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Brown algae hydrolysis in 1-*n*-butyl-3-methylimidazolium chloride with mineral acid catalyst system

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HIGHLIGHTS

- ▶ Sugars were successfully recovered from three brown algae species.
- ▶ Hydrolysis was most efficient in ionic liquid [BMIM]Cl with HCl as acid catalyst.
- ▶ Acid loading, time and temperature were critical for high TRS yield and selectivity.
- ▶ Biomass characterization supports the efficiency of hydrolysis in [BMIM]Cl/HCl.

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ABSTRACT

The amenability of three brown algal species, *Sargassum fulvellum*, *Laminaria japonica* and *Undaria pinnatifida*, to hydrolysis were investigated using the ionic liquid (IL), 1-*n*-butyl-3-methylimidazolium chloride ([BMIM]Cl). Compositional analyses of the brown algae reveal that sufficient amounts of sugars (15.5–29.4 wt.%) can be recovered. Results from hydrolysis experiments show that careful selection of the type of mineral acid as catalyst and control of acid loading could maximize the recovery of sugars. Optimal reaction time and temperature were determined from the kinetic studies on the sequential reducing sugar (TRS) formation and degradation. Optimal reaction times were determined based on the extent of furfurals formation as TRS degradation products. X-ray diffraction and environmental scanning electron microscopy confirmed the suitability of [BMIM]Cl as solvent for the hydrolysis of the three brown algae. Overall results show the potential of brown algae as renewable energy resources for the production of valuable chemicals and biofuels.

1. Introduction

Terrestrial biomass rich in carbohydrates have been widely utilized for biofuel production. But with limited land area, agricultural products cannot be fully exploited for energy production due to the growing demand on food supply. Alternatively, marine algae are attractive renewable energy resources due to their abundance, high photosynthetic efficiency and production rates (Ross et al., 2008). Particularly, numerous studies have reported the successful recovery of carbohydrates from red algae (*Rhodophyceae*). On the other hand, almost no investigation has been conducted on brown seaweeds (*Phaeophyceae*) despite being the second most abundant marine biomass (next to *Rhodophyceae*) (Rodriguez-Jasso et al., 2011).

Brown seaweeds are fast growing aquatic biomass in the subpolar regions with production cycles of 4–6 times annually. Unlike the carbohydrate rich *Rhodophyceae*, *Phaeophyceae* is more popular as a source of alginic acid. Thus, *Phaeophyceae* has been commonly used as biosorbents for heavy metals and as raw materials for phycocolloid and food industry (Davis et al., 2003). But aside from alginic acid, 30–50% of dry brown algae are carbohydrates mainly composed of glucose with minor amounts of xylose, mannose, galactose and fucose (Ruperez and Saura-Calixto, 2001). *Laminaran* is the principal carbohydrate reserve of *Phaeophyceae*, a polysaccharide composed of 20–25 glucose units linked by β-1,3-glucans terminated either by glucose (G-chain) or mannitol (M-chain) (Percival, 1979). Thus, the carbohydrates in *Phaeophyceae* could be sufficient for recovery and use as precursors for the production of industrially important chemicals and biofuels.

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