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EXTRACTION OF PROTEIN FROM MACROALGAE

INGRID UNDELAND, PROFESSOR

CHALMERS –FOOD AND NUTRITION SCIENCE

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Food and Nutrition Science-Chalmers
-Marine research group

We need a protein shift

The climate cannot handle the amount of animals we eat. There needs to be a protein shift, according to researcher Karolina Östbring who is involved in the Sustainability Week. Her vision is to create a platform for research on vegetable proteins at LU.

The protein shift: From fauna to flo

•Published on Published onAugust 25, 2016

The Protein Shift: Plant-Based Options

by Sanna Delmonico, MS, RDN, CHE on Oct 14, 2016

CEC Feature: How we're getting more protein in our diets without eating more meat.

Livsmedel ifokus.se LivsmedelsFöreningen

Livsmedelsdagarna LivsmedelsFöreningen Om Livsmedel i Fokus Branschguiden

11 MAJ 2016

Proteinskifte på gång

Livsmedelsindustrin står inför ett proteinskifte. Vilka utmaningar och möjligheter finns? Det tänker konsultföretaget Macklean belysa i nästa nummer av Insikter som presenteras på Livsmedelsdagarna den 7 september. För att få input till rapporten, bjöd Macklean in studenter till en workshop.

en av studenterna som deltog i Mackleans workshop om proteinskiftet. Längst till Ulf Berglund.

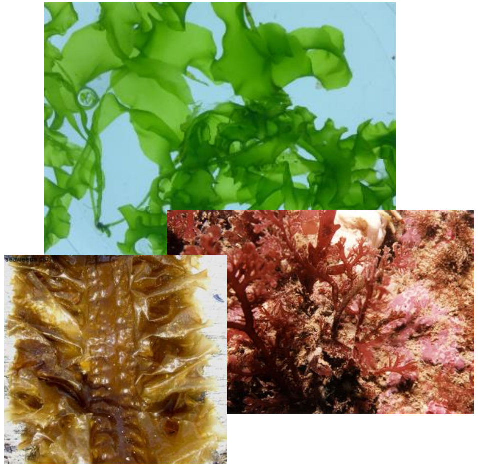
The protein shift!

From **red** to **blue**

From **red** to **green**

The protein shift!

From **red** to **blue**



- No need for watering/fresh water
- No need for pesticides and insecticides
- Remediates N, P
- Uptake of CO_2
- Effective growth rate per area
- No competition for arable land

Potential to cultivate large amounts!

Photo from Göran Nylund,GU

<90 ton algae biomass/ha/year

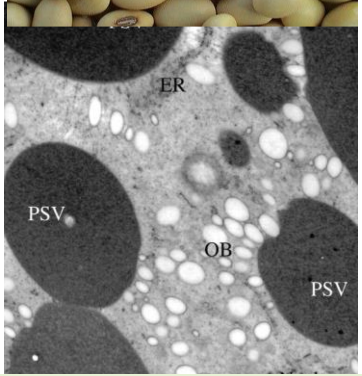
4-15 tons protein/ha/year

Photo from Wikimedia Commons

2.5 ton soy beans/ha/year

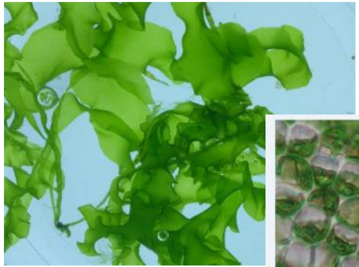
0.6-1.2 ton protein/ha/year

But, protein extraction more challenging from seaweed than e.g. beans!



Protein in storage vacuoles (PSVs)

Schmidt et al. Plant Physiology, May 2011, Vol. 156, pp. 330–345



Photosynthetic!

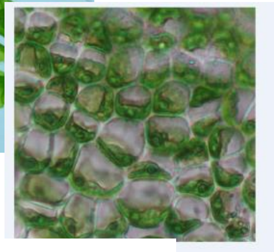
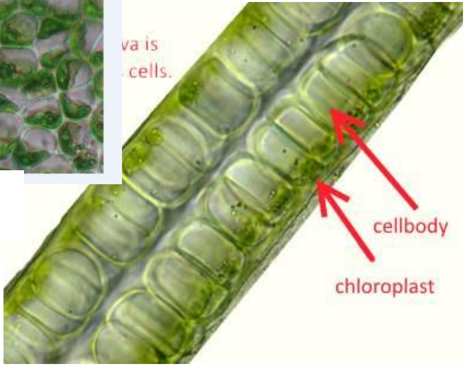
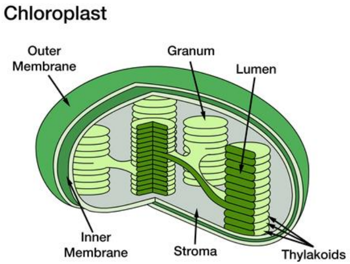


