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Ethanol production from *Saccharina japonica* using an optimized extremely low acid pretreatment followed by simultaneous saccharification and fermentation

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HIGHLIGHTS

- SSF conducted with extremely low acid pretreated *Saccharina japonica*, for bioethanol production.
- ELA pretreatment of algal biomass does not require processes such as neutralization.
- Three suspensions; buffer, deionized water and treated liquid hydrolysate were used for SSF.
- Deionized water as a fermentation broth may be possible for high bioenergy yield.
- Liquid hydrolysate of *S. japonica* can be used for biofuel fermentation using other microorganisms.

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ABSTRACT

An extremely low acid (ELA) pretreatment using 0.06% (w/w) sulfuric acid at 170 °C for 15 min was employed to extract non-glucan components from *Saccharina japonica*, a brown macroalgae. Subsequent simultaneous saccharification and fermentation (SSF) was conducted using *Saccharomyces cerevisiae* DK 410362 and cellulase (15 FPU/g-glucan) and ß-glucosidase (70 *p*NPGU/g-glucan). Deionized water was used for making fermentation suspension. After the ELA pretreatment, a glucan content of 29.10% and an enzymatic digestibility of 83.96% was obtained for pretreated *S. japonica*. These values are 4.2- and 2.4-fold higher, respectively, than those of obtained with untreated *S. japonica.* In SSF, a bioethanol concentration of 6.65 g/L was obtained, corresponding to a glucose equivalent concentration of 13.01 g/L, which indicated an SSF yield of 67.41% based on the total available glucan of the pretreated *S. japonica.* The remaining separated liquid hydrolysate, which contains mannitol and alginate-derived oligosaccharides can be applied to other fermentations.

1. Introduction

Macroalgae are a promising feedstock for bioethanol production due to their ability to generate a fast growth and high yields superior to those of many terrestrial crops (Wi et al., 2009). Furthermore, macroalgae generally have higher hydrolysable carbohydrate contents and provide more fermentable carbon sources than crops such as high-sugar perennial rye grass (Borinesa et al., 2011; John et al., 2011; Jeong et al., 2010; Jung et al., 2011; Farrar et al., 2012; Bryant et al., 2011).

Macroalgae are divided into three major groups based on their photosynthetic pigments: green, red and brown algae. Brown macroalgae are composed of alginate, glucan, mannitol, and some other polysaccharides (Borinesa et al., 2011; Anastasakis et al., 2011; Jang et al., 2012; Lee and Lee, 2011). Especially, *Saccharina* spp., a brown macroalgae, contains up to 55% (dry weight) of the carbohydrates laminarin and mannitol (Adams et al., 2009). Like other cellulosic biomasses, glucans from brown macroalgae can be enzymatically hydrolyzed into favorable fermentable sugars to be converted into bioethanol.

Establishment of a pretreatment method to make glucan more accessibly to enzymes is a key aspect of effective fermentable sugar production. One of the prerequisites of effective biomass pretreatment is that polysaccharides from biomass should be hydrolyzed directly or subsequently without sugar degradation which produces inhibitors. Energy and cost are also important factors. Acid pretreatment is one of the most popular methods to attain high sugar yields from lignocellulosic biomass. Diluted acids at concentrations between 0.2% and 2.5% (w/w) are usually used at temperatures between 130 and 210 °C (Sarkar et al., 2012; Balat, 2011; Ge et al., 2011).

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