

~~SPÖITZ~~

# Chemicals of Seaweed

*Past, Present, and Future*

A Focus on Important Agriculture and  
Industrial Applications of Marine Biomass

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Head of Science, Spoitz Liquified Seaweed





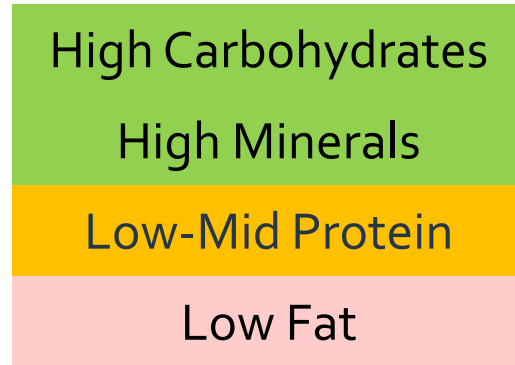


# Seaweed

## *General Information*

# Seaweed Families and Major Constituents

Seaweed =



→ **Once Dry**

Composition varies

- Species
- Harvest Season – growing cycle (early vs. late)
- Location (temperature, light intensity)
- Availability of Nutrients – **Seaweed = environment**

**Red**  
*Rhodophyceae*



**Brown**  
*Phaeophyceae*



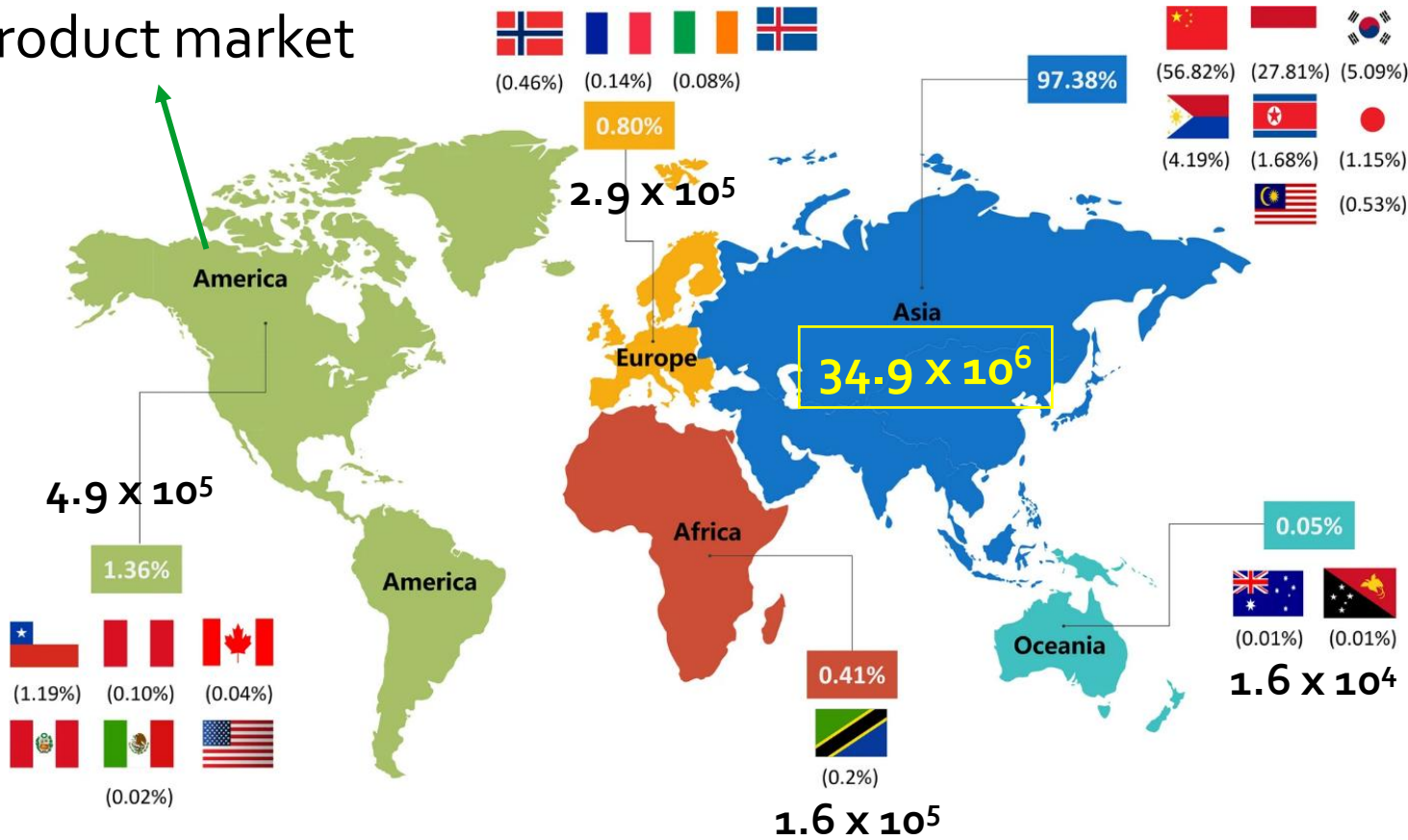
**Green**  
*Chlorophyceae*





# Global Market Estimates

20% global product market



All values, metric tonnes (1000 kg)

