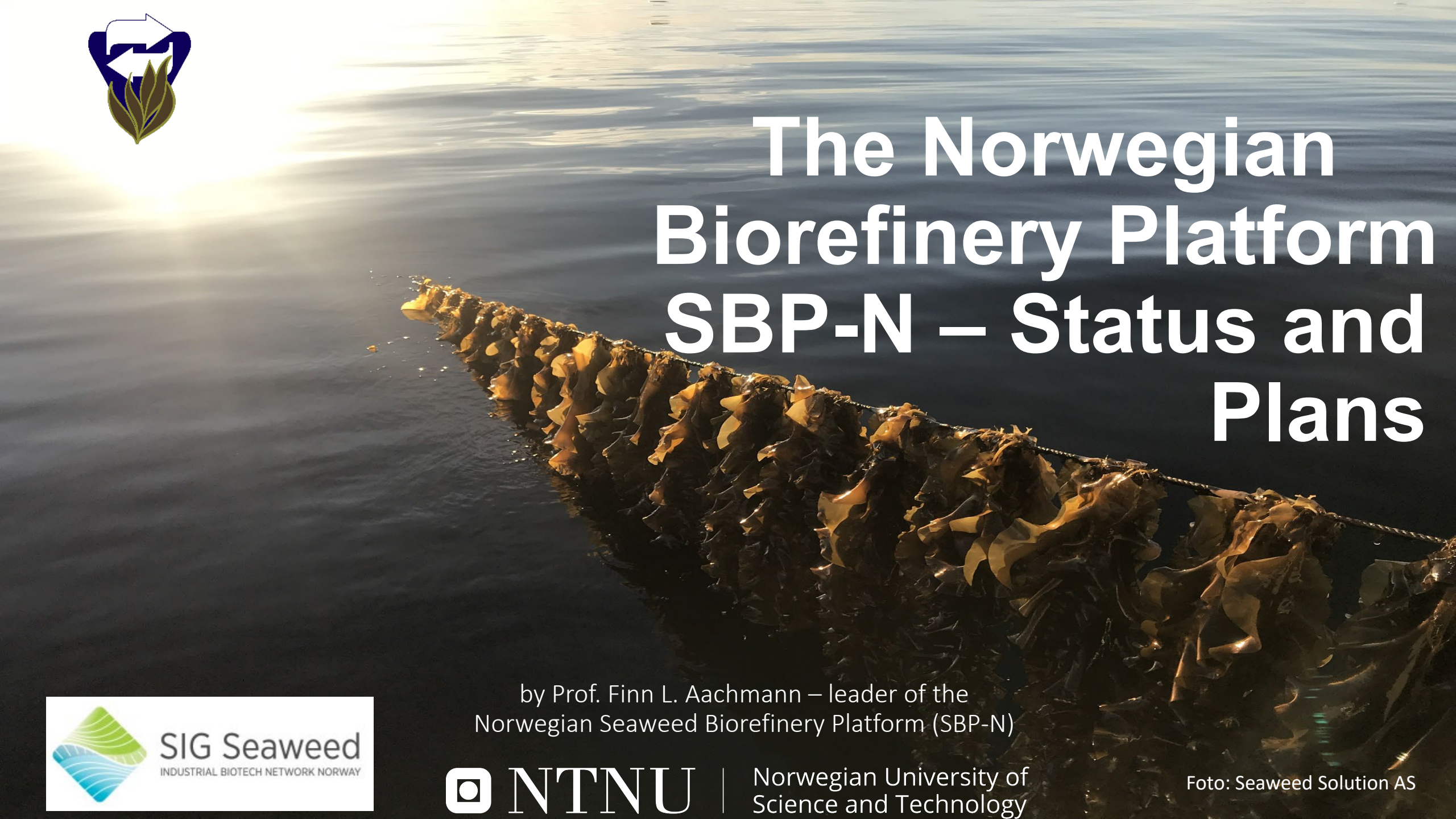


The Norwegian Biorefinery Platform SBP-N – Status and Plans

by Prof. Finn L. Aachmann – leader of the
Norwegian Seaweed Biorefinery Platform (SBP-N)

SIG Seaweed
INDUSTRIAL BIOTECH NETWORK NORWAY

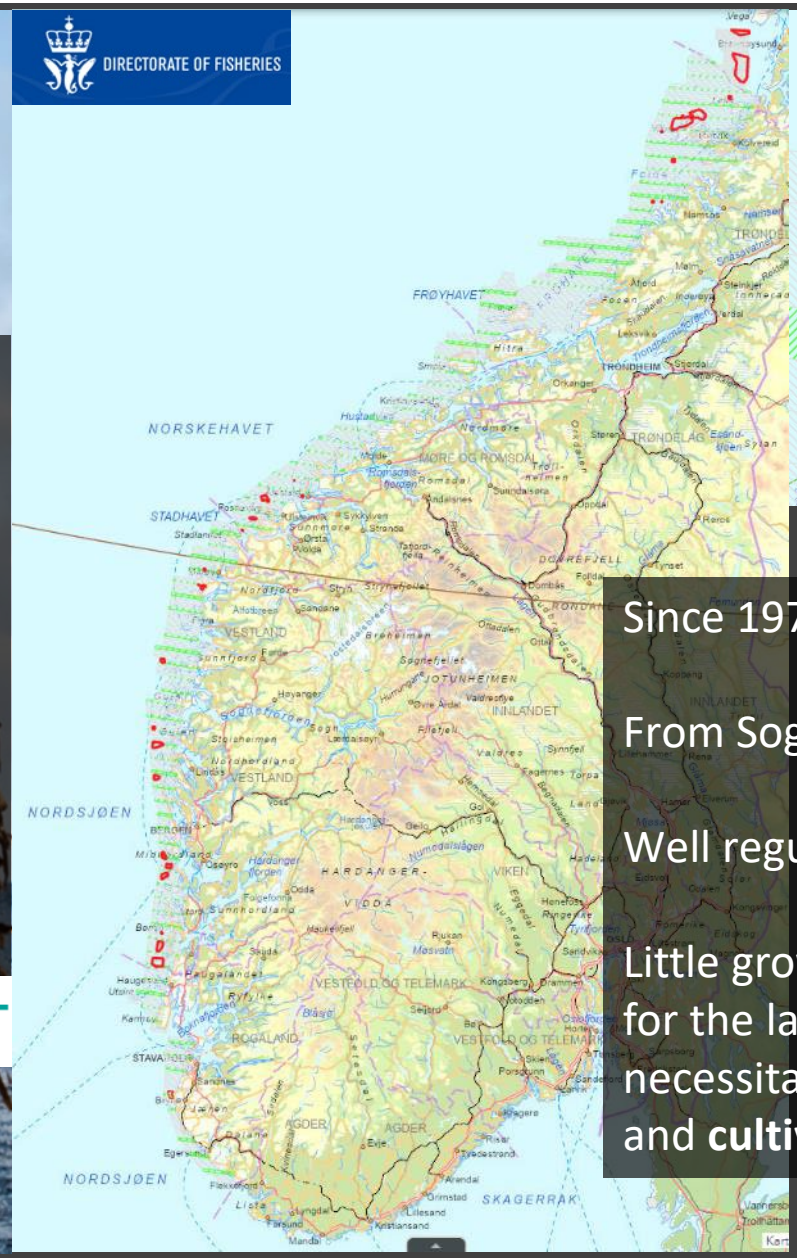
NTNU | Norwegian University of Science and Technology

