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Moisture displacement and simultaneous migration of surface-functionalized algae from water to an extraction solvent using ionic polyelectrolytes

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ABSTRACT

Effective moisture removal and the ability of algal biomass to be compatible with lipophilic solvents are key to making the algal lipid extraction processes economically viable. Here we report a simple technique to chemically remove moisture from algal water while forcing above 95% of the algal cell mass to migrate to a (hydrophobic) lipid extraction solvent. The technique is based on functionalization of algal cell surface with a water-soluble cationic polyelectrolyte, Poly(diallyldimethylammonium chloride) (PolyDADMAC) that has hydrophobic ligands in its structure. Studies indicate that algal cells continued to displace moisture even after migrating into the solvent phase - continuing to perform the chemical drying step. The general results indicate that the technique could be extended to systems that require separation of particles with charged surfaces - by using a surface active ionic polyelectrolyte with appropriate charge and ligand combination(s).

1. Introduction

Microalgae is a promising source of lipids for biofuel production and fatty acid, pigment, separation for nutritional and pharmaceutical production [1,2]. However, one major problem of lipid extraction from microalgae is caused by the huge amount of associated water [3–5]. Solvent extraction is an important step in lipid separation [6]. However due to large amount of moisture contact between algal cells and organic extraction solvent gets hindered. About 99.9% weight of the algae broth in an algal culture is water [3]. For conventional solvent extraction, a significant portion of this moisture is needed to be reduced during pretreatment [7,8]. For example, during initial coagulation and sedimentation steps, the moisture content is reduced to approximately 90% [3]. However further reduction of moisture requires costly centrifugation and drying operations [3,9,10] and is impractical due to high energy requirements [9,11,12].

During our preliminary investigations, it was observed that algal broth treated with ca. 1% (w/w) polyDADMAC cationic polyelectrolyte repelled water and migrated to the organic solvent (Fig. 1). Based on these encouraging results, this study was conducted to elucidate the effect of the molecular weight of the surfactant, solvent effects and time on moisture removal and solid separation characteristics of surface modified microalgae.

2. Methodology

Nannochloropsis oculata algal samples that has been subjected to nitrogen deprivation for increasing lipid content was obtained from algal culturing facility in Pecos, Texas. Lipid content of the samples is around 12% (w/w dry basis). These samples were concentrated to 22% TSS (Total Suspended Solids) using centrifugation, prior to shipping using centrifugation. Upon arrival, samples were refrigerated at 18 °C until used.

PolyDADMAC (Sigma Aldrich) with three different molecular weights (High: 400,000–500,000, Medium: 100,000–200,000 and Low: <100,000) were used as the surfactant. All surfactant samples were diluted to 20 g/l solid content using deionized water for ease of transferring and to increase the measurement accuracy.

Algal samples were diluted to 10% TSS using deionized water before the experiment. 10 ml of the 10% TSS algal sample was transferred to a 30 ml screw cap vial and 500 μl surfactant was added to the algal sample. After vortexing it for 1 min at 10,000 rpm, 10 ml of the solvent; Hexane, chloroform or dichloromethane; was added.

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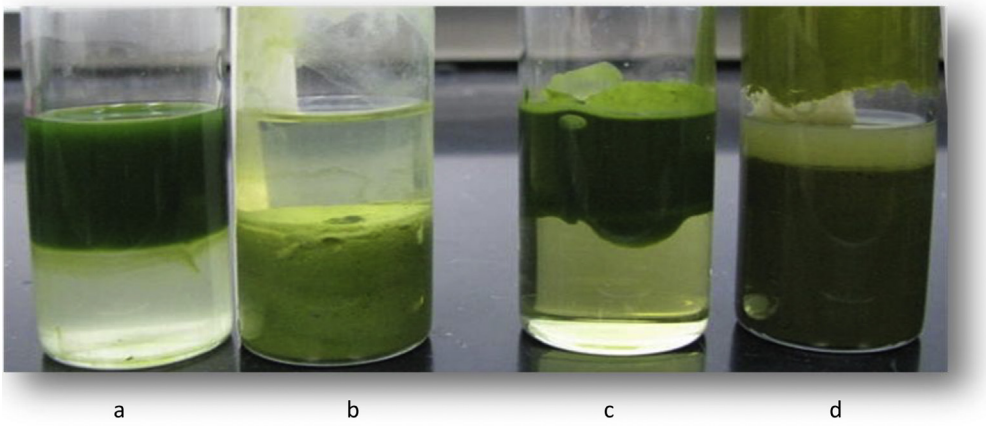

Fig. 1. Effect of surfactant on miscibility of algae with chloroform. (a) 0.1% TSS algae with solvent (b) 0.1% TSS algae mixed with polyDADMAC surfactant and then mixed with solvent (c) 10% TSS algae with solvent and (d) 10% TSS algae mixed with surfactant and then mixed with solvent.