Photo: Sophie Steinhagen





Proteins mainly in the form of enzymes and structural proteins

Steinhagen, et al. (2019). European Journal of Phycology, DOI: 10.1080/09670262.2019.1597925
https://pixels.com/featured/chloroplast-from-red-alga-griffithsia-sp-dennis-kunkel-microscopyscience-photo-library.html
https://awhitebiology.weebly.com/chloroplasts.html

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Swedish initiatives to cultivate and use seaweed for multiple products

KTH

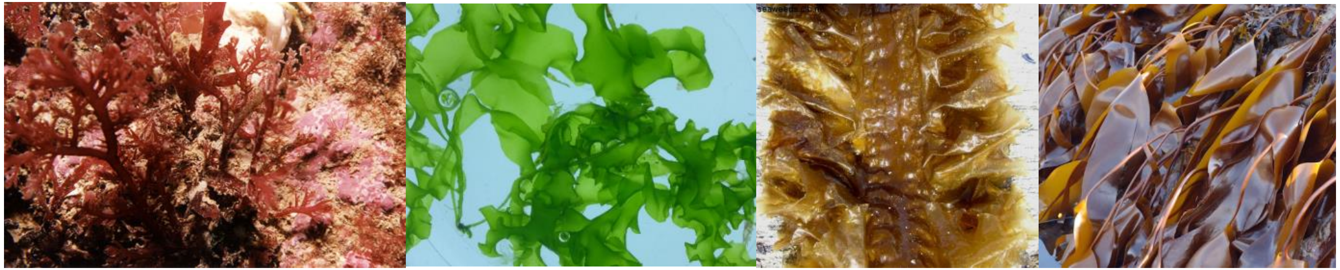
CHALMERS

GÖTEBORGS UNIVERSITET

Linnéuniversitetet

LUNDS UNIVERSITET

Forskningsrådet Formas



SWEAWEED

CirkAlg

seafarm

Makroalger för ett biobaserat samhälle

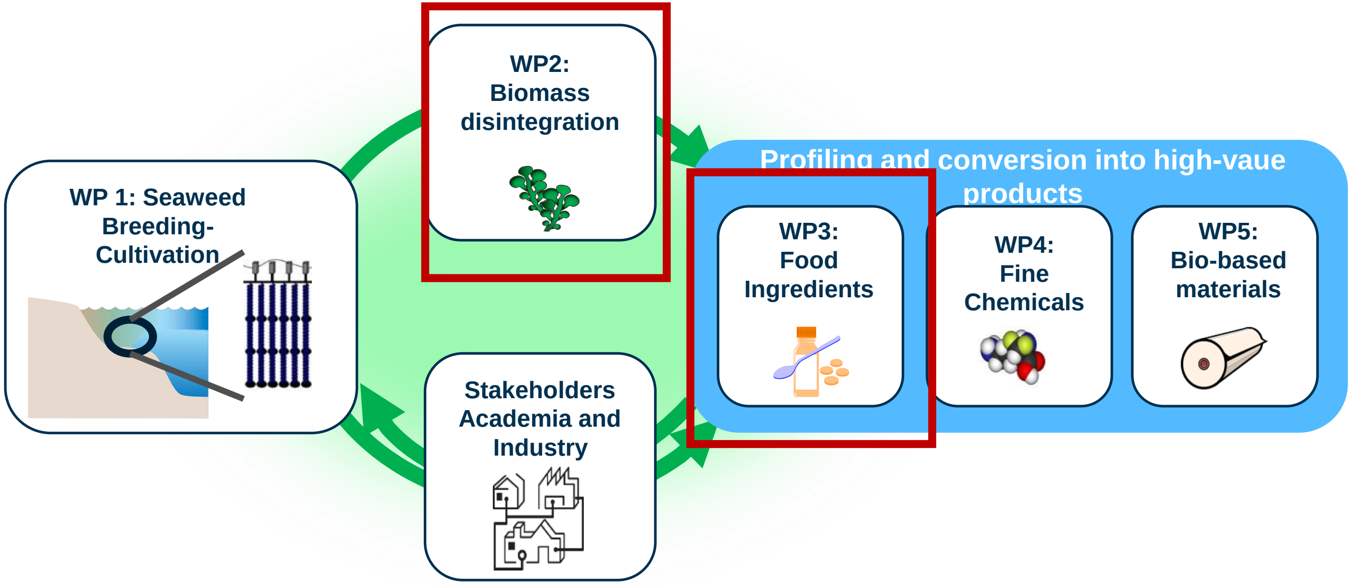
STIFTELSEN för STRATEGISK FORSKNING

FORMAS

Ingrid Undeland, Chalmers

Seaweed proteins –a contribution to the protein shift?

SWEAWEED



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pH-shift process for concentrating of protein

Homogenizing in water
algae + water (≥1:3)

↓

Protein solubilization
pH → ~12

↓

Centrifugation

↓

Precipitation
pH → ~2

↓

Centrifugation

↓

Protein isolate

↓

Drying

We have evaluated:

