Biorefining of seaweed for the production of furanic molecules

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5 authors, including:

Karla Dussan
TNO

Wouter J.J. Huijgen
Royal Cosun

MACROFUELS

Biorefining of seaweed for the production of furanic molecules

K. Dussan Rojas, W.J.J. Huijgen, D.F. Meyer, J.W. Dijkstra, J.W. van Hal
Biomass & Energy Efficiency Group

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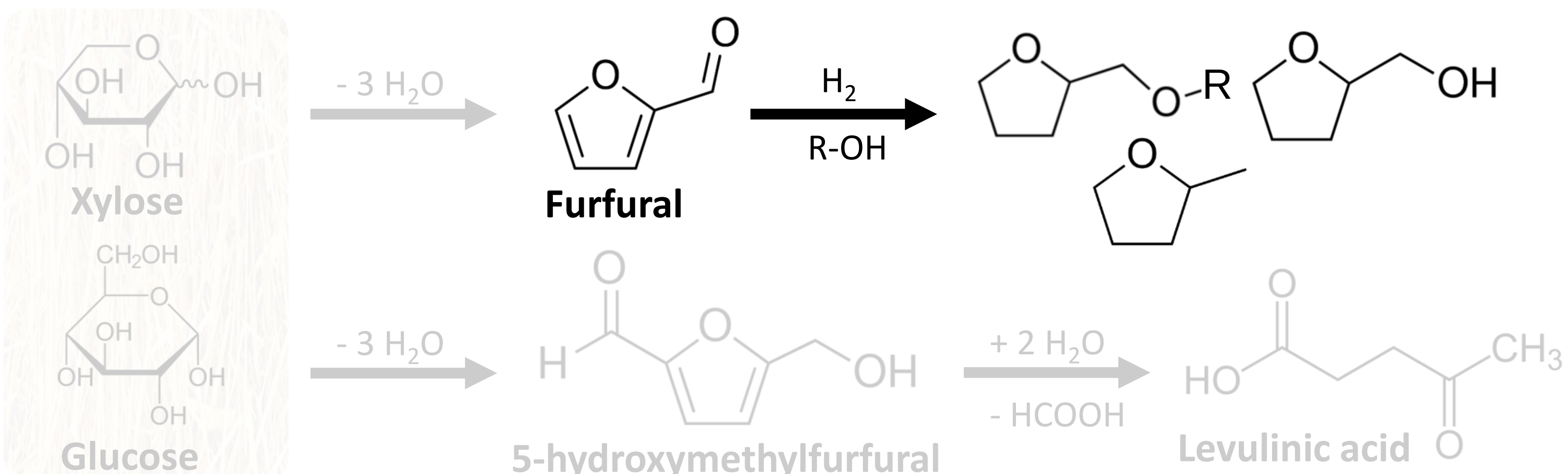
The MACROFUELS project

- MacroFuels aims to produce advanced biofuels from macroalgae.
- Fast growing biomass in Northern Europe.
- Large availability of marine waters: no competition with land crops.
- Opportunities for biorefinery: Specialty carbohydrates to complement (terrestrial) biomass biorefineries.

	GREEN  *Ulva* sp.	RED  *Palmaria palmata*
Xylose	2-10% wt	30-35% wt
Galactose	-	10-15% wt
Glucose	5-35% wt	5% wt
Rhamnose	5-10% wt	-

