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Production of acetone, butanol, and ethanol from biomass of the green seaweed *Ulva lactuca*

Hetty van der Wal [a,1], Bram L.H.M. Sperber [a,1], Bwee Houweling-Tan [a], Robert R.C. Bakker [a], Willem Brandenburg [b], Ana M. López-Contreras [a,*]

[a] Food and Biobased Research, Wageningen University and Research Centre, Bornse Weilanden 9, 6708 CT Wageningen, The Netherlands
[b] Plant Research International, Wageningen University and Research Centre, Droevendaalsesteeg 1, 6700 AP Wageningen, The Netherlands

HIGHLIGHTS

- *Ulva lactuca* was characterized as feedstock for the acetone, butanol and ethanol fermentation.
- Hydrolysates were obtained using mild pretreatment conditions and commercial cellulases.
- *Ulva lactuca* hydrolysate was used as substrate for fermentation by two different strains.
- Rhamnose was utilized by *C. beijerinckii* for production of 1,2-propanediol.

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ABSTRACT

Green seaweed *Ulva lactuca* harvested from the North Sea near Zeeland (The Netherlands) was characterized as feedstock for acetone, ethanol and ethanol fermentation. Solubilization of over 90% of sugars was achieved by hot-water treatment followed by hydrolysis using commercial cellulases. A hydrolysate was used for the production of acetone, butanol and ethanol (ABE) by *Clostridium acetobutylicum* and *Clostridium beijerinckii*. Hydrolysate-based media were fermentable without nutrient supplementation. *C. beijerinckii* utilized all sugars in the hydrolysate and produced ABE at high yields (0.35 g ABE/g sugar consumed), while *C. acetobutylicum* produced mostly organic acids (acetic and butyric acids). These results demonstrate the great potential of *U. lactuca* as feedstock for fermentation. Interestingly, in control cultures of *C. beijerinckii* on rhamnose and glucose, 1,2 propanediol was the main fermentation product (9.7 g/L).

1. Introduction

Different types of plant biomass, including energy crops, cereals and agricultural by-products, are promising starting materials for the production of fuels and chemicals, using the so-called biorefinery approach, in which the whole biomass is being valorized into a range of different products. The most developed biorefinery concepts are currently based on lignocellulosic feedstocks, where sugars are fermented into ethanol or other energy carriers, and other fractions (such as lignin) are converted into high value chemical additives (Cherubini, 2010). In order to meet the expected increasing demand for biofuels and biochemicals, and to diversify the feedstock and product portfolio of biorefineries, there is a need to find additional suitable biomass sources, in particular those that do not rely on using large amounts of agricultural land. This necessity has led to an interest into the use of biomass from aquatic environments, such as seaweeds (macroalgae) (Subhadra and Grinson, 2010; John et al., 2011; Kraan, 2011).

Seaweeds are fast growing marine plants that may reach large sizes, for example, 3–20 m length for certain kelp species (Lüning, 1993). Growth rates and yields of material per surface area that can be obtained in seaweeds forests are significantly higher than those reported for terrestrial plants (Gao and McKinley, 1994; Horn et al., 2000), mostly due to the lower energy required for the production of supporting tissue compared to that for land plants and a higher capacity of nutrient uptake over their entire surface. Seaweeds have a wide range of commercial applications, traditionally as feed or food, and soil fertilizer, and nowadays as source of hydrocolloids for the food industry, personal healthcare and pharmaceutical industry (McHugh, 2003). Seaweeds are classified into three broad groups based on pigmentation: Brown (Phaeophyceae), red (Rhodophyceae) and green (Chlorophyceae). Green seaweeds have

* Corresponding author. Tel.: +31 317481314; fax: +31 317483011.
E-mail address: ana.lopez-contreras@wur.nl (A.M. López-Contreras).
[1] Both authors contributed equally.

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