- Season
- Preservation

- Water volume
- Osmotic shock
- Enzymes
- Temperature/time

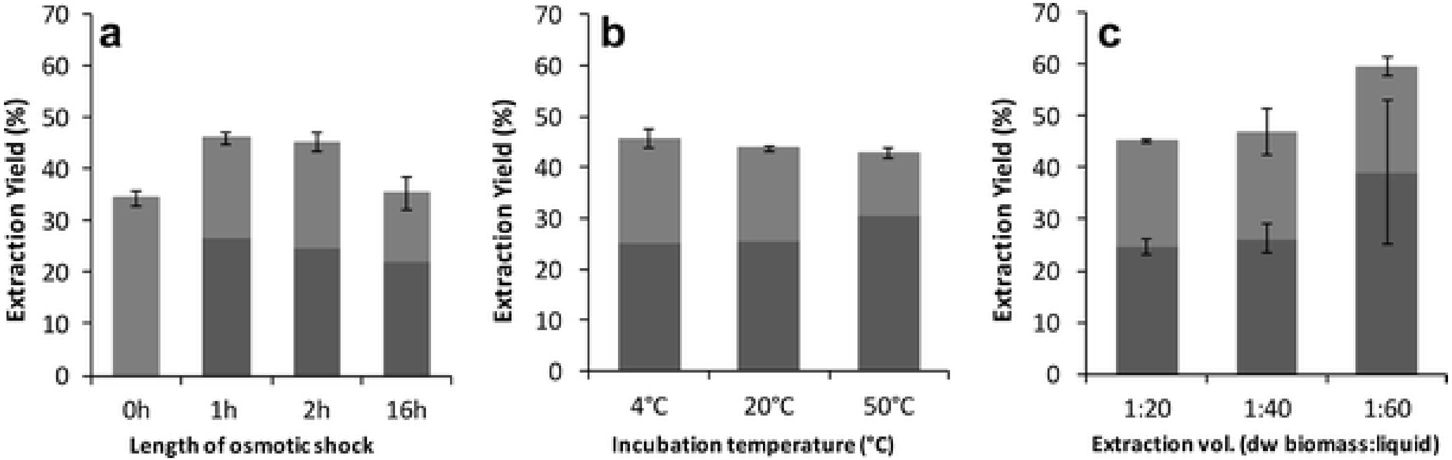
- Freeze thawing

- Nutrient profile
- Functionality
- Bioavailability

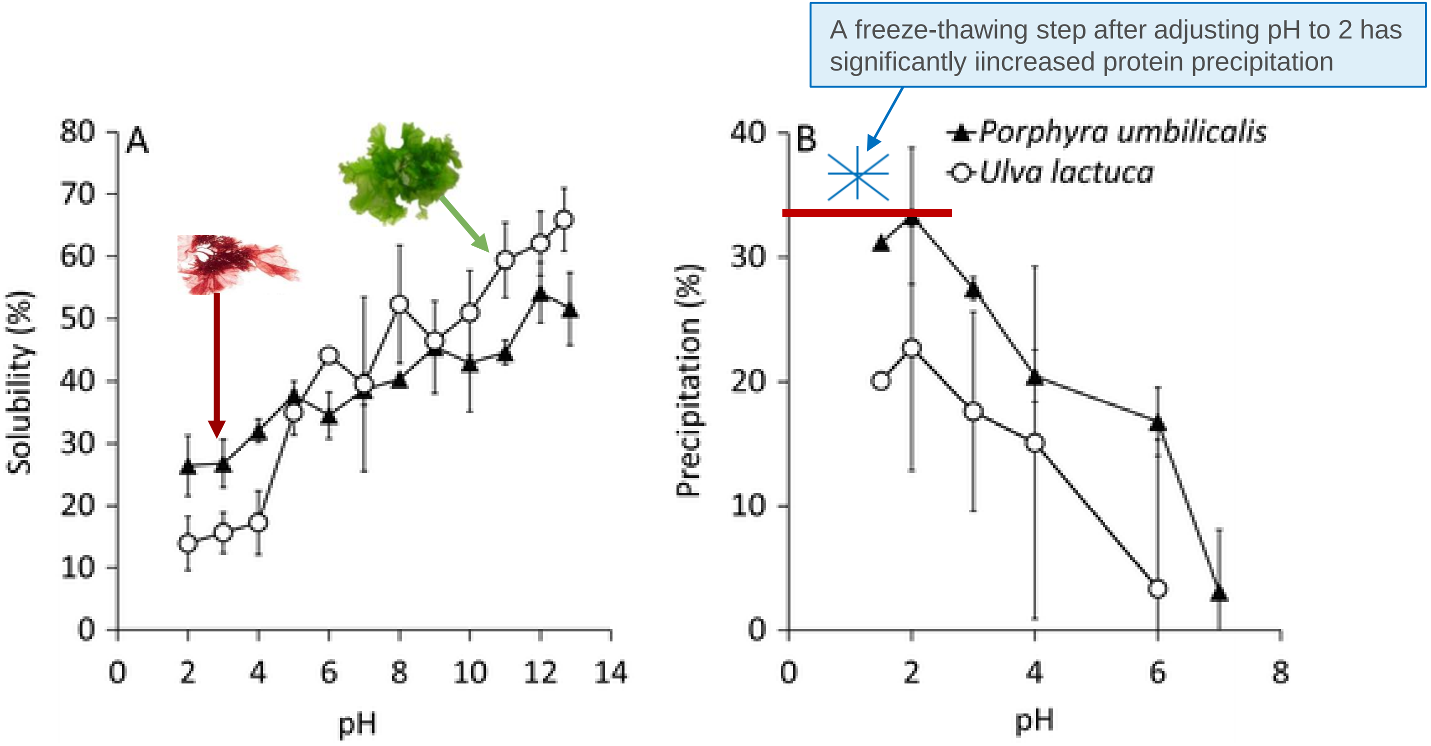
- Comparison to other methods

Ingrid Undeland, Chalmers

Effect of osmotic shock, temperature and water volume on extraction yield



Solubility and precipitation as a function of pH