Carbohydrates to furanics

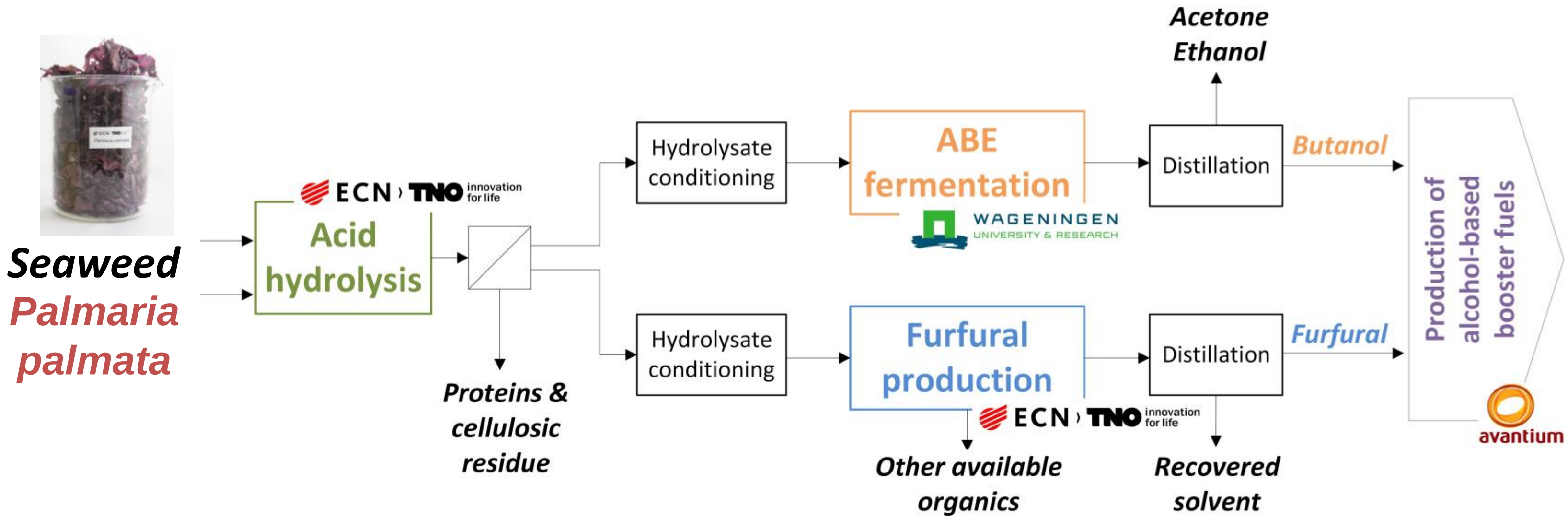
- Dehydration of carbohydrates yield furanic molecules.
- Building blocks and precursors for commodities and fine chemicals: furan ring and formyl group.
- Advanced fuels: (ethoxy) Alkyl furfuryl and tetrahydrofurfuryl ethers.
- Soot reduction in compressed engines and anti-knock properties.



Objectives and approach

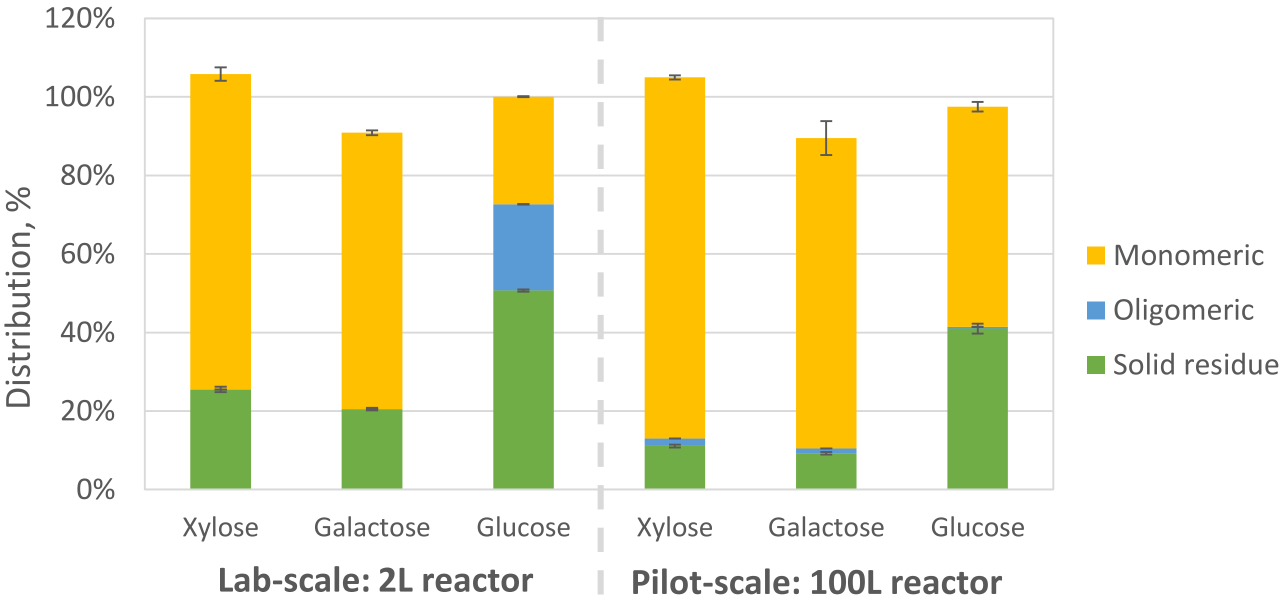
- **Our work:** Evaluate the feasibility and efficiency of the conversion of seaweed carbohydrates to furfural and 5-hydroxymethyl-furfural/levulinic acid.
- **Scale-up:** Hydrolysis 2L → 20L → 100L