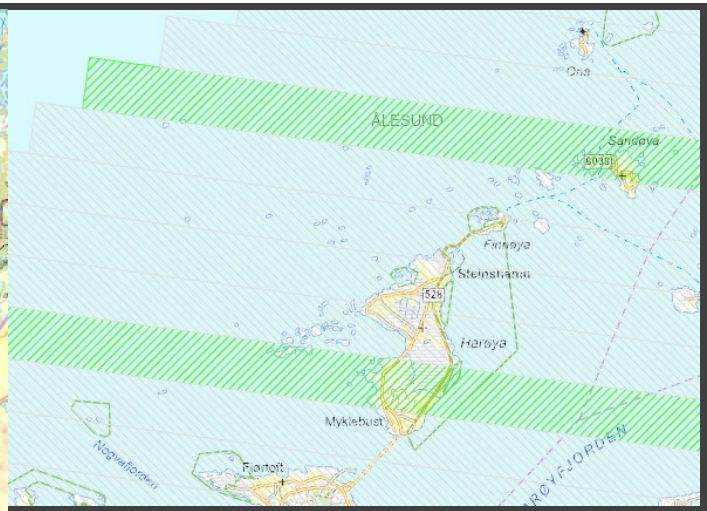
Foto: Seaweed Solution AS

Seaweed industry in Norway

In Norway: ~150 000 tons of harvested seaweed (20% world basis) annually for alginate production. >600 applications and export 1 Billion NOK

Process ~20 -30 000 tons harvested seaweed annually for feed ingredients and agriculture uses. Annual turnover ~180 million NOK.





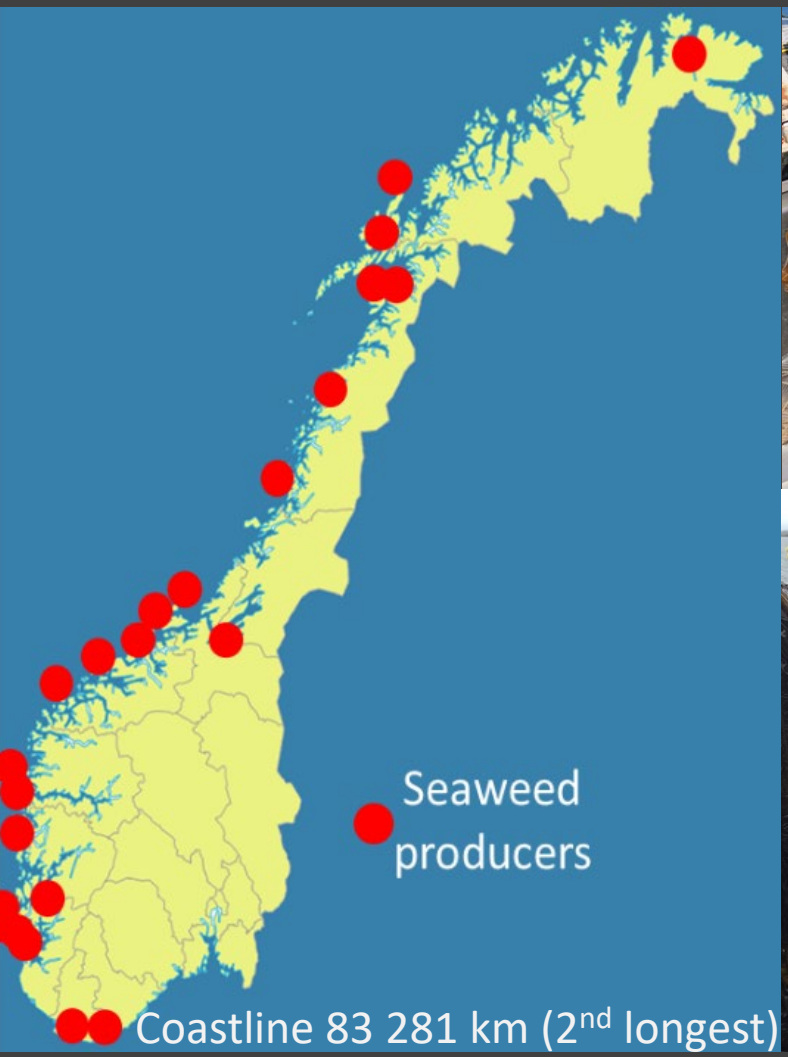
Since 1970s – mechanical harvest

From Sogndal to Brønnøysund

Well regulated - e.g. harvest every 5th year

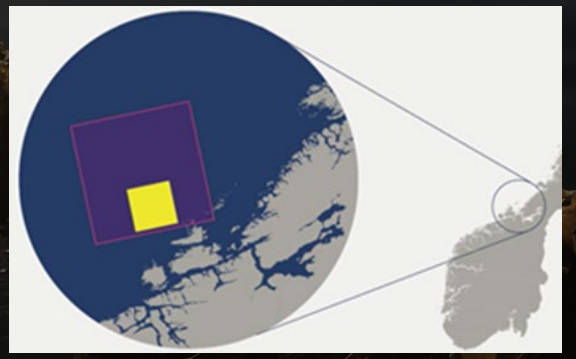
Little growth in harvest seaweed volumes for the last 15 years. An increasing demand necessitates utilizing additional species and **cultivated biomass**.

