

LIFE CYCLE GLOBAL WARMING POTENTIAL ASSESSMENT OF SEAWEED-BASED BIOETHANOL

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ABSTRACT

Bioethanol produced from a brown seaweed, *Laminaria japonica*, could be more sustainable and societally ethical than those for terrestrial biomass in response to increasing demands of biofuels and a requirement for biorefinery with low carbon emission. To achieve sustainable bioethanol production systems based on seaweed, we assessed global warming potentials (GWPs) of seaweed-to-biofuel process by using life cycle assessment (LCA). Bioethanol-producing processes using the seaweed and their GWPs were significantly different from the other land biomasses such as corn grain, corn stover, and switchgrass. This study can provide valuable R&D target information needed to effectively reduce the GWP of seaweed-based bioethanol and develop more sustainable bioenergy.

INTRODUCTION

Biofuels, as the next energy for the future, require stable supply security of feedstocks and lower net greenhouse gases (GHGs) emissions in their production. GHG emissions of bioethanol are originated from the cultivation of biomass feedstocks and bioethanol conversion. Current technologies for bioethanol production have focused on sugary and lignocellulosic biomass, which is based on land cultivation (Sánchez et al., 2008). This land cultivation needs a lot of inputs of energy and materials such as fresh water, fertilizer, and pesticides that can induce significant GHG emissions. Also, agricultural tillage practices to undisturbed ecosystem have caused surprisingly high GHG emissions from the plant and soil (Fargione et al., 2008).

Macroalgae, known as seaweeds, have been considered one of promising alternative bioenergy feedstocks and seem to have the potential to replace existing terrestrial biomass for bioethanol. Compared to terrestrial biomass, seaweed mass-cultivation does not require fertilizer, agrochemicals, fresh water, and land areas because seaweeds grow in seawater. Besides, seaweeds have high carbon contents (i.e. seaweed-specific carbohydrates) that can be biochemically converted to bioethanol (Jung et al., 2013).

The objective of this study was to evaluate the global warming potentials (GWPs) of seaweed (*L. japonica*) bioethanol production to compare to terrestrial biomasses (corn grain, corn stover, and switchgrass). For the comparison, life cycle assessment was used. This study can be used to develop sustainable seaweed-based bioethanol processes and to provide many insights into research and developments for marine biofuel.

MATERIALS AND METHODS

We carried out a life cycle GWP assessment of four bioethanols from a brown seaweed and three terrestrial biomasses. The functional unit was 1000 liters of bioethanol, and the system boundary included cultivation to bioethanol conversion stages based on currently available technology. Data for materials and energy used in the cultivation, transportation, and bioethanol production stages were collected from field survey and literature (Cherubini et al., 2010; Han et al., 2011; Humbird et al., 2011; Liska et al., 2009). The life cycle inventory was built based on the Ecoinvent database v2.2. The GWPs were assessed by using the ReCiPe with the hierarchist perspective. In the cultivation stage, we also considered the potential impacts of land uses including tillage practices. The life cycle stages of bioethanol consist of cultivation and bioethanol conversion stages.

RESULTS AND DISCUSSION

In the cultivation stage, the GWP for seaweed biomass was similar to the corn grains; however, the corn stover and switchgrass were about 60% of the seaweed. Although seaweed cultivation did not need any agrochemicals and fresh water (with contrast to corn grain), seaweed farming needed culture frames, seed strings, and rope made by petrochemical polymers (i.e. plastic materials), which has relatively high GWPs. If these frame materials can be changed from petroleum-based materials to biomaterial-based materials, the GWPs of seaweed biomass could be lower than the terrestrial biomass.

In the bioethanol conversion stage, the corn grain demanded only c.a. 40% of the GWPs for the other biomass feedstocks because of the simple carbon structures of corn grain. Seaweed-based bioethanol had slightly high GWP, which was similar to the corn stover and switchgrass because the seaweed was assumed to be processed in dilute-acid and enzyme saccharification-fermentation system, which are generally used for lignocellulosic biomass. In the bioethanol conversion of these three feedstocks, over 65% of GWPs were derived from the pretreatment system. Another reason for the high GWP of the seaweed is that the ethanol conversion yield of seaweeds was lower than land biomass. The GWP of seaweed-based bioethanol could be reduced by optimizing and customizing terrestrial biomass-based conversion processes to fit into the seaweed bioethanol and/or by developing advanced technology like genetic engineering for improvement of seaweed productivity and bioethanol conversion yields (Wargacki et al., 2012).

CONCLUSIONS

Seaweed biomass like *L. japonica* could become a potential candidate of the next sustainable feedstocks that can replace terrestrial biomass in the bioethanol industry. Seaweeds do not require the large scale of land areas for mass cultivation, additional agrochemicals, and fresh water with significant global warming impacts. Since research and developments for



seaweed-based biofuels are relatively in immaturity compared to land biomass-based biofuels, advanced biotechnology should be developed to overcome current obstacles related with seaweed-based bioethanol.

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