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Review article

Growing algae using water from coal seam gas industry and harvesting using an innovative technique: A review and a potential

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HIGHLIGHTS

- Amending coal seam gas water with chemicals.
- Potential of growing algae in CSG water.
- New innovative algae-cells harvesting technique.
- Estimation of potential algae-based biofuel production.

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ABSTRACT

This research is addressing the potential of growing micro-algae in coal seam gas (CSG) associated water. The two aims of the paper are (a) A literature review exploring the potential of CSG as a media for algal growth and (b) Predicting the yield obtainable from a novel bio-reactor design when using amended CSG water as a media. In the first part, a literature review was conducted to cover many aspects in regards to; the benefits of microalgae industry, its ability to grow in complex environment such as in CSG water, harvesting techniques in use and the extracted oil properties and yields. In the second part, a chemical component was presented which can be added to the CSG water to eliminate its negative impact on algae growth. It has been shown theoretically through balanced chemical reaction equations that adding small amount of acetic acid to the coal seam gas associated water will alter its chemical composition and may become a suitable environment for supporting algae growth. The potential of using an innovative technique in harvesting micro-algae is also discussed. A backed bed bio-reactor can be filled with micro/macro-diameter transparent silks' chops to support the algae growths and at the same time will serve as a harvesting tool. This innovative harvesting technique combined with amended CSG water has theoretically showed, based on balanced chemical equations and a literature review, a potential of dry-weight algae production of approximately 36 kg/d and an oil yield of 25 kg per each photo-bioreactor. However, while there are no studies addressing the above research potentials, there is plenty of research to back up its applicability.

Contents

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1. Introduction

Nowadays, higher oil prices, environmental concerns and increased interest in energy security have encouraged private and public investment in algal bio-fuels research. Algae have higher oil yield per acre compared to other crops like corn, soybeans, sunflower and rapeseed [1]. In addition, it is not a source of food for humans like many other sources of bio-oils. In some algae, more than half of the mass consists of lipids or tri-acyl-glycerides [2], which can be used to produce advanced bio-fuels such as biodiesel. It is commonly known that biodiesel is an alternative fuel for diesel and most diesel engines can function on 100% biodiesel with no modification. First generation biodiesel has been produced using vegetable oil, plant oil, and animal fat. There are many feedstocks currently in use for biodiesel production such as soy bean, canola seed or rapeseed, sunflower, and palm oil. There are also research activities on the production of second generation (advanced biodiesel) using alternative oils such as waste oils from kitchens and restaurants and micro-algal oils [3]. Furthermore, as carbon taxes are introduced, bio-fuel production through algae can potentially become profitable as this process is virtually carbon neutral when used in conjunction with CO_2 mitigation [4]. There are many gaps in the body of knowledge regarding the commercialization of micro-algae based fuel. These include many steps of the production process such as growing in a specific wastewater, harvesting and oil-extraction. Microalgae can be grown in many different ways in large-scale or small-scale photo-bioreactors [5]. Growing algae in CSG associated water is a great challenge due to the complicity and toxicity of this water on algal growth [6]. Harvesting of algae has been described by many researchers as the main challenge in the production of micro-algae [7]. The extraction of microalgae oil from the biomass can be another challenge in this process [8]. A variety of methods have been reported for harvesting and extracting the lipid of algae, many of these methods come with high energy consumption [4,5,8,9]. Ultrasound has been reported to be an efficient method for oil extraction. This can be achieved through the use of an ultrasonic reactor to crack the cells' membranes by the action of cavitation bubbles which break the cell wall [8]. Methods of micro-algae harvesting have been discussed in detail in Section 2.4 of this article.

Commercialization of this technology should have the following performance attributes, low energy consumption, complete recycling of water and nutrients, and no addition of harmful chemicals/materials [10]. The estimated amount of coal seam gas wells of water production in Australia is around 300 GL each year, this will have a significant impact on the agriculture sector if treated efficiently [11]. In this research amended water from the coal seam gas industry is suggested for growing micro-algae to achieve two aims; produce suitable water for irrigation from the CSG water and renewable energy from algae cells. It has been shown theoretically that there is a good potential for cultivation of micro-algae in CSG water after amending it with a specific chemical. Also, innovative lab-scale and pilot-scale photo-bio-reactors are designed to overcome the harvesting difficulties. This innovative design will simplify the algae harvesting process and reduce energy consumption.

2. Literature review

This section presents and discusses algae as a potential bio-fuel source alternative to fossil and first generation biodiesel fuel sources. Investigation into the potential of growing micro-algae in salty/sodic medium such as coal seam gas associated water is also covered. Furthermore, this section addresses the methods of harvesting in regards to energy consumption and efficiency.

2.1. Benefits to industry and environment

Fossil fuel is becoming less available, more expensive and environmentally disputable. Therefore, alternative sustainable energy sources such as bio-fuels are currently being sought to reduce the reliance on fossil energy sources. Bio-fuel production using microalgae is gaining popularity, this is because it does not consume food resources compared to traditional crop- based bio-fuels. In addition, they can be exploited to remove nutrients from wastewater. Nutrient removal from wastewater is a significant issue since it is related to green algae outbreaks in water ways which may cause significant damage to the ecosystem. In recent years, micro-algae have been used for polishing wastewater, which can subsequently be used for bio-fuel extraction [12]. Therefore, such projects have dual significance, one is to use the micro-algae for treating wastewater, and second is to investigate the possibility of extracting useful bio-diesel out of the harvested algae [13]. Microalgae has the highest oil productivity and can produce many times more than crops, and it is the only renewable source that has the capacity to meet the global demand for transportation fuel [14,15]. Table 1 presents the calorific value of diesel with a different biodiesel, it is obvious that algae biodiesel has the same calorific value as many biodiesel generated from crops [16].

The fuel produced from microalgae has been proven to produce fewer emissions than conventional fuels [13]. Transesterification is one of the most attractive and widely acceptable techniques used for biodiesel production from algal cells due to its simplicity and low power consumption [17]. Transesterification is a reaction process that forms esters and glycerol from reactions between alcohol and oil (triglyceride). The most common alcohol used for

Table 1
Comparison of calorific value of diesel with different biodiesel [16].

Different biodiesel oil	Lower heating value (MJ/kg)
Diesel	42.7
Jatropha	39.7
Sunflower oil	39.6
Soya bean	39.6
Karnja	38.8
Algae	39.5