Seaweed industry in Norway



Seaweed Solutions · LERØY · B'ZEOS GREEN TECH · Orkla · ++

Fast growth seedlings to 1-2 m plants in 4-5 months. Requires only sunlight, seawater, and CO_2

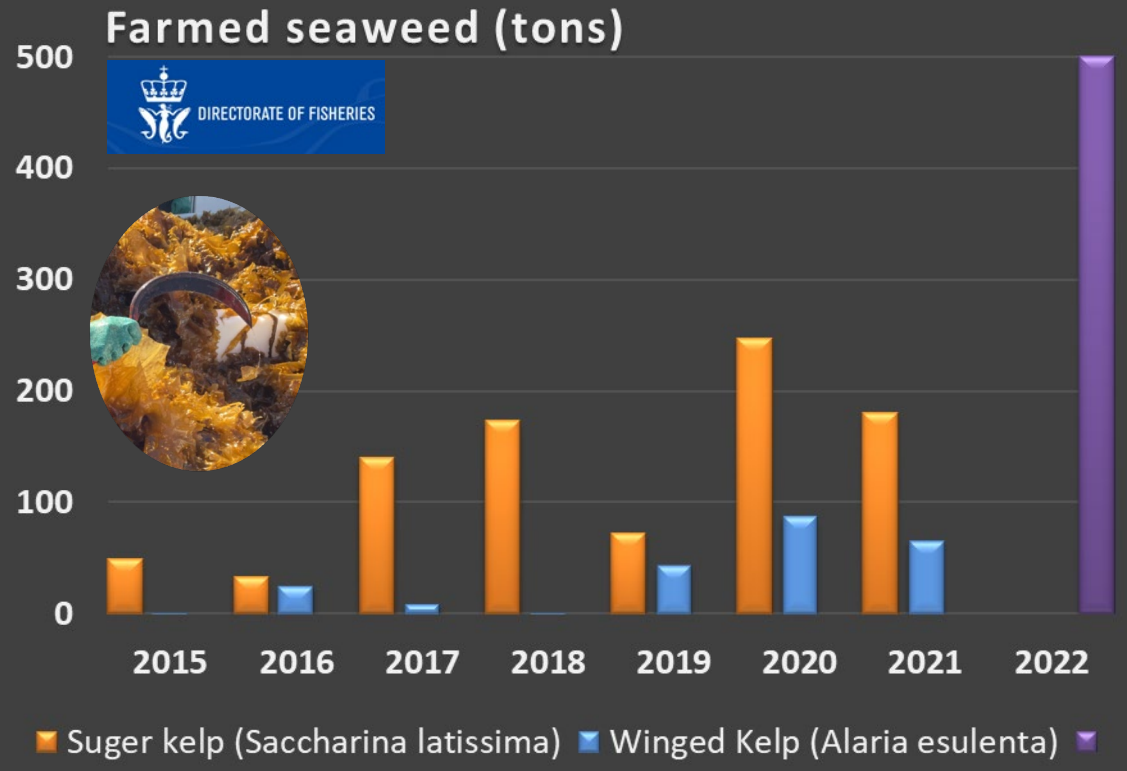


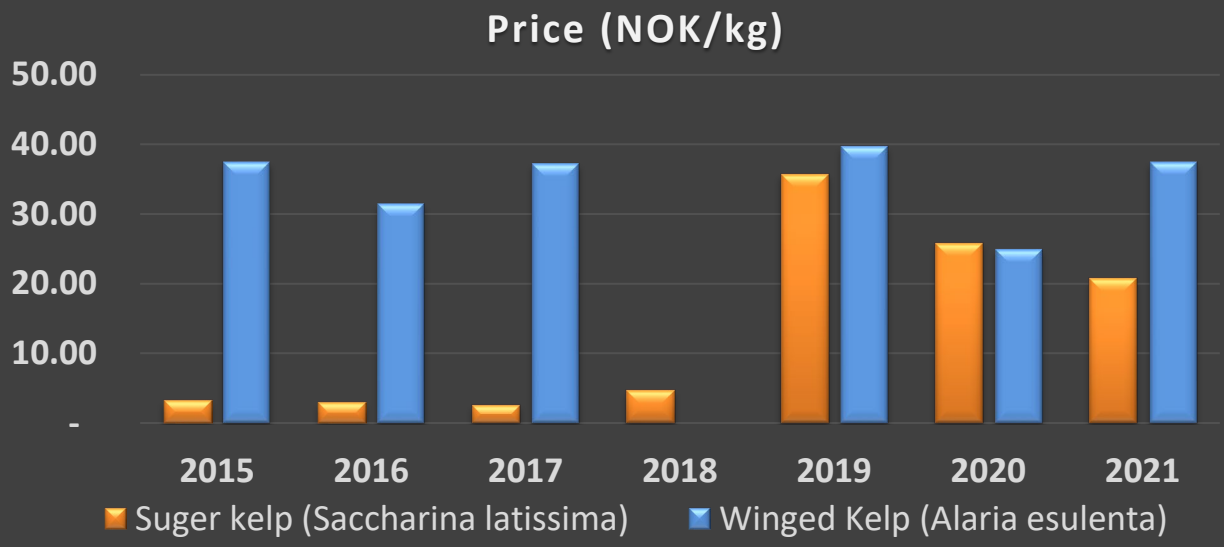
Today annually production 500 tons, but rapid development