Harrysson et al. *J Applied Phycol* (**2018**) 30: 3565-3580

Journal of Applied Phycology (2018) 30:3565–3580
https://doi.org/10.1007/s10811-018-1481-7

CrossMark

Production of protein extracts from Swedish red, green, and brown seaweeds, *Porphyra umbilicalis* Kützing, *Ulva lactuca* Linnaeus, and *Saccharina latissima* (Linnaeus) J. V. Lamouroux using three different methods

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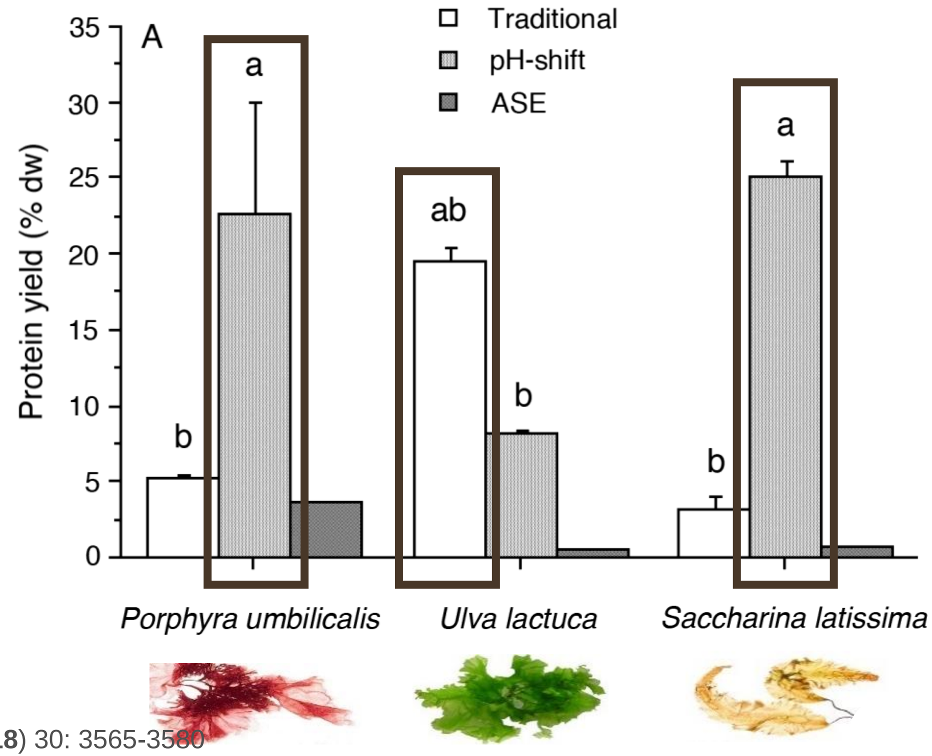
Abstract

