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The bio-methane potential of whole plant and solid residues of two species of red seaweeds: *Gracilaria manilaensis* and *Gracilariopsis persica*

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ABSTRACT

Macroalgae, known commonly as seaweed, is extensively used in industry for extraction of its valuable products such as agar and carrageenan. This extraction process generates a large amount of waste in the form of biomass residues. In this study, bio-methane potential of two red seaweeds, *Gracilaria manilaensis* and *Gracilariopsis persica*, both as whole plant and their industrial residues, were compared after a mild acid pre-treatment at pH 2, 100 °C and 1 h in batch assays. The results showed that the pre-treated residual biomass of both *G. manilaensis* and *G. persica* had higher bio-methane potentials at 70% and 62% of the theoretical yield, respectively, compared to the whole plant biomass which achieved only 48% and 46% of the theoretical yield, respectively. The pre-treatment step increased the initial reaction rate of the residues by 47% and 77% compared to the untreated samples. On the other hand, the pre-treatment step only enhanced the initial reaction rates by 25% and 39%, respectively, with the whole plant sample. The results confirm that the seaweed residues are more suitable as a feedstock for anaerobic digestion compared to whole plant biomass.

1. Introduction

Seaweeds or macroalgae are often referred to as third generation biomass. Seaweeds are abundant and renewable, rendering them a potential substrate for biofuel production [1,2]. Seaweed biomass mainly consists of carbohydrate, proteins, and lipids. However, the level of these respective components varies significantly from species to species and season to season. The carbohydrate content of macroalgae (green, red, and brown) is relatively high and varies between 25 and 60% of its dry weight (DW) [3]. The protein content can be 5–47% DW, and it is strongly dependent on the species [4,5]. The lipid and lignin contents in seaweeds are often low, varying between 1 and 5% DW and ~0.03 g/kg DW, respectively [6,7]. The rest of the biomass consists of a variable content of mineral ash, at ~7–38% DW [8].

The global demand for macroalgae is expected to increase as the industrial usage of seaweed is shifting from its traditional use as a food source to a variety of value-added products, such as agar, carrageenan, alginates, biopolymers, and pharmaceuticals [9,10]. Regardless of its product, the macroalgae processing industry always generates solid waste [11]. Unfortunately, the seaweed processing industry currently does not properly process its solid waste residues. These residues could potentially be processed further to generate value-added products. The solid algal biomass residues after agar extraction typically contain 62–68% cellulose, which could be enzymatically hydrolysed to yield ~0.87 g sugars/g cellulose [12]. In addition, due to its low lignin content, the algal biomass and its remaining residues from the agar processing industry make for an attractive feedstock for biofuels [7,13,14].

The majority of studies on anaerobic digestion using algal biomass as feedstock typically uses whole plant/raw seaweed instead of the processed biomass residues. The utilisation of whole plant green (*Ulva lactuca*), red (*Gracilaria vermiculophylla*), and brown (*Laminaria* sp. and *S. latissima*) seaweed resulted in a methane yield of 0.12–0.5 m^3 CH_4/kg VS [7,8]. On the other hand, investigations of industrial seaweed processing residues for methane production remain limited. Nonetheless, a few studies reported promising results. Edyvean et al. [15] produced 320 mL/g VS biogas with 62% methane using seaweed waste after alginate extraction. Two other studies used alginate-extracted residues

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