20 million tons of seaweed will require area equal the size of Trondheimsfjorden

23 Companies with sites along the coast (2021)

Seaweed cultivation in Norway





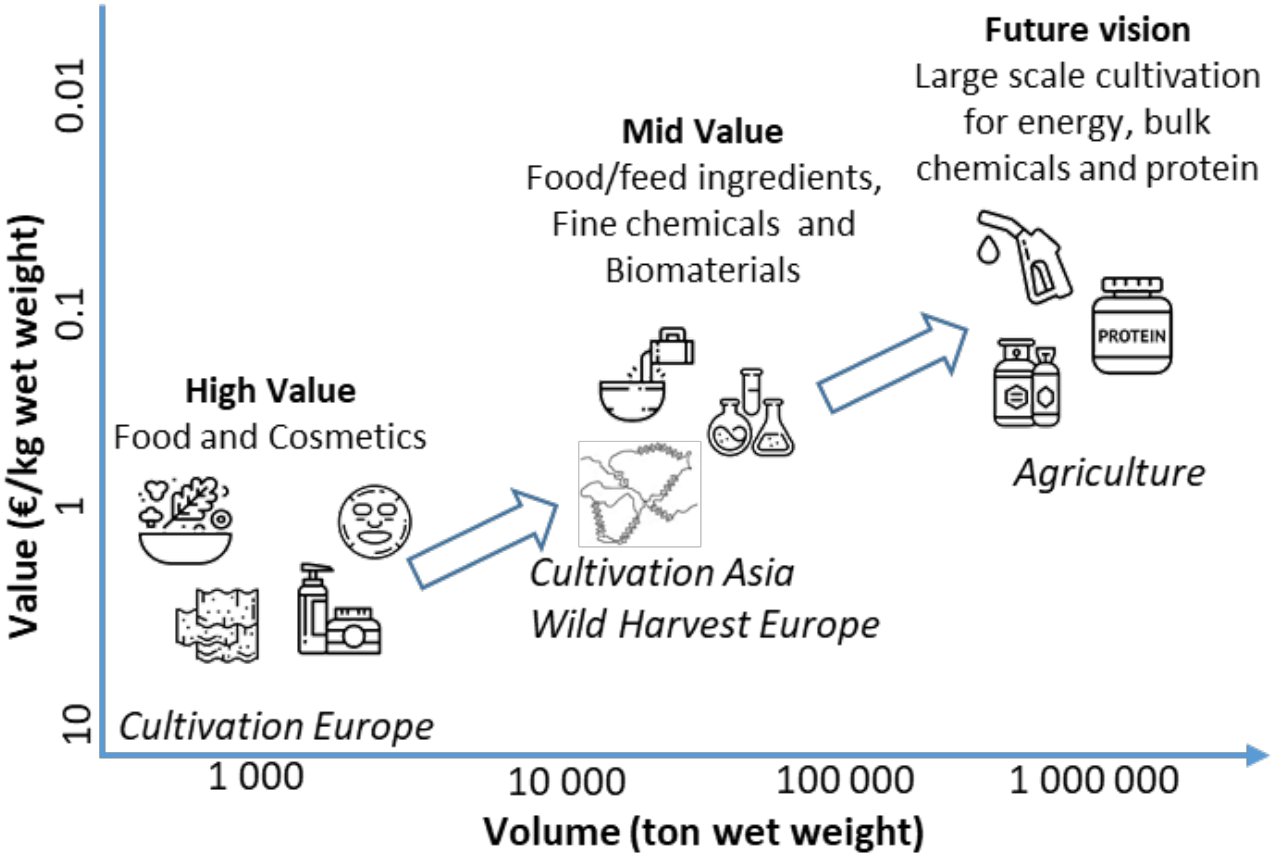
249 tons (2021)

Aim for 2022 **500** tons (~1000 tons Europa)

– Estimated potential (current quota) **150 000** tons

The Norwegian farmed seaweed industry have unrealized potential

From high value Food to industrial commodities



Industrialization of cultivation, harvest and processing necessary to reduce production cost

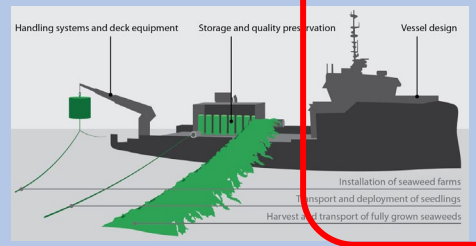
The supply of biomass must be high enough to enable a market pull

The Norwegian Biorefinery Platform SBP-N

"BREEDING"

CULTIVATION

HARVESTING AND PROCESSING

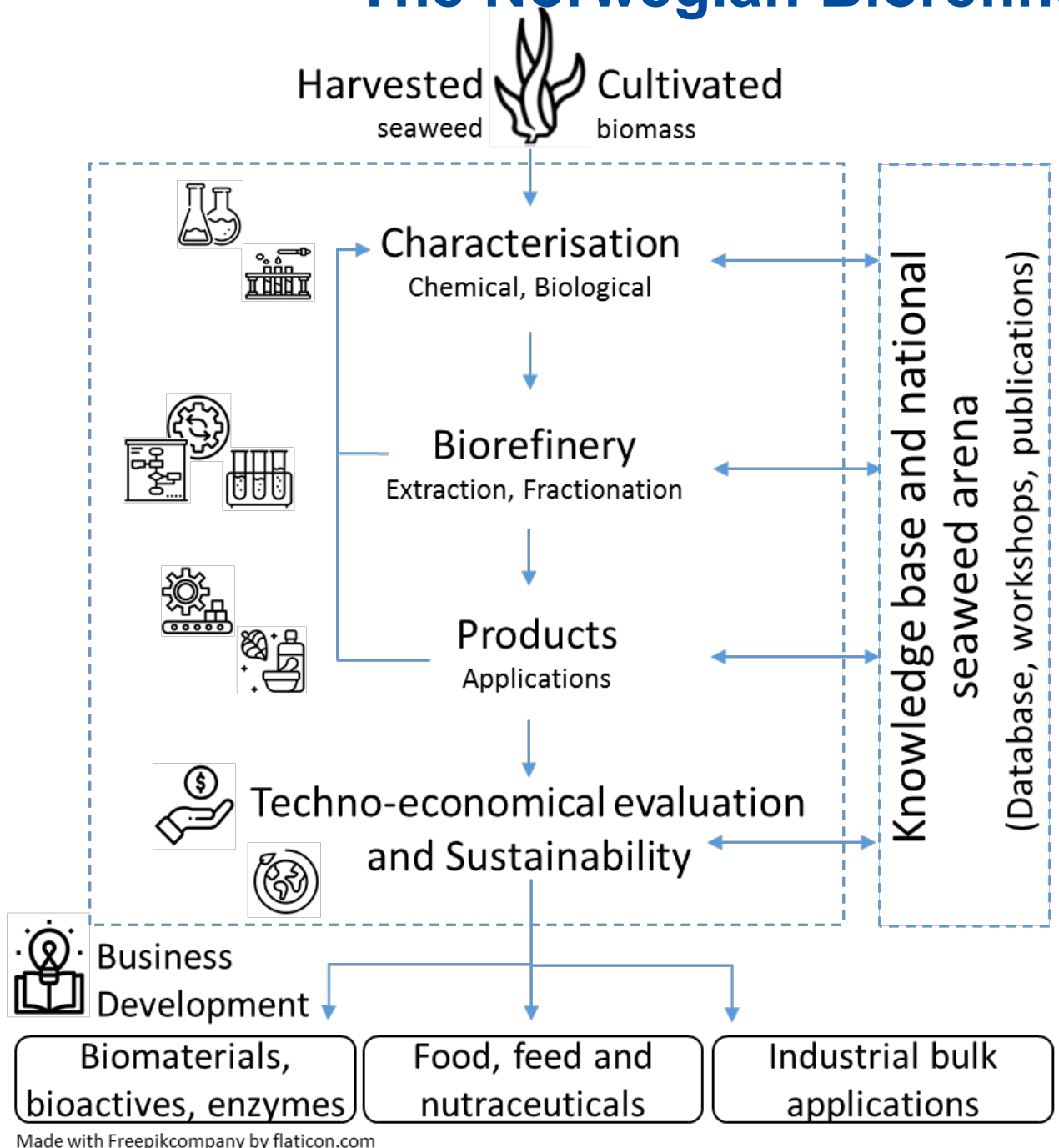


BIOREFINERY

PRODUCTS AND APPLICATIONS

RESEARCH, INNOVATION, NEW SEAWEED BASED INDUSTRY

The Norwegian Biorefinery Platform SBP-N



The main goal of the platform will be to serve as a hub for research, knowledge, methodology and stakeholder networks.