  Dehydration & solvent recovery mL → 20L



Acid hydrolysis of seaweed

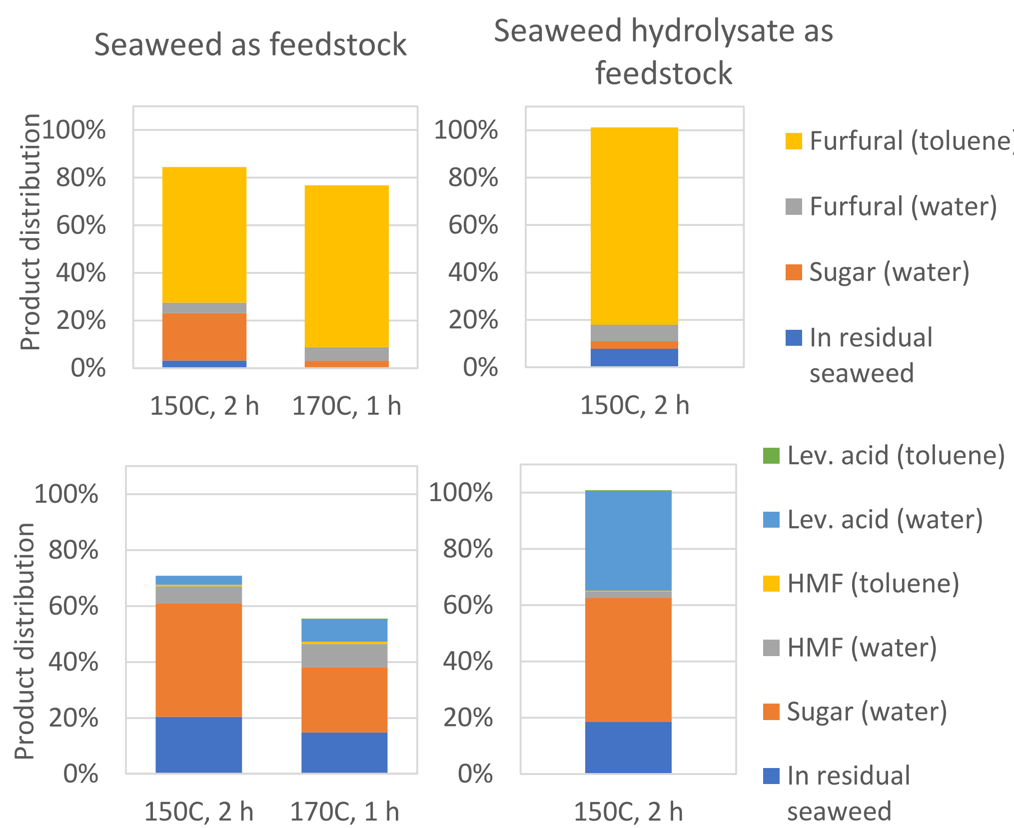
- Temperature/acid screening at 2L-scale: 80-140 °C / pH 0.5-2.0.
- Xylose/galactose yields >80% at low T/high acid and mild T/low acid.
- **Scale-up to 100L:** 35 kg dw seaweed and 480 L raw hydrolysate.
- Varying degrees of buffering capacity in seaweed.



Sugar dehydration: Screening of batch reaction

- To increase limited selectivity in single water phase: Water-immiscible solvent (toluene).
- Direct conversion vs. *via* hydrolysis: Reducing reactor volume & processing steps.

