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Harvesting microalgae with microwave synthesized magnetic microparticles

Gita Prochazkova [a], Ivo Safarik [b,c], Tomas Branyik [a,*]

[a] Department of Biotechnology, Institute of Chemical Technology Prague, Technicka 5, 166 28 Prague, Czech Republic
[b] Department of Nanobiotechnology, Institute of Nanobiology and Structural Biology of GCRC, AS CR, Na Sadkach 7, 370 05 Ceske Budejovice, Czech Republic
[c] Regional Centre of Advanced Technologies and Materials, Palacky University, Slechtitelu 11, 783 71 Olomouc, Czech Republic

HIGHLIGHTS

- ▶ Successful harvesting of microalgae with new magnetic agent.
- ▶ Iron oxide magnetic microparticles prepared solely from Fe(II) precursors.
- ▶ High separation efficiencies (up to 99%) achieved in a matter of minutes.
- ▶ Non-covalent electrostatic interactions have great influence upon separation.

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ABSTRACT

To make magnetic harvesting a more viable option, a suspension of inexpensive iron oxide magnetic microparticles (IOMMs) prepared by microwave treatment is presented as a new agent for separating *Chlorella vulgaris* from a highly diluted suspension. Separation efficiencies were tested under various conditions (model environment, cultivation media, different pH), revealing not only a dependency on the pH and amount of IOMMs, but also the influence of the ions present in the culture medium. Phosphorus ions were identified as the medium component interfering with algae–IOMMs interactions that are essential for magnetic cell separations in the culture medium. Phosphorus limited *C. vulgaris* cells were magnetically separated from the medium at separation efficiencies of over 95% at a 3:1 mass ratio of IOMMs to microalgae. A rapid and complete demagnetization of harvested algae was achieved by acidic treatment (10 vol.% H_2SO_4) at 40 °C under the influence of ultrasound.

1. Introduction

Microalgae have received attention of the scientific community due to their biotechnological potential. Lipids and carbohydrates for biofuels, ω-3 fatty acids, proteins, pigments, food supplements or animal feed are only a few examples of their wide usability. Cost-effective, sustainable processing technologies of microalgal biomass are one of today's core challenges of algal biotechnologies, the harvesting being one of the main bottlenecks.

The cost of algae harvesting is usually high, since the cell concentrations in culture broth are generally low. The major strategies currently applied in the harvesting of microalgae include centrifugation, filtration, flocculation, sedimentation, and flotation (Chen et al., 2011; Christenson and Sims, 2011; Uduman et al., 2010). Among the numerous cell separation procedures for microalgae, magnetic nano- and microparticles draw an increasing attention in this field. Their application in bioseparation processes is characterized by biocompatibility, easy manipulation and regeneration, accompanied by the usage of simple devices and non-destructive nature of magnetic fields (Cerff et al., 2012; Lim et al., 2012; Prochazkova et al., 2012; Safarik et al., 2012; Safarik and Safarikova, 2009; Safarikova et al., 2008; Xu et al., 2011; Yavuz et al., 2009). Nevertheless, the application of large-scale magnetic harvesting of microalgae is yet to be optimized and several key factors clarified (e.g. the choice of an appropriate, cost-effective harvesting agent for the given strain under moderate/physiological conditions).

Generally, a microorganism tends to adhere to solid surfaces to minimize the free interfacial energy. In the course of algal adhesion to magnetic particles in an aqueous environment a whole range of interactions such as non-covalent Lifshitz van der Waals forces, electrostatic forces, and acid–base interactions have to be considered (Bos et al., 1999). Microalgae culture media can be divided into low ionic strength (<0.1 M), or high ionic strength environments (>0.1 M) (Bilanovic et al., 2009). In an aqueous environment surfaces tend to uphold various surface charges, which result in

* Corresponding author. Tel.: +420 220 444 126; fax: +420 224 311 082.
E-mail address: tomas.branyik@vscht.cz (T. Branyik).

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