsible for the colour and at the same time withstand the very high nutrient concentrations. The main problem faced now is that the majority of studies conducted are simulated using synthetic wastewater that actually removes out issues such as colour interference, suspended solids and presence of other organisms [5].

Upon selecting the best strain, the environment for cultivation also needs to be considered such as the habitat of the microalgae (freshwater, saltwater and wastewater). Selection of the environment is essential as different water provides different nutrients and environmental aspects that could affect the growth of the cells. Besides that, there are different types of growth modes available for microalgae that include photoautotrophic, heterotrophic, mixotrophic and photoheterotrophic growth. The growth rate and the cell content of microalgae are highly dependent on the cultivation method as each of them provides different amount of nutrients and energy. In addition, the cultivation method plays a significant role in the productivity of microalgae. Different methods have distinct characteristics such as agitation in photoreactors that provide higher shear rates, open systems that are directly exposed to harsh sunlight and various sizes that offer different capacity. Examples of common cultivation methods are closed systems, open system, dark system and offshore cultivation. After cultivation, harvesting is needed to collect the algae for further processing into usable products. Algae can be harvested using centrifugation force by spinning, sedimentation of the algae towards the bottom by gravity, filtration method where membrane is used with the presence of pressure difference and also flotation method where low-density algae are able to float onto the surface upon aeration.

The selection of a suitable strain for downstream processing is crucial as it will affect the production efficiency, growth conditions, harvesting methods, yield and quality of the products. Some of the key criteria are high biomass productivity, high lipid content and high lipid productivity [6]. Higher productivity of biomass and lipid directly increases the production yield for biodiesel industries [7]. High tolerance to extreme environmental conditions may be useful when there is contamination occurring during outdoor cultivation. A wide range of salinity and temperature tolerance is important because evaporation will occur during large scale cultivation that causes the increase of salinity and temperature over time [8]. The microalgae strain selected should be able to survive in a high shear stress environment as the reactor may consist of agitator or mechanical parts that produce high shear rate. So far, over 30,000 strains have been identified, with the majority of them being *Chlorella*, *Botryococcus*, *Scenedesmus*, *Haematococcus* and *Nannochloropsis* which are suitable for biodiesel production [9, 10]. However, for large scale production in wastewater, there has