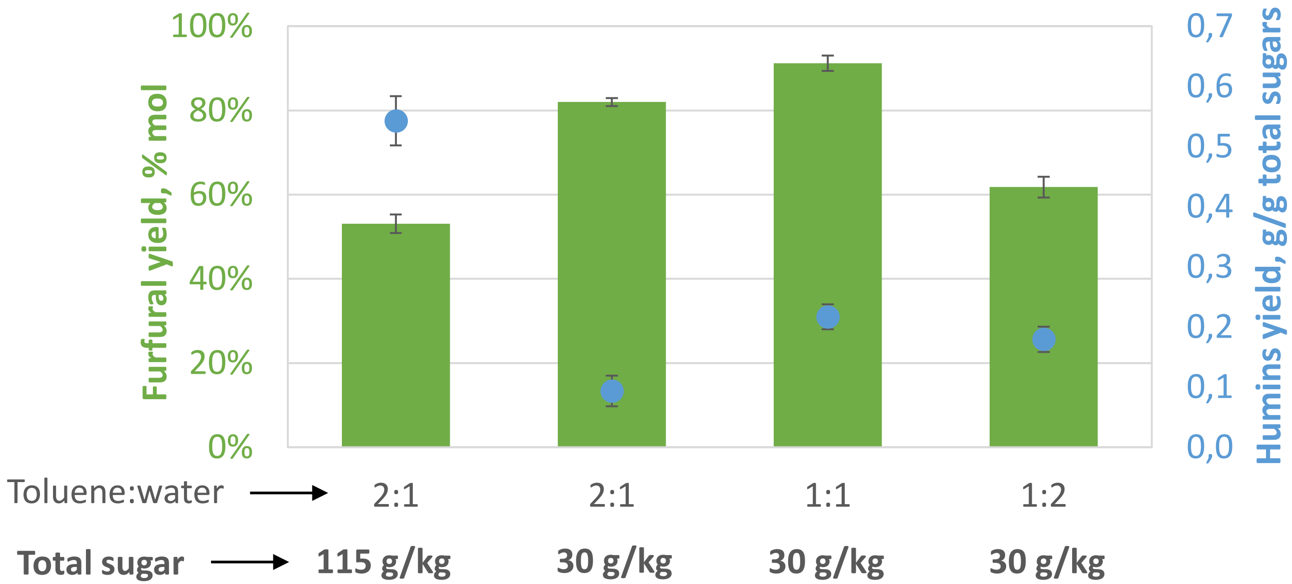
- At 100mL-scale:
  ✓Max. Y_{FUR}=80-85%
  ✓Max. X_{C6}=40%
  ✓Max. furfural conc. = 0.7% wt.

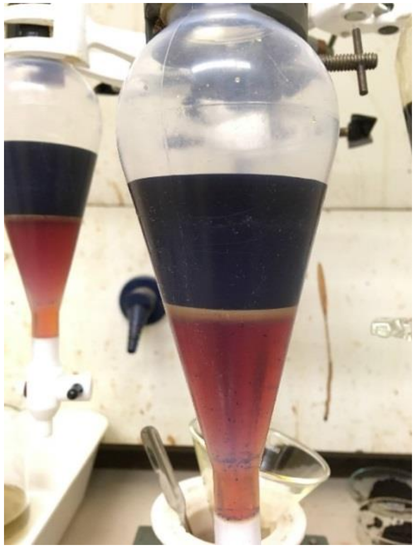


Water:toluene ratio = 1:2

Sugar dehydration: Increasing throughput

- Reduction of toluene-to-water ratio: Solvent consumption reduced by half without affecting conversion.
- Higher sugar concentration: Lower furfural yield / More humins produced.





Sugar dehydration: Increasing scale to 20L

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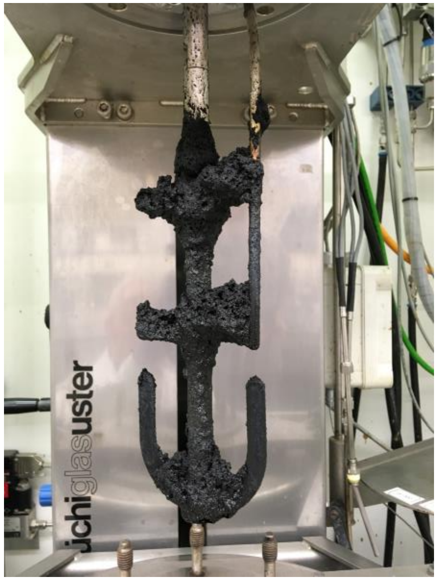
- Hydrolysate was evaporated to reduce reaction volume.
- Toluene:water ratio of 1:1.
- Solvent recovery reduced productivity!