## Raw Seaweed Production, 2019

$34.7 \times 10^6$  tonnes cultivated

$1.1 \times 10^6$  tonnes harvested

## Seaweed Product Market, 2017

Food	10,748	82 %
Feed	391	3 %
Agriculture	338	3 %
Others*	1,593	12 %

\*fuel, cosmetics, and pharmaceuticals

# Seaweed Chemicals

## *Historical Uses*



## Minerals - Potassium

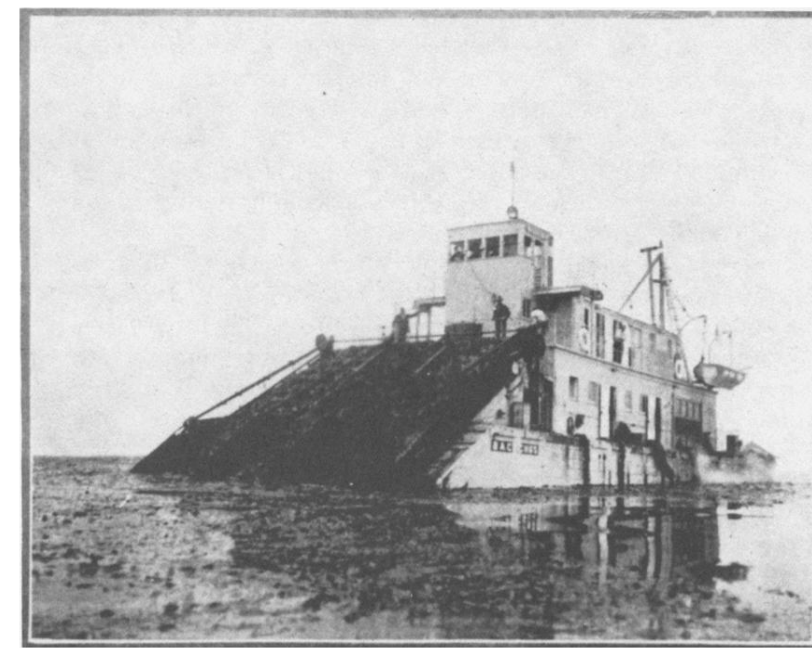
Most abundant minerals in dry **kelp**: chloride (10-30%) and potassium (8-16%)

### WWI put pressure on potassium for US Farmers

- » 1914, Germany placed an embargo on potash – price increased 20x
- » 1911 and 1915 – USDA published reports on kelp as a domestic K source
  - “The amount of potash from dried kelp ran about 12% per ton”
- » 1915, Fermentation of kelp for potassium and acetone
- » 1916, Hercules plant in Chula Vista: 1,100 workers (24/7)  
350,000 tonnes/year (1916-1918)