- ✓ SBP-N will aid in the regulation of macroalgae cultivation and harvesting industries, and in the characterization of macroalgae-derived products.
- ✓ Focus on characterization of the biomass, development of technology enabling future economically and environmentally sustainable biorefinery processes, and establishment of high-value and bulk product pipelines.

Norges miljø- og biovitenskapelige universitet
MØREFORSKING
Nofima
SINTEF
NTNU
Norwegian University of Science and Technology
The Research Council of Norway

WP 2 – Characterization

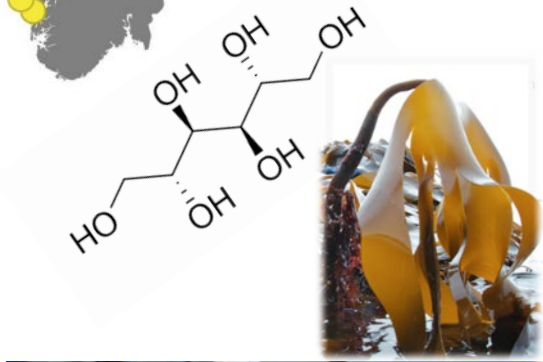
National Sampling campaign

I: 8 sites, 12 SL and 3 AE (23.04-01.07 -2020)

II: in collaboration with SES during harvest (2021)

Analytical protocols (SOP) for seaweed - Become available through publications – *and providing better understanding of the biomass*

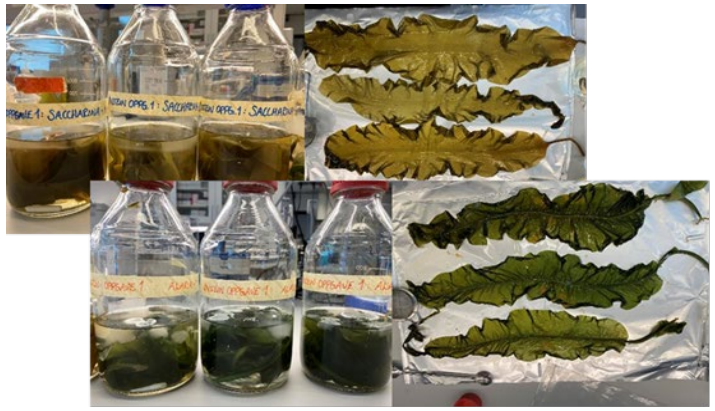
- ✓ Monosaccharide analysis (MSA) for the sugar composition
- ✓ CHNS – overall composition of the organic matter and sulfate being import for fucoidan
- ✓ Extraction protocols how to extract one component and the consequence for the other components in the biomass
- ✓ Dry matter, Ash, mineral content - especially iodine and heavy metals
- ✓ Establishment of method for arsenic speciation in seaweed
- ✓ Microbial profiling of wild and cultivated seaweed



SBP-N plans - 2022-2024

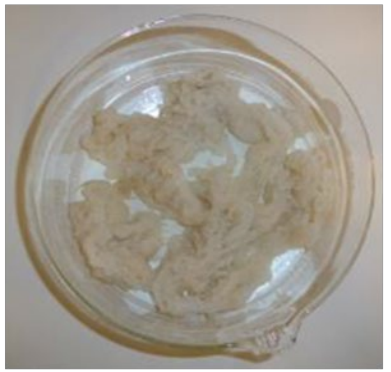
Keywords: Application-driven research, industry involvement

Sampling campaign III



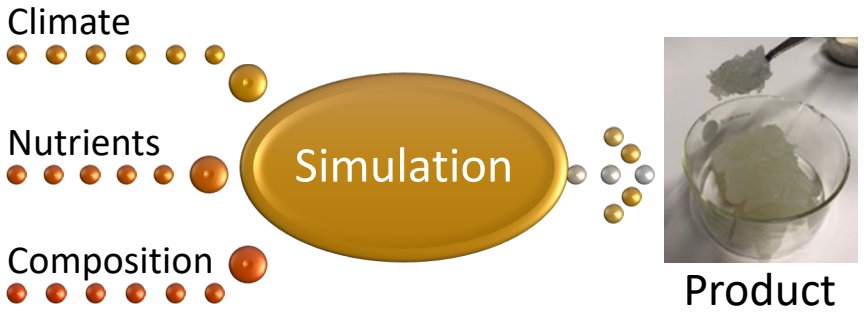
Understand seasonal variations before and during harvest

Collaboration with SAMS to map geographical differences between Scottish and Norwegian harvesting locations.



Simulate the expected composition of seaweeds to optimize the harvesting time.

Use information from sampling campaigns in combination with other available monitoring data to create a predictive model (climate, nutrients, growth, composition) for optimal harvest for selective products.



WP 3 – Seaweed biorefineries

Pretreatment and Processing

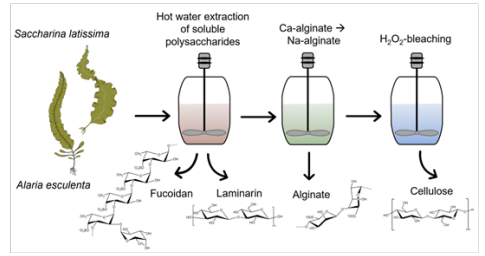
- ✓ Evaluation of quality of alginate and cellulose from acid preserved seaweed
- ✓ Evaluation of alginate extraction from fermented Saccharina latissima in collaboration with Ocean Forest

Chemoenzymatic processing and fractionation of seaweed

- ✓ Chemical sequential extraction and fractionation of four polysaccharides
- ✓ Ongoing Seaweed biorefinery – how can enzymes aid to increase yield?
- ✓ Most of the extraction are now performed in ***a consolidated manner!***

Sequential extraction and fractionation of four polysaccharides from cultivated brown algae *Saccharina latissima* and *Alaria esculenta*

Authors: Paulina S. Birgersson[1], Maren Oftebro[1], Wenche I. Strand[1], Olav A. Aarstad[1], Gerd Inger Sætrom[1], Håvard Sletta[2], Øystein Arlov[2], Finn Lillelund Aachmann[1]



Acid preservation of cultivated brown algae *Saccharina latissima* and *Alaria esculenta* and characterization of extracted alginate and cellulose