The demand for vegetable proteins increases globally and seaweeds are considered novel and promising protein sources. However, the tough polysaccharide-rich cell walls and the abundance of polyphenols reduce the extractability and digestibility of seaweed proteins. Therefore, food grade, scalable, and environmentally friendly protein extraction techniques are required. To date, little work has been carried out on developing such methods taking into consideration the structural differences between seaweed species. In this work, three different protein extraction methods were applied to three Swedish seaweeds (*Porphyra umbilicalis*, *Ulva lactuca*, and *Saccharina latissima*). These methods included (I) a traditional method using sonication in water and subsequent ammonium sulfate-induced protein precipitation, (II) the pH-shift protein extraction method using alkaline protein solubilization followed by isoelectric precipitation, and (III) the accelerated solvent extraction (ASE®) method where proteins are extracted after pre-removal of lipids and phlorotannins. The highest protein yields were achieved using the pH-shift method applied to *P. umbilicalis* (22.6 ± 7.3%) and *S. latissima* (25.1 ± 0.9%). The traditional method resulted in the greatest protein yield when applied to *U. lactuca* (19.6 ± 0.8%). However, the protein concentration in the produced extracts was highest for all three species using the pH-shift method (71.0 ± 3.7%, 51.2 ± 2.1%, and 40.7 ± 0.5% for *P. umbilicalis*, *U. lactuca*, and *S. latissima*, respectively). In addition, the pH-shift method was found to concentrate the fatty acids in *U. lactuca* and *S. latissima* by 2.2 and 1.6 times, respectively. The pH-shift method can therefore be considered a promising strategy for producing seaweed protein ingredients for use in food and feed.

Keywords Seaweed · Protein extraction · Ammonium sulfate precipitation · pH shift · Accelerated solvent extraction (ASE®) · Amino acids