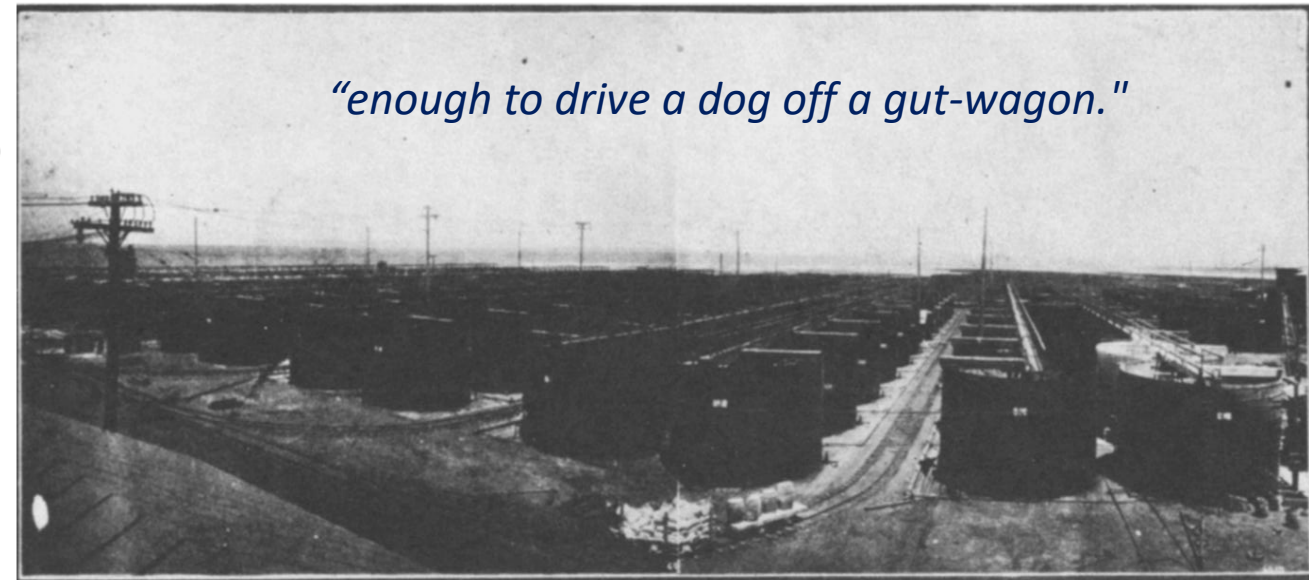
### Largest processing of seaweed in US history

- » 1919, Potash import resumes with Germany = the end



Kelp Harvester, *Bacchus* (San Diego)

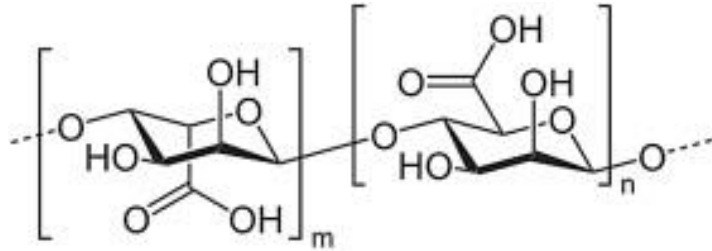
### California Kelp Fermentation Tanks (50,000 gallons)



*“enough to drive a dog off a gut-wagon.”*



# Carbohydrates Phycocolloids



Alginic Acid

(1,4)  $\alpha$ -L guluronic acid (G),  $\beta$ -D mannuronic acid (M)  
High G:M = brittle gels, Low G:M = flexible gels