Katharina Nøkling-Eide[1,3], Fangchang Tan[2], Shennan Wang[2], Qi Zhou[2], Mina Gravdahl[3], Anne-Mari Langeng[1], Vincent Bulone[2], Finn Lillelund Aachmann[3], Håvard Sletta[1], Øystein Arlov[1*]

[1]Department of Biotechnology and Nanomedicine, SINTEF Industry, Richard Birkelands vei 3 B, 7034 Trondheim, Norway

[2]Division of Glycoscience, Department of Chemistry, School of Engineering Sciences in Chemistry, Biotechnology and Health, KTH Royal Institute of Technology, AlbaNova University Centre, SE-106 91 Stockholm, Sweden

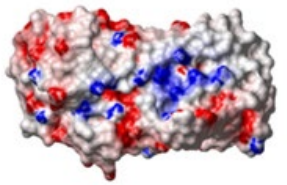
[3]Norwegian Biopolymer Laboratory (NOBIPOL), Department of Biotechnology and Food Science, NTNU Norwegian University of Science and Technology, Sem Sælands vei 6/8, 7491 Trondheim, Norway

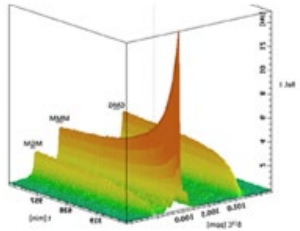
* Corresponding author oystein.arlov@sintef.no

Abstract

Production of test-batches for application testing

- ✓ Alginates (SNAP, OptiAlgea, PlastiSea)
- ✓ Fucoidan (SNAP, SFI-IB, SFI-Foods of Norway)
- ✓ Laminarin (Nutrimar, SFI-Foods of Norway, SNAP)





SBP-N plans - 2022-2024

Keywords: Application-driven research, industry involvement

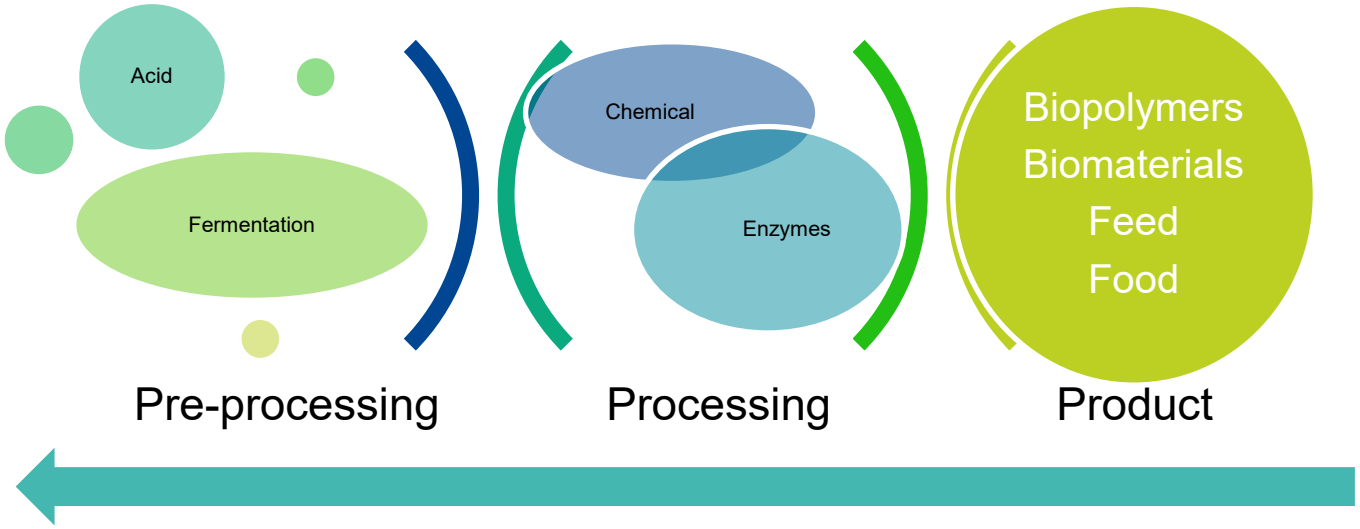
Pre-processing of Seaweed

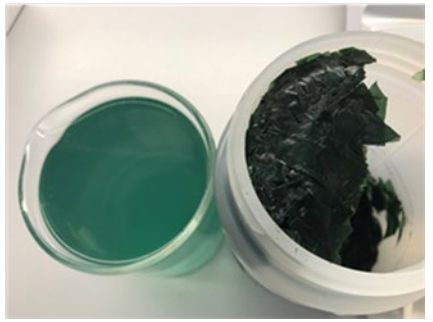
Establish new fermentation and preservation methods for seaweed, which is adapted to down stream processing.

Total Biorefinery

Dualistic understanding of a total biorefinery process

Now we are at a point were a set of pre-prosessing and processing methods enables a range of products. In a dualistic understanding it will also be possible to select product and know the correct pre-processing and processing.

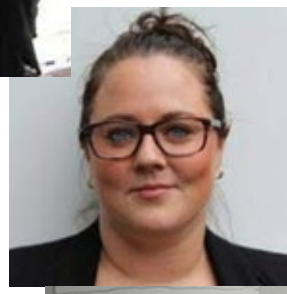


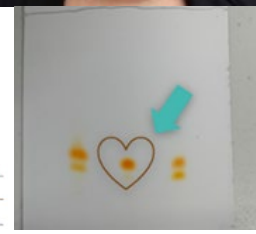


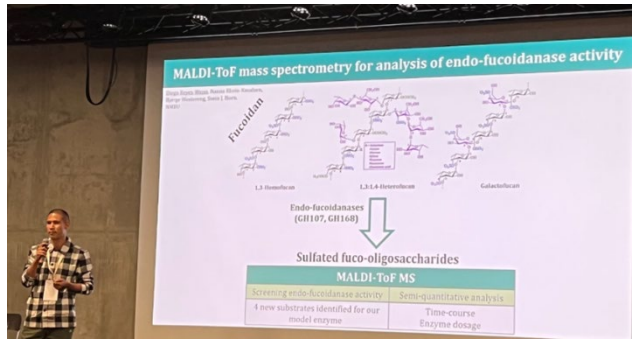
WP 3/4 – Bioactive products

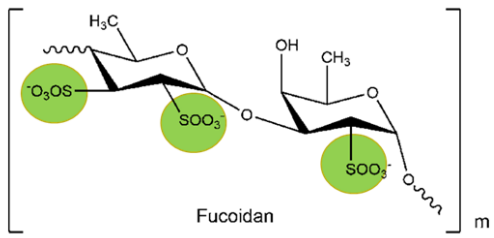
Preparation of pure seaweed components

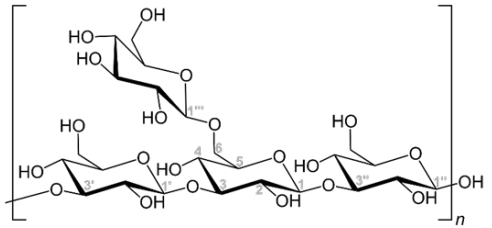
- ✓ Laminarin extraction protocol → testing in fish trials (SFI - Foods of Norway)
- ✓ Ongoing activity on fucoidan extraction and fractionation protocol (SNAP, SFI-IB)