Effect of process method and species on protein yield



Harrysson et al. *J Applied Phycol* (**2018**) 30: 3565-3580

Protein, fat and ash of the extracts

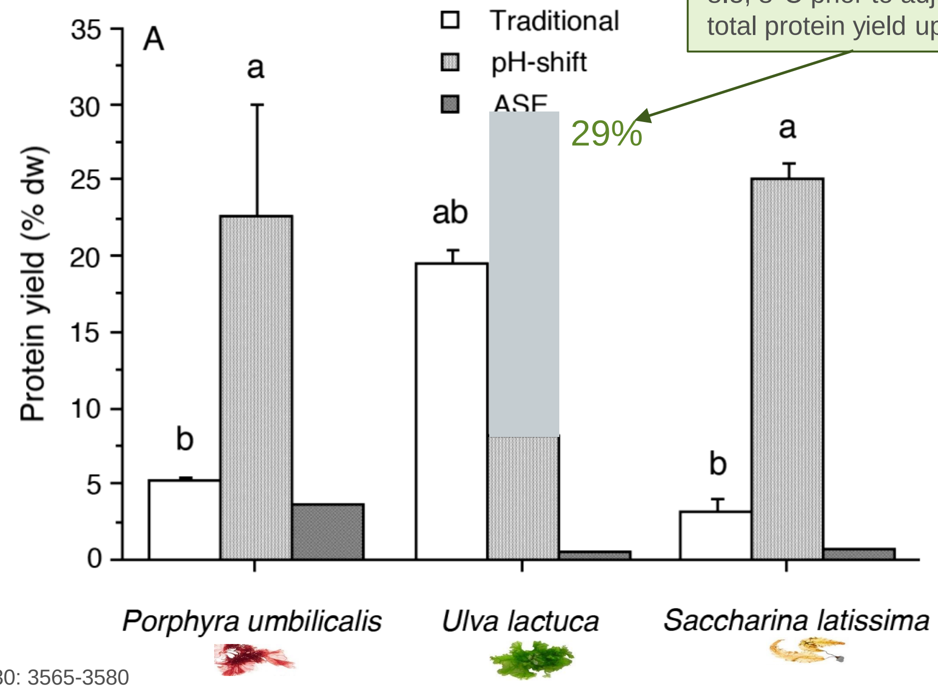
	∑ Amino acids[a] (% dw)	∑ Fatty acids[b] (% dw)	Ash[c] (% dw)
Dry *Porphyra*	**31.8**	**2.5**	**23.2**
Porphyra traditional	13.9	0.5	3.1
Porphyra pH-shift	71.0	2.2	4.7
Porphyra ASE	21.2	0.7	46.3
Dry *Ulva*	**19.6**	**2.3**	**26.0**
Ulva traditional	10.7	0.7	1.1
Ulva pH-shift	51.2	5.0	13.9
Ulva ASE	13.0	2.1	51.3
Dry *Saccharina*	**10.1**	**2.1**	**49.6**
Saccharina trad.	1.9	0.1	2.6
Saccharina pH-shift	40.7	3.3	15.9
Saccharina ASE	5.0	1.6	67.7

EAA%:
40→42.5
after pH-shift
processing

Harrysson et al. *J Applied Phycol* (**2018**) 30: 3565-3580

Effect of process method and species on protein yield

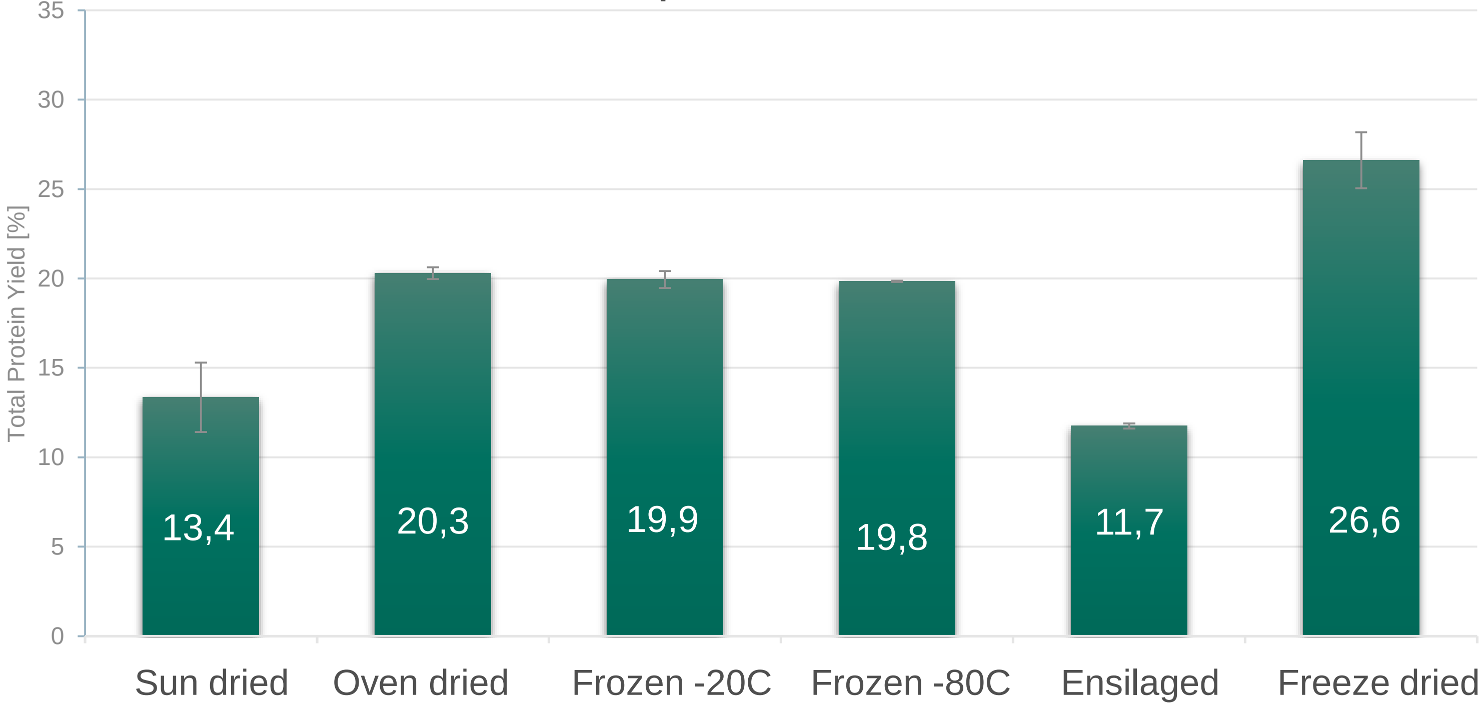
When including an extra incubation step at pH 8.5, 8°C prior to adjustment to pH 12, increase in total protein yield up to 29%!