## Brown Seaweeds

Ascophyllum, Ecklonia, Laminaria, Macrocystis,

Thickening, gelling, film formation and stabilizing

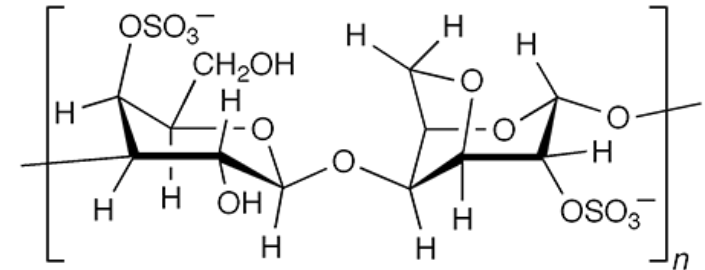
**\$730M (2020)**

## Structure

## Sources

## Applications

## Market



Carrageenan

(1,3 and 1,4) galactose disaccharides  
Multiple sulfation and anhydro patterns

## Red Seaweeds

Kappaphycus, Eucheuma, Chondrus, Gigartina

Thickening, gelling, film formation and stabilizing

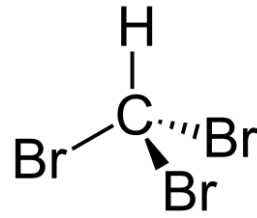
**\$932M (2020)**



# Seaweed Chemicals *Modern Uses*



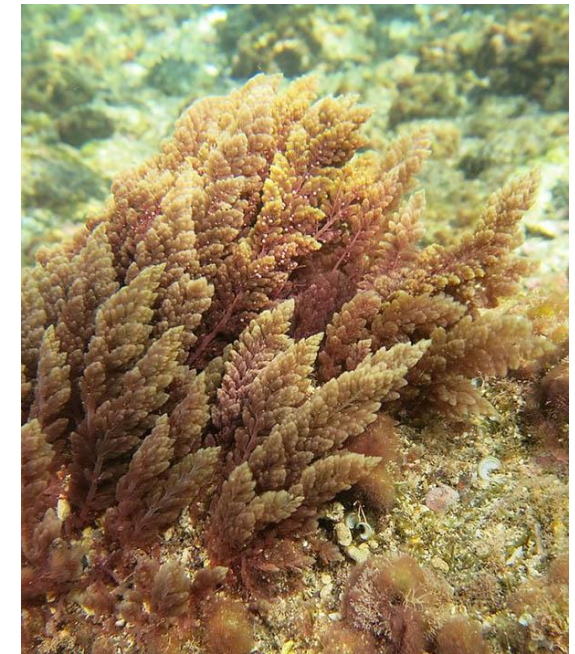
## Bromoform, $\text{CHBr}_3$



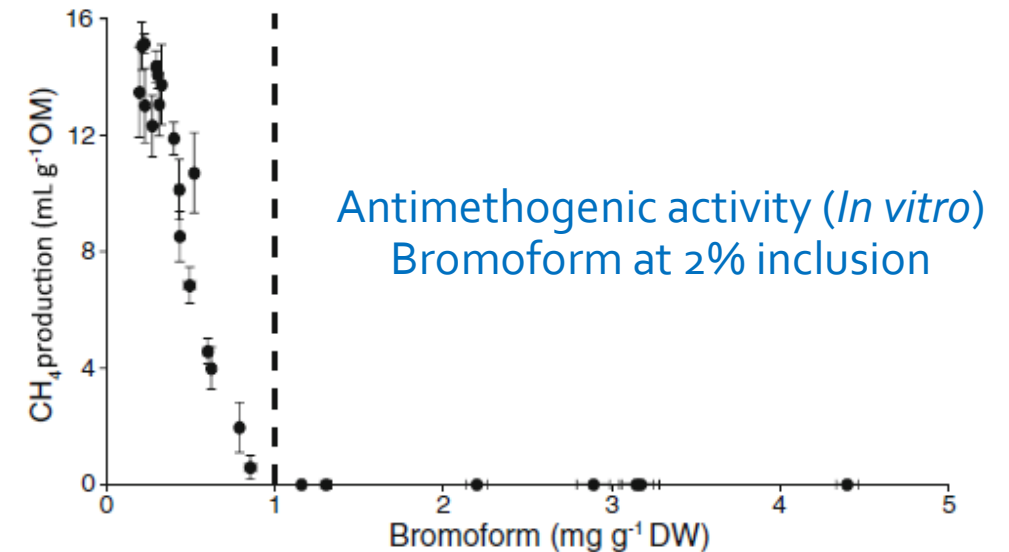
Bromoform rich *Asparagopsis spp.* can reduce  $\text{CH}_4$  emissions by up to 98% at concentrations of 0.5 – 2% of dry matter intake inclusion in feeds

