



# Ratio between autoflocculating and target microalgae affects the energy-efficient harvesting by bio-flocculation

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## HIGHLIGHTS

- ▶ Bio-flocculation is a promising pre-concentration step for harvesting microalgae.
- ▶ Bio-flocculation reduces the energy for harvesting to at least 1.83 MJ kgDW<sup>−1</sup>.
- ▶ The ratio autoflocculating to target microalgae increases the recovery.
- ▶ Sedimentation rate increases with ratio autoflocculating to target microalgae.

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## ABSTRACT

The effect of ratio between autoflocculating and target microalgae in bio-flocculation was studied with emphasis on the recovery, sedimentation rate and energy demand for harvesting the target microalgae. When the autoflocculating microalgae *Ettlia texensis*, *Ankistrodesmus falcatus* and *Scenedesmus obliquus* were added to *Chlorella vulgaris* at a ratio of 0.25, the recovery of *C. vulgaris* increased from 25% to, respectively, 40%, 36% and 31%. The sedimentation rate increased as well. Addition of *Tetraselmis suecica* to *Neochloris oleoabundans* at a ratio of 0.25 increased the recovery from 40% to 50%. Application of bio-flocculation at a ratio of 0.25, followed by centrifugation reduces the energy demand for harvesting of the target microalgae from 13.8 MJ kgDW<sup>−1</sup> if only centrifugation is used to 1.83, 1.81, 1.53 and 1.34 MJ kgDW<sup>−1</sup>, respectively, using *T. suecica*, *E. texensis*, *A. falcatus* and *S. obliquus* and 3 h sedimentation before centrifugation.

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## 1. Introduction

Microalgae are regarded as one of the most promising feedstocks for biofuel production from lipids, but a significant reduction in the energy costs for production of the microalgal biomass should be realized to make microalgal biofuel production economically feasible (Wijffels and Barbosa, 2010). Current harvesting costs of microalgae are high (Uduman et al., 2010; Christenson and Sims, 2011; Schlesinger et al., 2012). The energy needed for harvesting of microalgae from a 0.3 gDW L<sup>−1</sup> microalgal suspension via centrifugation was calculated to be 13.8 MJ kgDW<sup>−1</sup>, while the combustion energy of the oleaginous microalgae was estimated to be 26.2 MJ kgDW<sup>−1</sup> (Norsker et al., 2011). With such high energy demand for harvesting, it is obvious that cost-efficient methods for harvesting microalgae should be developed (Molina Grima et al., 2003; Shelef et al., 1984) with emphasis on pre-concentration of microalgal biomass prior to centrifugation (Vandamme et al., 2012).

Uduman et al. (2010) postulated that in an ideal pre-concentration step, the dilute microalgal suspension (typically 0.2–10 gDW L<sup>−1</sup>) should be concentrated to a microalgal slurry of 20–70 gDW L<sup>−1</sup> and for this step it is not preferred to add chemical flocculants to the medium as it ends up in the final microalgal product and might complicate the reuse of the medium without further treatment.

Bio-flocculation of a non-flocculating fast-growing oleaginous microalga with a second autoflocculating microalga has been presented as a promising pre-concentration step in harvesting of microalgae (Salim et al., 2011). The recovery efficiencies and the time needed for sedimentation observed in this study proved to be in the same range as for chemically induced flocculation (Papazi et al., 2010; Lee et al., 1998). The major advantage of bio-flocculation is that the energy required for harvesting will be reduced, while no extra chemicals are needed. Autoflocculating bacteria (Lee et al., 2009) and diatoms (Schenk et al., 2008) can also be used as bio-flocculant. However the production of these bio-flocculants requires different cultivation conditions which acquire additional medium costs and increases the risk of microbial contamination of the medium. In the case of bio-flocculation with autoflocculating

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