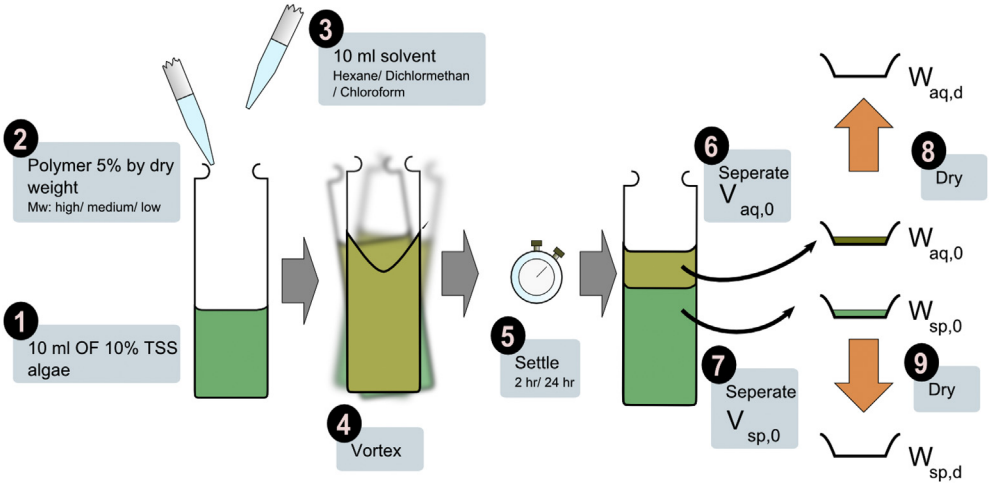

Fig. 2. Summary of the methodology.

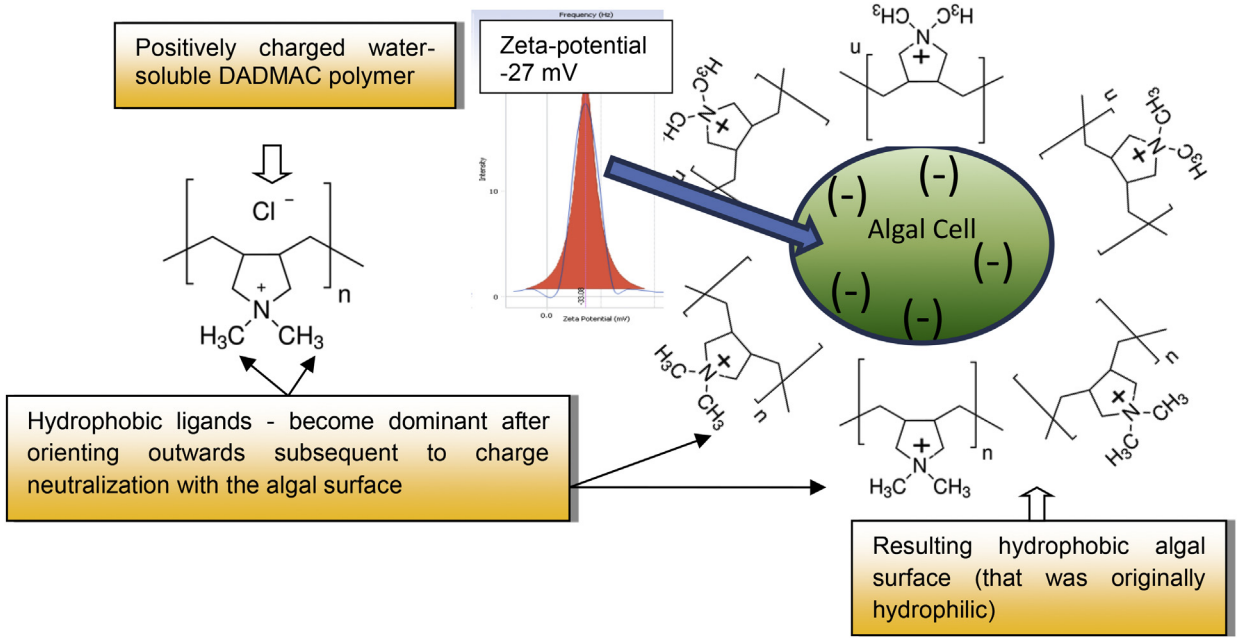

Fig. 3. Pictorial depiction of possible mechanism – hydrophilic algal surface (or chemical moiety) can be functionalized to be hydrophobic via cationic polymer attachment (or vice versa) by modulating the ligands of the surface active polymer.