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Flotation harvesting of microalgae

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ABSTRACT

Microalgae are a promising source of third generation renewable fuels. However, the biofuel production process from microalgae growth through to fuel production is still generally regarded as not economically viable. One area of particular consideration, for requiring more cost effective methods, is the recovery or harvesting stage. Among the several harvesting methods that have been proposed and used, flotation is emerging as one of significant promise. This review highlights why flotation can offer better harvesting characteristics than other methods by looking at work that has been carried out to date, as well as discussing the need for further developments in key areas.

Contents

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1. Introduction

Currently initiatives are being taken in many areas to move from fossil fuel to a biodiesel-based economy [1]. However for a biofuel to be viable, it needs to be produced at a competitive price, require low or no land usage, use minimal water and ideally have a reduced environmental impact [2].

Microalgae are efficient at converting solar energy into triglycerides suitable of transesterification into biodiesel [3] and also have the potential for coproduction of nutraceuticals, foods and other value-added products [4,5]. Microalgae-sourced biodiesel in comparison to terrestrial sourced biofuels has higher productivities, requires no arable land and can purify wastewater [6,7]. Another notable advantage is their ability to be used in process-coupled sequestration of CO_2 from industrial off-gas such as power stations, cement factories and smelters [8–12]. The typical microalgae production process is shown in Fig. 1.

Extensive research has been done on different microalgae species with regards to productivity and lipid production [14], but the resulting biodiesel remains more expensive than fossil fuels [13]. A major economic hurdle is the separation (harvesting) of the microalgae from their growth medium [15].

A reliable and cost effective method of bulk harvesting has not been developed. Difficulties arise arises from harvesting being affected by microalgal strain selection and their growth characteristics [15], and impacts on downstream processing [16]. The development of such a technology has, however, been highlighted as of prime importance in achieving economic production of microalgae sourced biofuels [6,7,17].

As the microalgae harvesting stage is of significant technical and economic importance, this review briefly highlights current methods and their limitations, which have led to flotation recently emerging as a promising alternative. This promise is based on good scale-up potential due to technical and economic parameters, such as lower energy and maintenance costs. In this review, results and trends from microalgae and other bioseparations utilizing flotation are discussed.

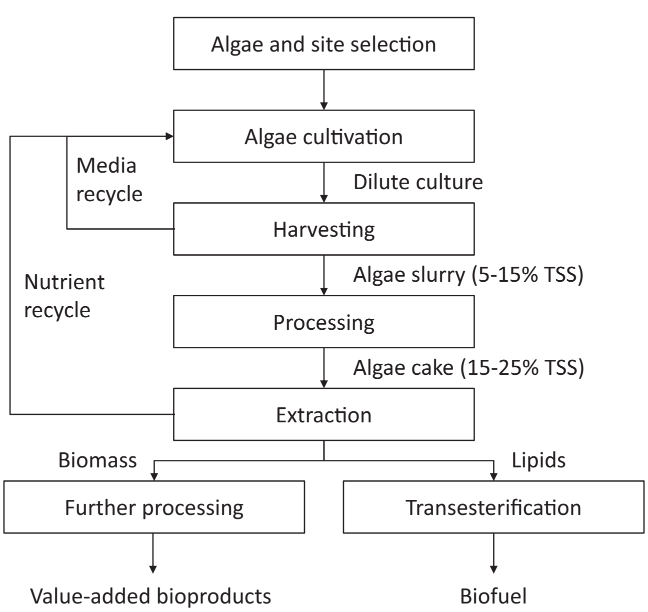

Fig. 1. Flow sheet of algae production (TSS = total suspended solids) (adapted from [13]).

2. Microalgae harvesting

Harvesting requires microalgae to be separated from the growth medium and then concentrated [6]. Bulk harvesting usually results in 100–800 times concentrating, producing a 2–7% solid slurry [2,18]. This slurry must then be concentrated, as industrial conversion requires 300–400 g/L dry weight of microalgae [19]. The bulk harvesting method plays an important role in the energy requirement for the thickening process [7]. As a consequence, there has been significant research into different bulk harvesting methods, namely: centrifugation, filtration and membrane separation, gravity sedimentation, flocculation and flotation [20,21].

Algae require light to undergo photosynthesis and produce biomass, however as cultures become dense mutual shading occurs and limits productivity at approximately 0.5 g/L dry weight in an open system and 5 g/L in a photobioreactor [1]. Subsequently, this dilute concentration creates a considerable separation challenge [22]. Additional challenges arise from the small cell size, similar specific gravities of microalgae and the aqueous medium, negative surface charges, and the requirement for frequent harvesting [22–24]. The separation process may also need to take into account the strain to be used in production [5].

There are currently no universal techniques for harvesting [2], so it is important that the constraints of each separation method are examined in biofuel production [25]. In addition to the considerations with regards to microalgae's characteristics, the technique also depends on other considerations including water composition and salinity [26], and process development, as the method will affect downstream processes [16]. The harvesting method must also produce an acceptable level of moisture in the product [27]. Most current harvesting methods have either economic or technical limitations, which include high energy costs, flocculant toxicity, or non-feasible scale-up [28, 29].

Despite research into different methods, current bulk harvesting remains energy extensive and expensive [30], and methods are both species and final product specific [5]. Separation from the aqueous growth medium is difficult as microalgae are small (3–15 μm), have a specific gravity similar to that of their medium and are in dilute suspension [23]. In addition, separation is also influenced by hydrophobicity, microalgal density, medium composition and salinity [26].

Based on the difficulties of microalgae harvesting, there have been several methods developed and each method has advantages and limitations [25]. A feasible harvesting method should have low energy consumption, allow for the recycle of water and nutrients, avoid the additions of harmful chemicals and have a small footprint [21]. The optimal method should in addition to these considerations, be species independent and allow for the release of intracellular materials [14]. The main methods that are researched for microalgae separation are centrifugation, flocculation, filtration, gravity sedimentation and flotation [20–22]. The main characteristics of these methods are summarized in Table 1.

Centrifugation is well characterized and is commonly used at the laboratory scale production stage. An advantage of centrifugation is that it avoids the addition of chemicals, which can