

Development of Seaweed Biorefineries for Fuels and Chemicals





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www.ecn.nl



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Take-home Messages

- Seaweeds: promising complementary feedstock for the biobased economy.
- ECN develops biorefinery processes for each main class of seaweeds.
- Seaweed storage: crucial for seaweed biorefineries, but challenging.
- Multi-product utilization of seaweed required for economic use (cascading biorefinery, not only biofuels).

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(Biorefining of) Seaweeds



Why Seaweeds?

Large potential availability

- Fastest growing biomass at the latitude of The Netherlands.
- Farth's surface ~70% water.

No competition for land use

Opportunity for simultaneous production of food and chemicals.

Chemical composition

- Complementary to micro-algae and lignocellulose.
- Comprised of (specialty) carbohydrates, proteins and ash.
- Various potential applications of biorefinery products, including biofuels.

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Seaweed Biorefinery

- ECN: Development of biorefinery processes for cultivated seaweeds to produce 3rd generation biofuels & bulk chemicals.
- Large compositional differences between main classes of seaweed (brown, red and green).
- Development of specific biorefinery schemes for each type of seaweed.





Blade

Stipe

Holdfast



ECN Focus: North Sea Native Seaweeds

BROWN



Saccharina latissima



Laminaria digitata

GREEN



Ulva sp.

RED



Palmaria palmata

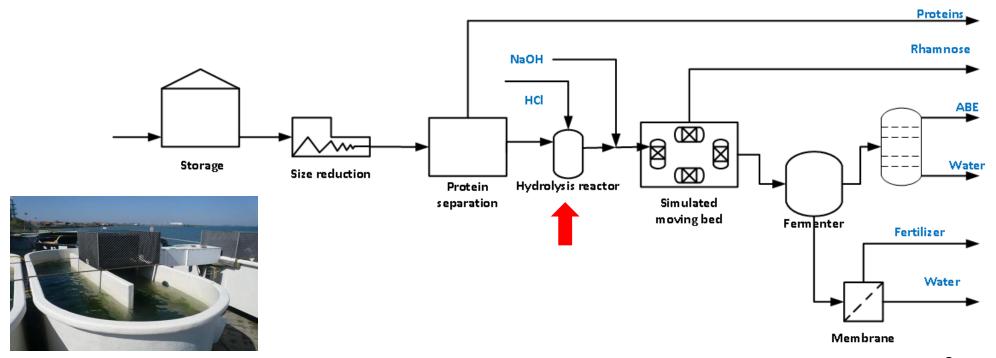


Green Macroalgae - *Ulva*



Ulva sp.

- Ulva from cultivation in race-way ponds at WUR-IMARES (Yerseke, NL).
- Co-production of proteins and carbohydrates (rhamnose, glucose, Glc-A).



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Hydrolysis Process

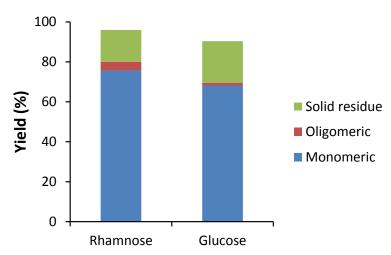
- Goal: one-step hydrolysis to monosaccharides.
- Bench-scale tests:
 - 5 kg seaweed, 20 L reactor.
 - Optimum conditions: 140 °C, 0.2M HCl, 60 min.
 - Good yields of monomeric rhamnose and glucose.



- Selective isolation of proteins difficult.
- Alternative: mild carbohydrate isolation and use of residu for animal feed*.



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^{*} P. Bikker et al. (2016) J of Appl Phyc (DOI 10.1007/s10811-016-0842-3)



Brown Macroalgae - Kelps



Kelps

• Feedstocks:

- Saccharina lattissima from Norway (EU-FP7 @Sea project)
- Laminaria digitata from Ireland

Carbohydrates in Kelps:

- Mannitol
- Alginate (mannuronic & guluronic acid)
- Laminarin (glucose)
- **–**

Mannitol:

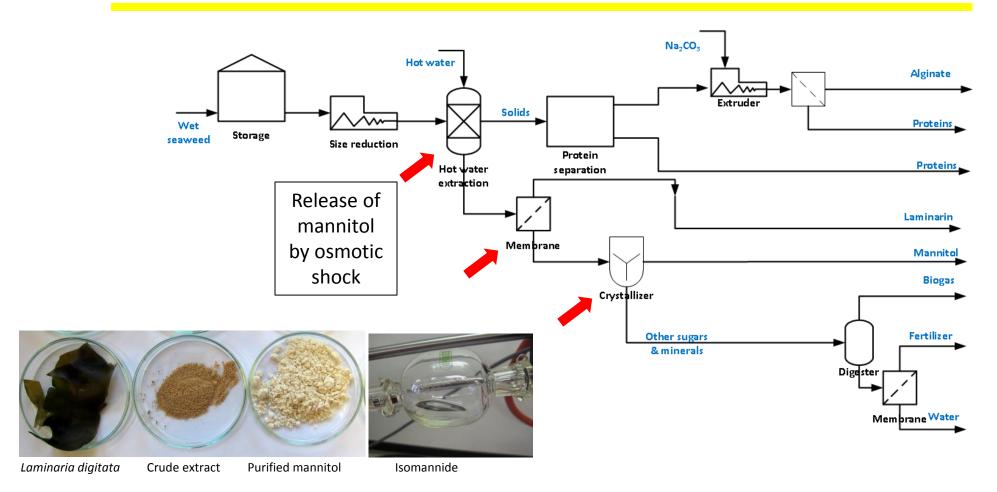
- Food (low-calorie sweetener) and pharmaceutical ingredient
- Conversion to isomannide: plasticizers, fuel additives, PUR,



isomannide



Biorefinery of Kelps



^{*} J. van Hal & W.J.J. Huijgen, Process for mannitol extraction from seaweed, patent application NL 2009482