## Reduction of Ruminant Enteric Methane Emissions

- » 2014 – CSIRO (Australia) identify *A. taxiformis* as antimethanogenic seaweed
  - DOI: 10.1371/journal.pone.0085289 + files worldwide patent
- » 2016+ – Animal trials show methane reduction in ruminants
  - 80% in Sheep @ 3% DOI: 10.1071/AN15883
  - 67% in Dairy @ 1% DOI: 10.1016/j.jclepro.2019.06.193
  - 98% in Beef @ 0.2% DOI: 10.1016/j.jclepro.2020.120836
  - 52-80% in Dairy @ 0.5% DOI: 10.1371/journal.pone.0247820
  - 99% in Beef @ 51 mg/kg diet DM DOI: 10.1093/jas/skae109
- » Bromoform decreases methanogens present in rumen
  - Review - DOI: 10.1016/j.algal.2022.102673



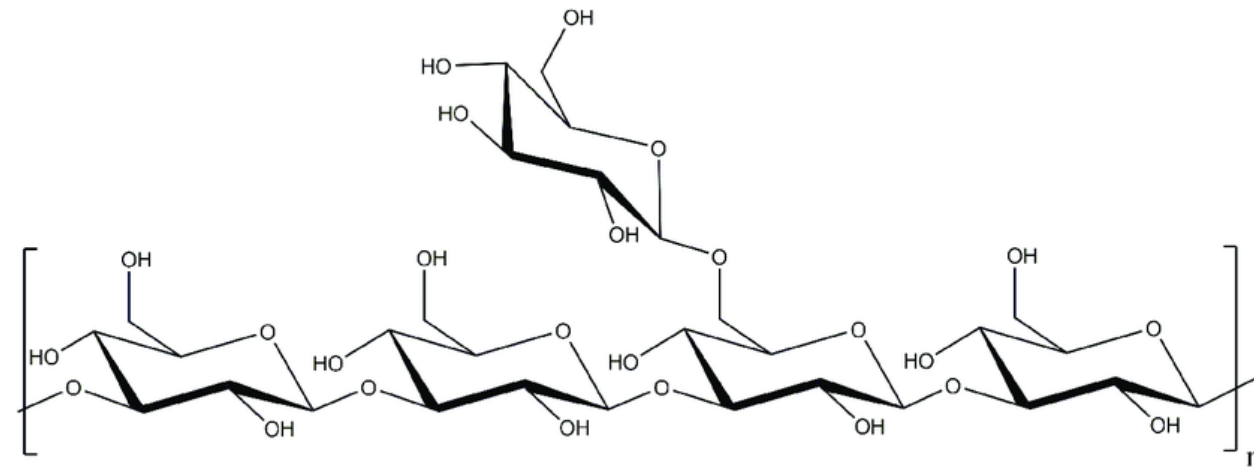
*Asparagopsis taxiformis*



The effects of processing on the *in vitro* antimethanogenic capacity and concentration of secondary metabolites of *Asparagopsis taxiformis*. DOI:10.1007/s10811-016-1004-3

# Laminarin, Fungicide

(1,3)-linked glucose with (1,6)-branching  
brown seaweed (dry weight): up to 35%



Laminarin General Structure

## Biofungicide for Agricultural Applications

- » 2003 – **Activate** plant natural defence mechanisms – H<sub>2</sub>O<sub>2</sub> production
  - Grapes @ 0.1-1.0 g/L DOI: 10.1094/MPMI.2003.16.12.1118
- » 2010 – **Safe**: EPA regulation 40 CFR 180.1295: exemption from the requirement of a tolerance for residues of laminarin on food commodities when applied preharvest.

