



Influence of growth phase on harvesting of *Chlorella zofingiensis* by dissolved air flotation

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ABSTRACT

The effects of changes in cellular characteristics and dissolved organic matter (DOM) on dissolved air flotation (DAF) harvesting of *Chlorella zofingiensis* at the different growth phases were studied. Harvesting efficiency increased with Al^{3+} dosage and reached more than 90%, regardless of growth phases. In the absence of DOM, the ratio of Al^{3+} dosage to surface functional group concentration determined the harvesting efficiency. DOM in the culture medium competed with algal cell surface functional groups for Al^{3+} , and more Al^{3+} was required for cultures with DOM than for DOM-free cultures to achieve the same harvesting efficiency. As the culture aged, the increase of Al^{3+} dosage due to increased DOM was less than the decrease of Al^{3+} dosage associated with reduced cell surface functional groups, resulting in overall reduced demand for Al^{3+} . The interdependency of Al^{3+} dosage and harvesting efficiency on concentrations of cell surface functional groups and DOM was successfully modeled.

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1. Introduction

Algal biomass is emerging as a renewable feedstock for biofuels and bioproducts and a major effort has been devoted in recent years to scaling up algal mass culture from pilot-scale to commercial scale (Hu et al., 2008; McKendry, 2002; Patil et al., 2008; Pittman et al., 2011). However, harvesting of algal cells from dilute cultures (typically 1–5 g L⁻¹ dry weight) remains a major technical and economic challenge to algal biomass production (Greenwell et al., 2010). Commonly used harvesting methods include physical processes such as centrifugation, hydrocyclones, screening and filtration in which algal cells were separated by centrifugal force or by size exclusion (Molina Grima et al., 2003; Zhang et al., 2010), and physical–chemical processes like sedimentation and flotation, in which chemicals were used to change cellular surface properties resulting in cells that aggregate or were easily captured by bubbles (Knuckey et al., 2006; Wiley et al., 2009; Wyatt et al., 2012).

Flotation is generally believed to be more efficient than sedimentation for algal–water separation (Edzwald, 1993; Edzwald, 2010; Ma et al., 2007). The hydraulic loading rate of flotation systems is typically much higher than that of a sedimentation tank with a tube settler (Crittenden et al., 2005). Because of these advantages, flotation has increasingly been used for algal harvesting (Cheng et al., 2010; Wiley et al., 2009; Xu et al., 2010). In the

flotation-harvesting, air bubbles are introduced into a flotation tank or basin where they adhere to algal flocs generated by coagulation/flocculation. The algal flocs attached to air bubbles have a lower density than water and float to the surface of the medium where they can be collected by a skimming device. Dissolved air flotation (DAF) uses small air bubbles (40–80 μm) generated by releasing pressurized air-saturated water into the flotation tank/basin to increase efficiency (Edzwald, 2010).

DAF harvesting efficiency is affected by several operational parameters and by the characteristics of the particles and water to be treated (Edzwald, 2010). Applying DAF for algal harvesting differs from algal separation during water/wastewater treatment. The algal cell concentration in algal mass culture typically exceeds 1×10^7 cells mL⁻¹, which is thousands of times greater than the typical algal concentrations occurring in water/wastewater treatment (Conti et al., 2005; James et al., 1994). The concentration of dissolved organic matter (DOM) in the culture medium is also much greater than found in water treatment (Hendricks, 2006). Most importantly, the properties of algal cells and culture medium change considerably depending on algal strains and culture conditions. It is not well understood how cellular characteristics and culture medium properties affect the effectiveness and efficiency of algal harvesting. Based on studies of algal separation in wastewater treatment processes, cell surface area was first identified as a useful preliminary indicator of coagulant dosage (Henderson et al., 2008). Later Henderson et al. (2010) reported a stronger correlation between the coagulant dosage and the charge density. In their study, DOM in *Chlorella vulgaris* culture contributed 84% of the

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