Parameters	Exp. 1	Exp. 2
[Xylose]	110 g/kg	73 g/kg
$[Fur]_{tol}$	5.1% wt.	3.5% wt.
Humins yield	0.90 g/g total sugars	0.52 g/g total sugars
Solvent recovery	48%	41%



Gas formation!
57% CO_2 vol

Sugar dehydration: Increasing scale

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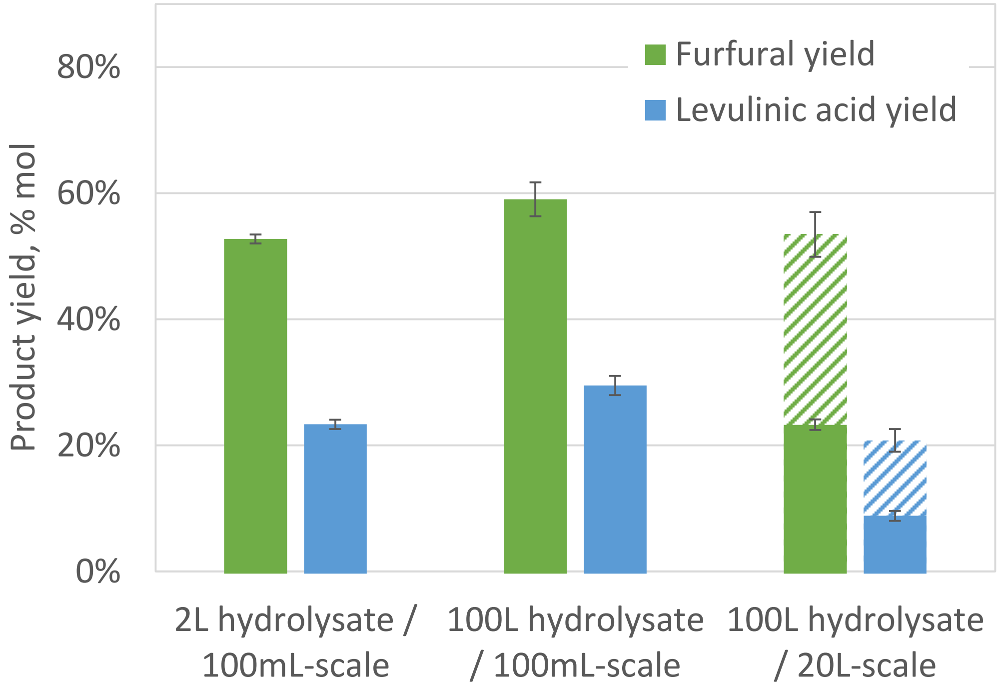
- Different reactor geometry & stirring design did not cause major losses of overall yield.

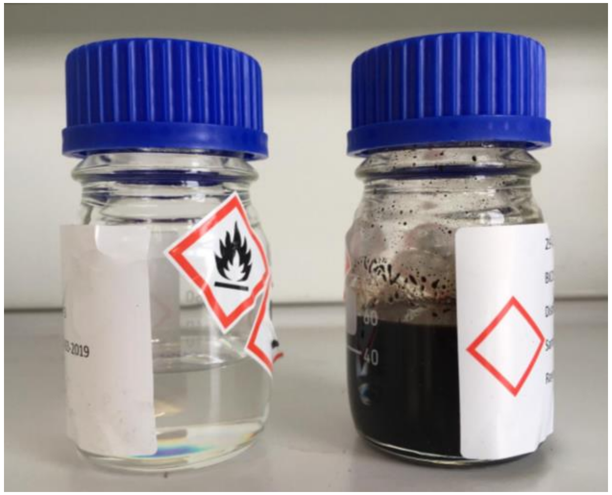
- Lower overall production of furfural & levulinic acid.
  ✓Solvent losses: Reduction of total yield by 50%.



Total sugar = 110-115 g/kg
Toluene:water = 1:1

Furfural recovery

- Solvent evaporation carried out in two stages.
- Strong black colour and mild formation of condensated particles, without affecting density/viscosity of product.
- Research required into aspects of impurities and colour removal.



Features	Values
Vol. toluene product	6 L
$[\text{Furfural}]_{tol}$	4.4% wt.
Furfural product	180 g
Overall furfural recovery	**93%**

Conclusions

- Reduction of chemicals during acid hydrolysis and implement appropriate hydrolysate conditioning steps.
- Balance between reaction efficiency and energy demands associated to sugar dehydration and furfural recovery.
- Product recovery, purity and quality for downstream applications.

Thank you!

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macrofuels@dti.dk