### FIFRA Label (UPL)

- » Fungicide Resistance Action Committee (FRAC) under host/plant defense induction  
Category: Po<sub>4</sub> polysaccharide elicitors
- » 2015 – NOSB accepted for use on **organic** operations

Group	<b>P4</b>	Fungicide
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**Vacciplant**®

STIMULANT OF PLANT DEFENSE REACTIONS

<b>Active Ingredient:</b>	
Laminarin.....	3.51%
<b>Other Ingredients:</b> .....	<u>96.49%</u>
<b>Total</b> .....	100.00%

<b>ACCEPTED</b>
Jan 07, 2022
Under the Federal Insecticide, Fungicide and Rodenticide Act as amended, for the pesticide registered under EPA Reg. No. 70506-608



Seaweed Chemicals  
*Future Uses*



## Seaweed Biostimulants

Stimulate plant nutrition processes independently of the product's nutrient content with aim of improving the plant or the plant rhizosphere

### Biostimulant for Plant and Soil Health

- » Seaweed extracts: **stimulate root growth, improve abiotic stress resistance, nutrient uptake**
  - Application: foliar, soil drench, seed coatings, different growth stages
  - EBIC, 2023: Recent insights into the mode of action of seaweed-based plant biostimulants
- » Mechanism not fully understood – what chemicals are most important?
  - Several compounds have been proposed: carbohydrates, betaines, polyphenols...
  - Polymers vs. Oligomers, degree of sulfation, etc.
- » Plant biostimulants based on seaweed extracts: 758 million dollars (2021)
- » Global regulation is varied – Biostimulant is not a “global” term
  - 2018 – Agriculture Improvement Act defined Biostimulant (USA)
  - 2022 – Product Function Category 6: “Biostimulant” (Europe, (EU) 2019/1009 )
  - 2023 – Plant Biostimulant Act introduced, currently not passed (USA)