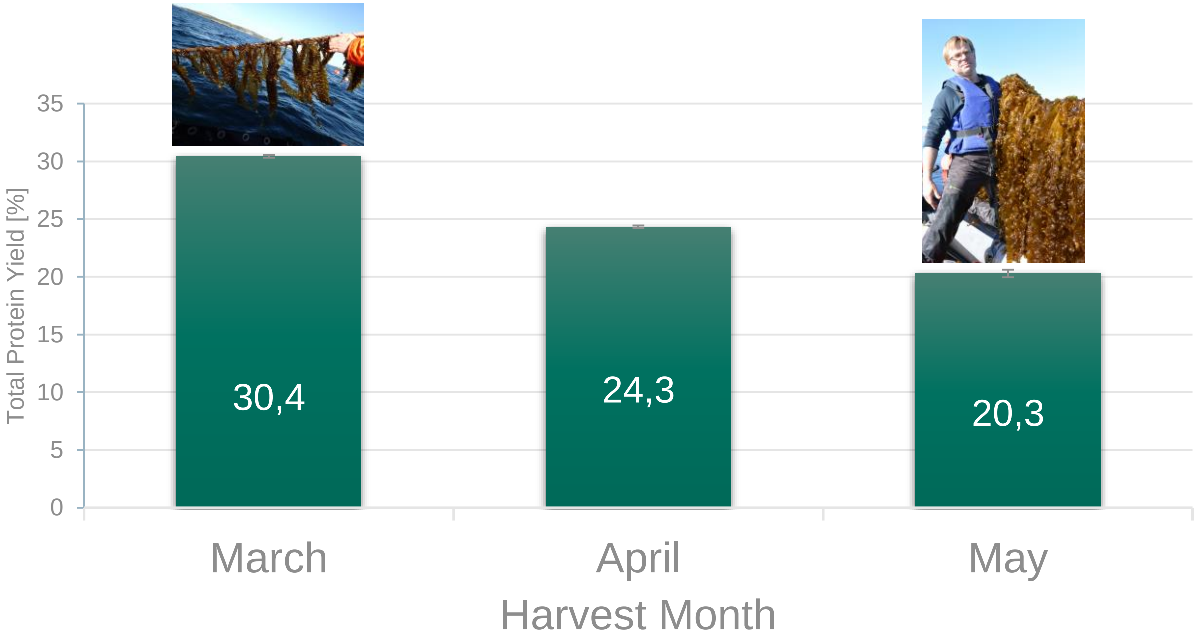
- Harrysson et al. *J Applied Phycol* (**2018**) 30: 3565-3580
- Harrysson et al. Strategies for improving the protein yield in pH-shift processing of Ulva lactuca Linnaeus - Effects of ulvan lyases, pH-exposure time and temperature, *ACS Sustainable Chemistry & Engineering*. In Press **2019**

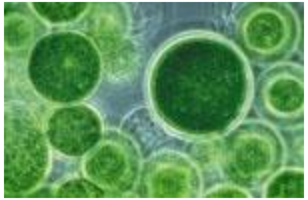
How to preserve seaweed post harvest?