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Economic Evaluation



Approach

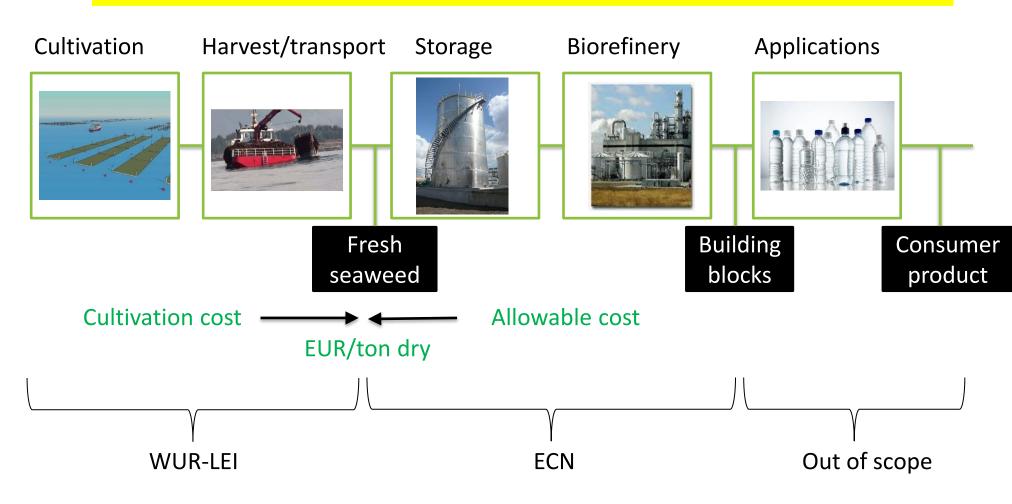
- Objective: insight in the economics of seaweed cultivation and valorization, in particular the main drivers and challenges.
- Approach: coarse economic evaluation using standard cost engineering approaches, literature and experimental data.
- Cases:
 - Saccharina lattisima.
 - Ulva sp.
- Seaweed input: 200 kton_{dw}/yr







Economic Evaluation

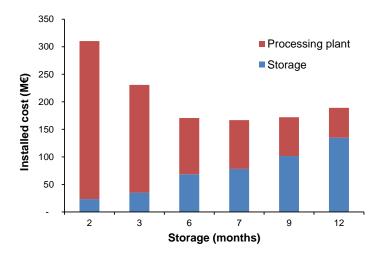


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Results

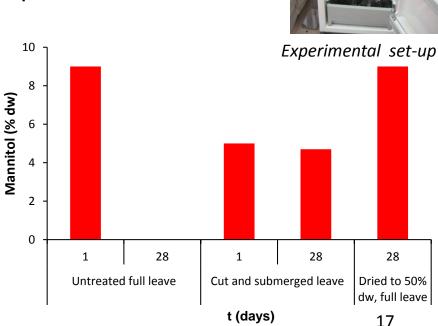
- Economic seaweed utilization requires:
 - Storage of seaweed (CAPEX reduction). However, year-round not required!
 - Biorefinery: efficient co-production of high-value and bulk products.
- Allowable seaweed cost:
 - Saccharina lattisima: 478 €/ton_{dw}.
 - Ulva: 290 €/ton_{dw}.
- Substantially lower than projected seaweed cost (>1000 €/ton_{dw}).
- However, major potential improvements identified (such as rotating crop).





Seaweed Storage

- Seaweed storage crucial for economy future biorefineries:
 - Seasonal growth.
 - Large seasonal variations in composition seaweeds.
- Development of storage concepts for kelps:
 - Fast rotting of fresh seaweeds observed.
 - Potential measures identified:
 - Storing seaweed in seawater.
 - Partial drying.
 - pH reduction by lactic acid addition.



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Ensiling

• Ensiling:

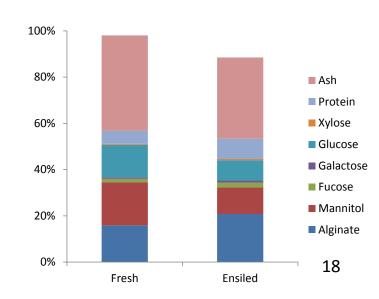
- Anaerobic lactic acid fermentation (pH \downarrow).
- Commonly applied in cattle breeding for grass.
- Saccharina ensiled by covering with plastic and water on top and storing for weeks.





• Effects:

- Rotting stopped, structure largely intact.
- Reduction of mannitol and glucose content.
- Alginate and proteins largely preserved.
- Approach to preserve components with highest value.





The Future



Challenges Ahead

- Priority: reduction of feedstock cost
 - Development reliable cultivation & supply chain of seaweeds.
 - Early stage of development → scale-up & efficiency improvement.
- Biorefining of seaweed
 - Development of efficient storage and fractionation concepts.
 - Valorization of multiple components from seaweed.

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MACROFUELS

Ongoing Initiatives

Dutch TO2 project (2015)

- Cooperation Dutch applied research institutes along the value chain of seaweed.
- Public report presented last week (North-Sea-Weed-Value-Chain: Sustainable seaweed from the North Sea, an exploration of the value chain).
- Available soon on http://www.to2-federatie.nl/.

EU-H2020 MacroFuels (2016-2019)

- Developing the next generation macroalgae-based biofuels for transportation via advanced biorefinery processes
- www.macrofuels.eu



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Thank you for your attention!

More information:

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http://seaweed.biorefinery.nl

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