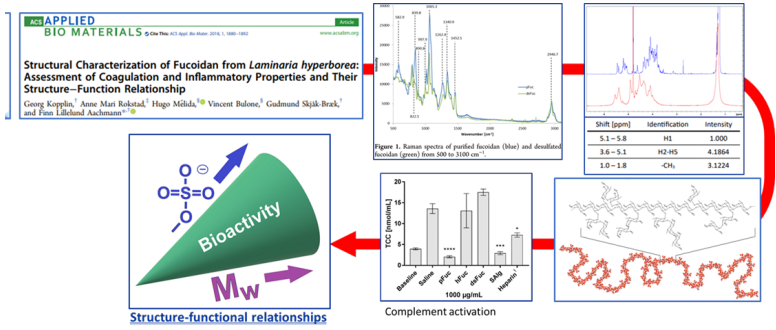








Products from yeast- and cereal-based beta glucans



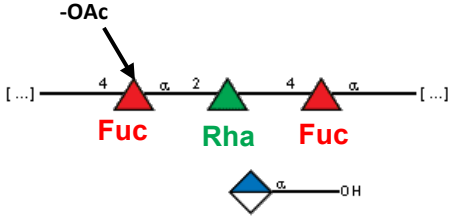
SBP-N plans - 2022-2024

Keywords: Application-driven research, industry involvement

Fucoidan

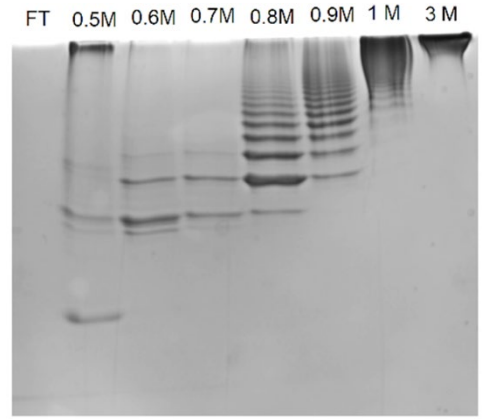
Characterization of Fucoidan from selected Norwegian kelps

Aim to characterize fucoidan from relevant Norwegian kelps. Understand the difference between. Further development of extraction, purification and fractionation protocols will be emphasized.



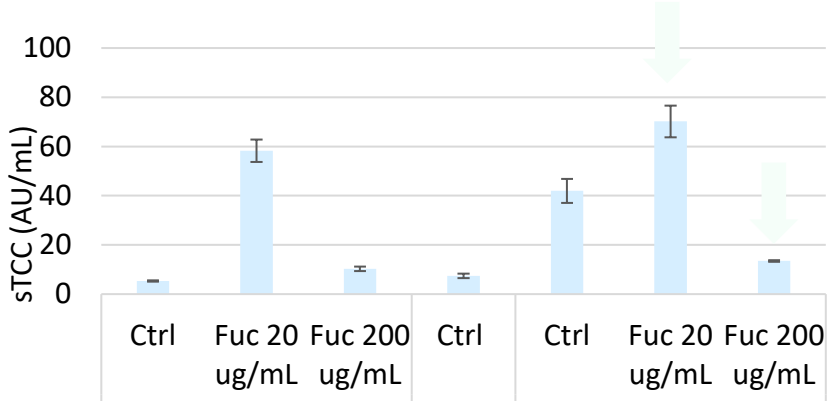
Fucoidan Modifying Enzymes

Aim to characterize both fucoidan and fucoidan modifying enzymes. Fine-structure elucidation of enzymatically degraded oligosaccharides.

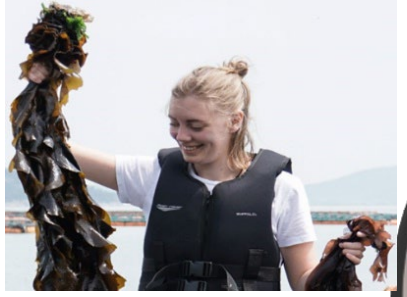


Biological activity

Aim to identify and understand biologically active fucoidans. Biological testing of polymeric, desulphated and oligosaccharides from fucoidan. Based on biological results, relevant feed-trials will be considered.



WP 4 – Products and applications



Polysaccharides for high costs and industrial applications

- ✓ Enzymatic tailored alginate designed to specific applications
- ✓ An alternative ressource of Oligo-G

Proteins and peptides for food and feed applications

- ✓ Test of seaweed as salt-replacer and flavour ingredients

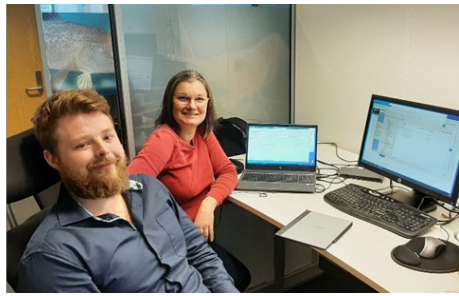
Processed seaweed as food ingredients

- ✓ Blanching of Norwegian sugar kelp and winged kelp
- ✓ Effects of novel seaweed ingredients on gluten-free bread quality

