Advanced and integrated biorefinery technologies for South Australia's brown seaweed valorization

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Australia’s southern coastline is a biodiversity hotspot for seaweed, with up to 1,500 described species, of which approximately 62 % are endemic to the region. While this unique resource presents great industry development potential, however the seaweed industry in South Australia is currently limited to the small-scale manufacture of agricultural commodities from beach-cast and imported algae. The aims of our study are to assess the potential of South Australia’s seaweed resources as feedstocks for higher-value products, and to develop advanced and integrated processing technologies for their valorization.

Bioprospecting activities revealed that the harvestable beach-cast seaweed in the south-east of South Australia was taxonomically diverse and highly variable across multiple time scales. *Ecklonia radiata* was selected as the model feedstock due to its abundance, potential for aquaculture, and possession of compounds of commercial interest.

To develop a cost-effective and environmentally friendly technology, a biorefinery approach is deemed to be essential for the comprehensive valorization of seaweed biomass for the production of multiple products, including alginate, fucoidan and fertilizer. When the kinetics of a classical extraction process of fucoidan were studied, only 22% of the total available fucoidan was extracted from *E. radiata*, accompanied by a gradual reduction in purity, cleavage of sulfate groups, and rapid depolymerization

A sequential extraction process was devised, based around the acidic extraction of fucoidans and the sodium carbonate extraction of alginates. The acidic treatment was considered to be a critical step, as it served as both an extractant for fucoidan and an important pre-treatment for alginate extraction. Therefore, response surface methodology and desirability functions were used to predict the best overall process for improved fucoidan yield and the high-yielding sequential extraction of high molecular weight alginates.

The optimized process was applied to three other brown algae: *Durvillaea potatorum*, *Seirococcus axillaris*, and *Macrocystis pyrifera*, and the products were assessed for key indicators of value. The fucoidans from *E. radiata* demonstrated the ability to stimulate the proliferation of human skin fibroblasts; the alginates from *S. axillaris* had strong gel-forming capacity; and the alginate extract of *M. pyrifera* was lightly colored and highly viscous.
Finally, a techno-economic analysis was performed to assess the potential industrial production of fertilizers, fucoidans and alginates in South Australia. The integrated production of fucoidans and fertilizers from *M. pyrifera* was predicted to be the most profitable option. In a scenario of limited biomass availability, the project could break even if a minimum of 140 dry tonnes of feedstock could be accessed annually.

The outcomes from this study are expected to guide decision making, and facilitate the development of sustainable, yet profitable marine-based industries in South Australia and

elsewhere in the world to participate internationally in the emerging “blue economy”.

Keywords: Biorefinery, Brown algae, Fucoidan, Alginate, Techno-economic analysis