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ORIGINAL PAPER

Evaluation of tropical seaweeds as feedstock for bioethanol production

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Abstract Limited resources of freshwater and decreasing fossil fuel resources are two main reasons to consider the ocean as a huge resource for producing food, feed, fertilizer and feedstock for fuel. In this study, twenty-nine tropical seaweeds (11 green, 10 red and 8 brown seaweeds) collected in Malaysia were assessed as potential feedstock for bioethanol production. Total carbohydrate content ranged from 12.16 to 71.22% dry weight (DW) with total reducing sugar content ranging from 5.17 to 34.12% DW. During hydrolysis using dilute sulphuric acid, the dominant fermentation inhibitors were 5-hydroxymethylfurfural and phenolic compounds. Overliming was found to reduce the content of fermentation inhibitors by up to 79%. The red seaweeds, *Kappaphycus alvarezii* (Doty) Doty ex P.C.Silva and *Gracilaria manilaensis* Yamamoto and Trono, were selected for optimization of saccharification and fermentation of the hydrolysate, because they had the highest carbohydrate contents and are commercially cultivated. The most suitable dilute acid conditions obtained in present study was sulphuric acid (2.5%, w v^{-1}) treatment at 121 °C for 40 min that produced 0.29 and 0.34 g g^{-1} DW reducing sugar for *K. alvarezii* and *G. manilaensis,* respectively. Fermentation of the hydrolysates with *Saccharomyces cerevisiae* produced bioethanol yields of 20.90 g L^{-1} (71.0% of theoretical yield) for *K. alvarezii* and 18.16 g L^{-1} (67.9% theoretical yield) for *G. manilaensis.*

Keywords Dilute acid hydrolysis · Fermentation inhibitors · Tropical seaweeds · *Kappaphycus* · *Gracilaria* · Bioethanol

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Introduction

The algae comprising both microalgae and seaweeds serve as important sources of diverse useful products which find applications in nutrition, chemical and pharmaceutical industries, waste bioremediation and recently as feedstock for renewable energy. Biofuel in the form of biodiesel, bioethanol, biomethane, hydrogen and hydrocarbons is obtainable from algae (Jones and Mayfield 2012). The advantages of algae as feedstock for biofuel over other sources are based mainly on the high biomass productivities, non-competition with use as food, tolerance to habitats unsuited to other crops and the lower environmental impacts compared to use of fossil fuel (Wei et al. 2013). This is similarly true for the production of bioethanol resulting from fermentation of algal carbohydrate, available from seaweeds and as a co-product after lipid extraction from microalgae for diesel production (John et al. 2011). Algal biomass production contributes to carbon removal from the atmosphere. *Eucheuma denticulatum* cultivated using long-line system in Lombok, Indonesia, was reported to incorporate from 16.08 to 68.43 tonnes C ha^{-1} a^{-1} in the biomass (Erlania and Radiarta 2014). Seaweed cultivation is beneficial in integrated multi-trophic aquaculture (IMTA) systems. Seaweeds provide refuge from predators for the fish or shrimps in the IMTA and perform bioremediation of the wastes (Phang et al.