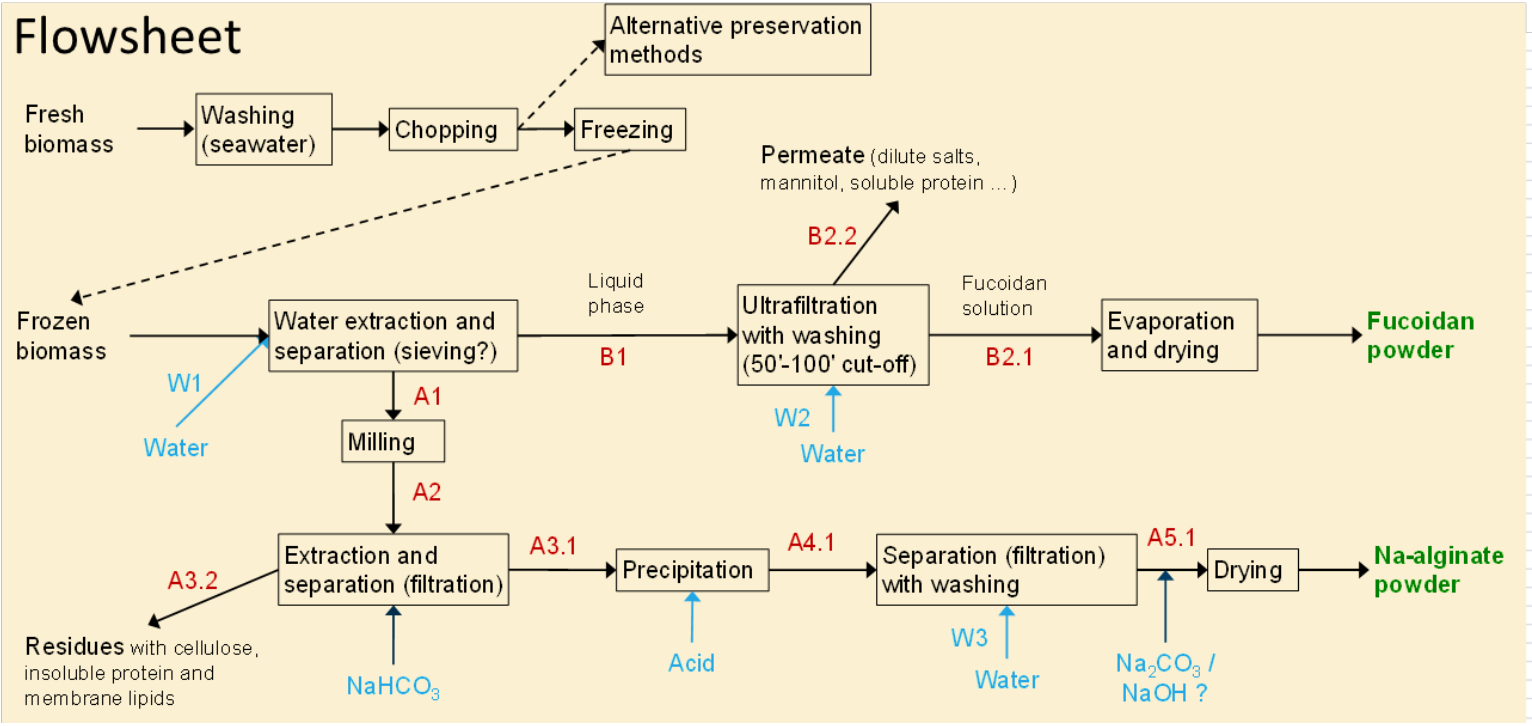
Novel products

- ✓ Bioplastics based on alginate, cellulose and residual seaweed materials (PlastiSea)

WP 5 – Sustainability and techno-economical evaluations



Energy Flow, Techno-economical assessment and Value chain



Mass balance

Alginate extraction and separation			*In: A2 (milled biomass after separa*	
		tonne	t/h	
Solids [t]		77	0,01	
Water [t]		838	0,10	
Added water [t]				
Dilution before extraction		2 000		Alginate concentration [g/
Washing on the filter		4 000		
Total water		6 838	0,85	
Total mass		6 915	0,86	
Water in residue [t]		330	0,04	5 % insoluble dw in residu
Added chemicals				
NaOH [g/kg]				
NaHCO3 [kg/kg tv]	1,5			
NaOH [t]	0,0			
NaHCO3 [t]	150			

	A3.2				
	'Residue' [t]				
Components	Total	Comp [% of dw]	Soluble	Insoluble	Yield [%]
Laminaran	0,03	0,2	0,03	0,0	3,5
Mannitol	0,3	1,6	0,32	0,0	2,6
Alginate	2,1	10,4	1,00	1,1	10
Fucoidan	0,1	0,3	0,06	0,0	1,1
Cellulose	6,0	29,6	0,00	6,0	100
Protein	6,7	33,3	0,21	6,5	61
Polyph+Lip+Fucx	2,4	12,0	0,03	2,4	81
Minerals	2,6	12,7	1,23	1,4	6,4
SUM	20,3	100	2,9	17,4	
Seaweed solids	20,3		3	17	0
Added chemicals	7,2		7,2	0,0	
Water	330				
Total mass, inc. chemicals	358				

Selected products

- ✓ Alginate and fucoidan, from the same raw material
- ✓ Can be extended to isolate cellulose from the residues.

- ❑ Expand the mass-balance model with cost data – will benefit from SFI-IB, which also involves TEA

SBP-N plans - 2022-2024

Keywords: Application-driven research, industry involvement

Establish bioactivity testing protocol to characterize the biological active of well characterized molecules and factions from seaweed.

Material prototypes (gel-based and/or bioplastics) based on seaweed biopolymers like alginate and cellulose

Make seaweed-based food ingredients making a more natural ingredient in term of salt-replacer, flavour and structural / rheological properties.

Calculation of investment for a biorefinery of alginate and fucoidan.

Operating costs, investment analyses, product prices for profitability as a function of the feedstock costs, biomass costs. Sensitivity analysis on scale, product yields, energy costs.

SBP-N plans - 2022-2024

- **Seaweed Applications II**

Opportunities and Challenges 2023

22-24 March 2023 Jegtvolden

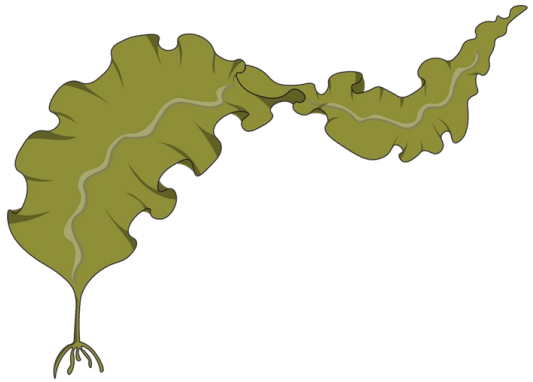
- **Newsletters**
- **SIG Seaweed meeting (annually)**
- **Seagriculture 2023**
- **Forskningsdagene (annually)**
- **Researchers Night (annually)**

12th International Seaweed Conference EU

Seagriculture

21 - 22 JUNE 2023

TRONDHEIM, NORWAY



Thank you for your attention!

Foto: Olav Øiehaug

SEAWEED INDUSTRY
-A part of the solution for a new bioeconomy in Norway