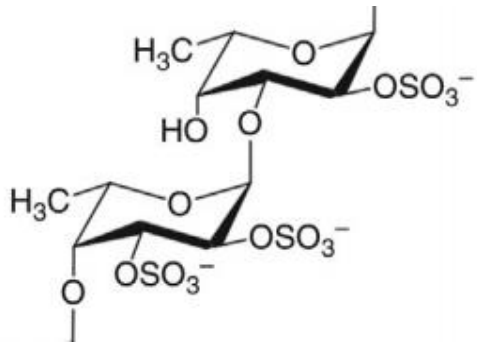




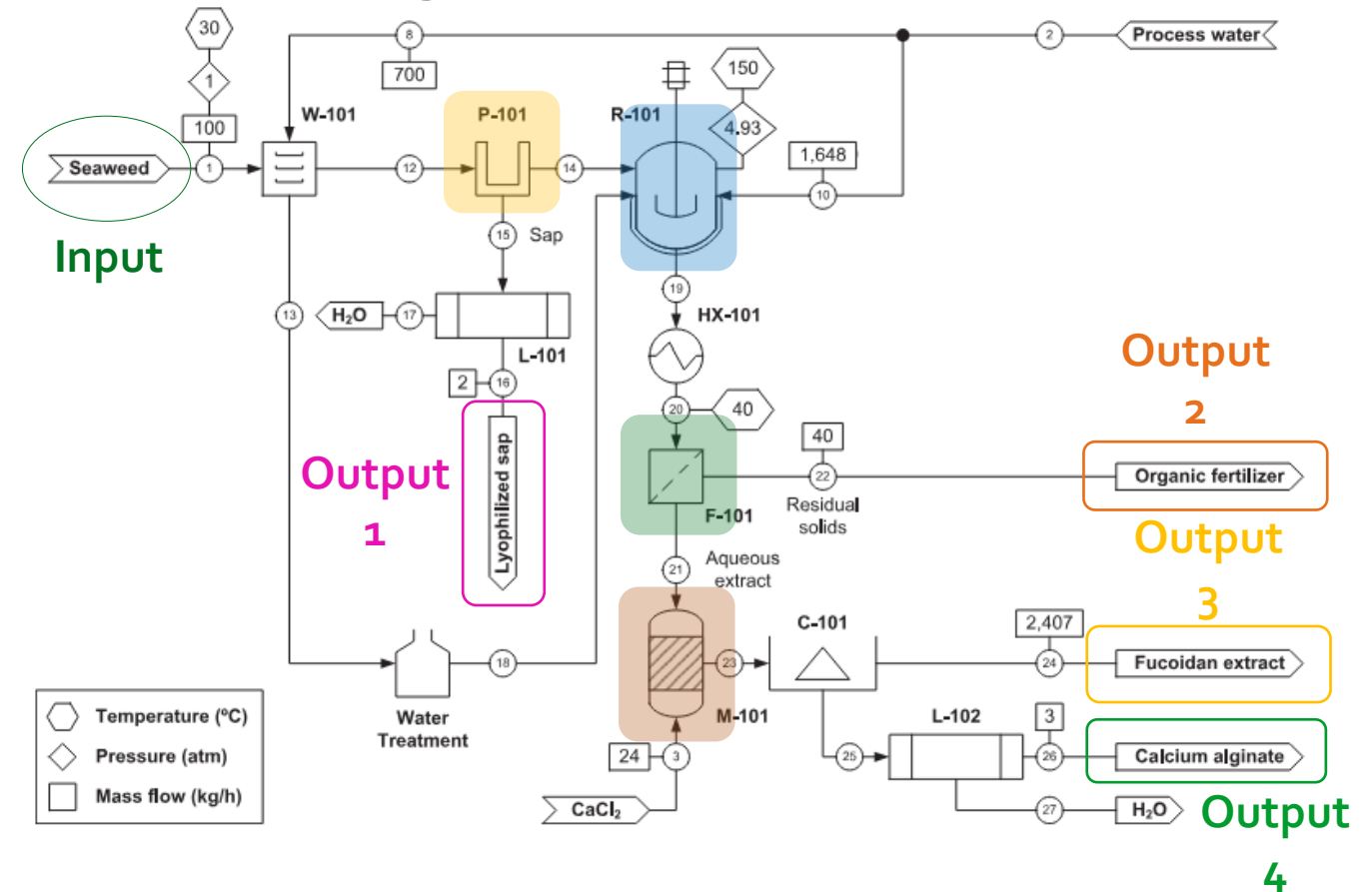
# Seaweed Biorefining & Fucoidan

(1,3) and (1,4)-linked fucose with varying sulfation patterns.  
Up to 30% of some brown seaweed

## Seaweed as a Pharmaceutical Development Target



- » Fucoidan: Extremely variable chemical structure
  - Structure Review DOI: 10.3389/fpls.2020.556312
- » Bioactivity is dictated by many factors: structure, molecular weight, sulfation
  - Bioactivity Review DOI: 10.3390/md17030183
- » May be manufactured using a biorefinery to produce multiple product streams
  - *S. muticum* DOI: 10.1016/j.biortech.2021.126152

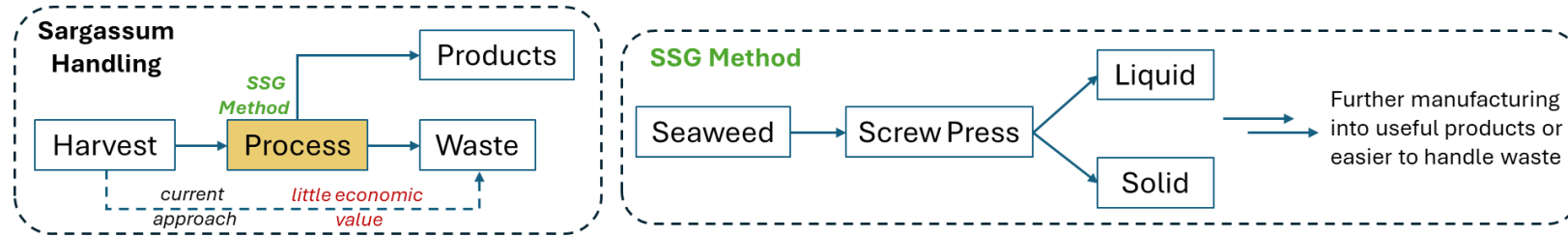




*Thank You*

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# SPOITZ



Decrease volume of solid waste (4:1) | New product streams | Quality managed product streams: Food, Agriculture, Materials, Health



Sargassum – Caribbean/Florida



Kelp – Alaska/Western Canada

Systems Engineering, Installation, and Optimization  
 Product Development, Training, and Quality Management  
 Support Government, Industry, and Academia Initiatives