Effect of seaweed preservation method



Effect of harvest month



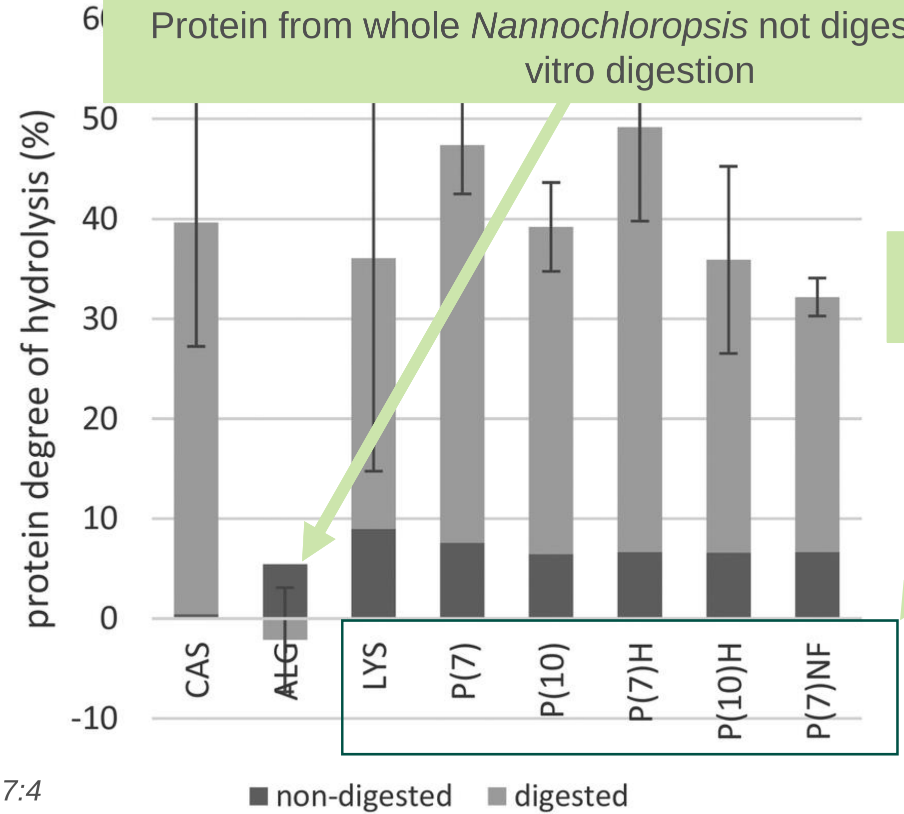


https://www.andaluciaecologica.com/empresas/endesa-microalgas/

Digestibilty of algae proteins?

Protein from whole *Nannochloropsis* not digestible during in vitro digestion

Digestibility increased after pH-shift processning

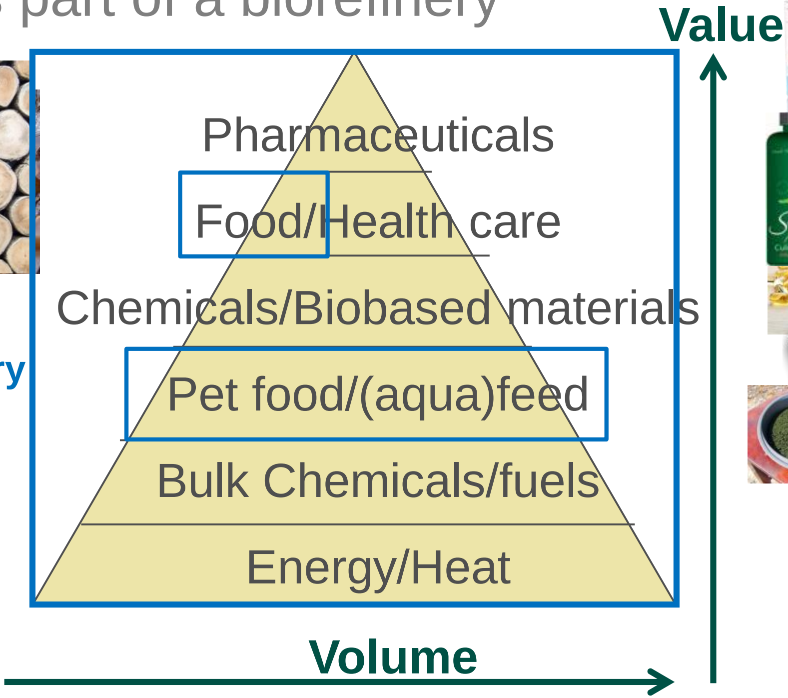


Cavonius et al. Food & function (2016),7:4

The pH-shift process as part of a biorefinery

Biomass

The blue biorefinery



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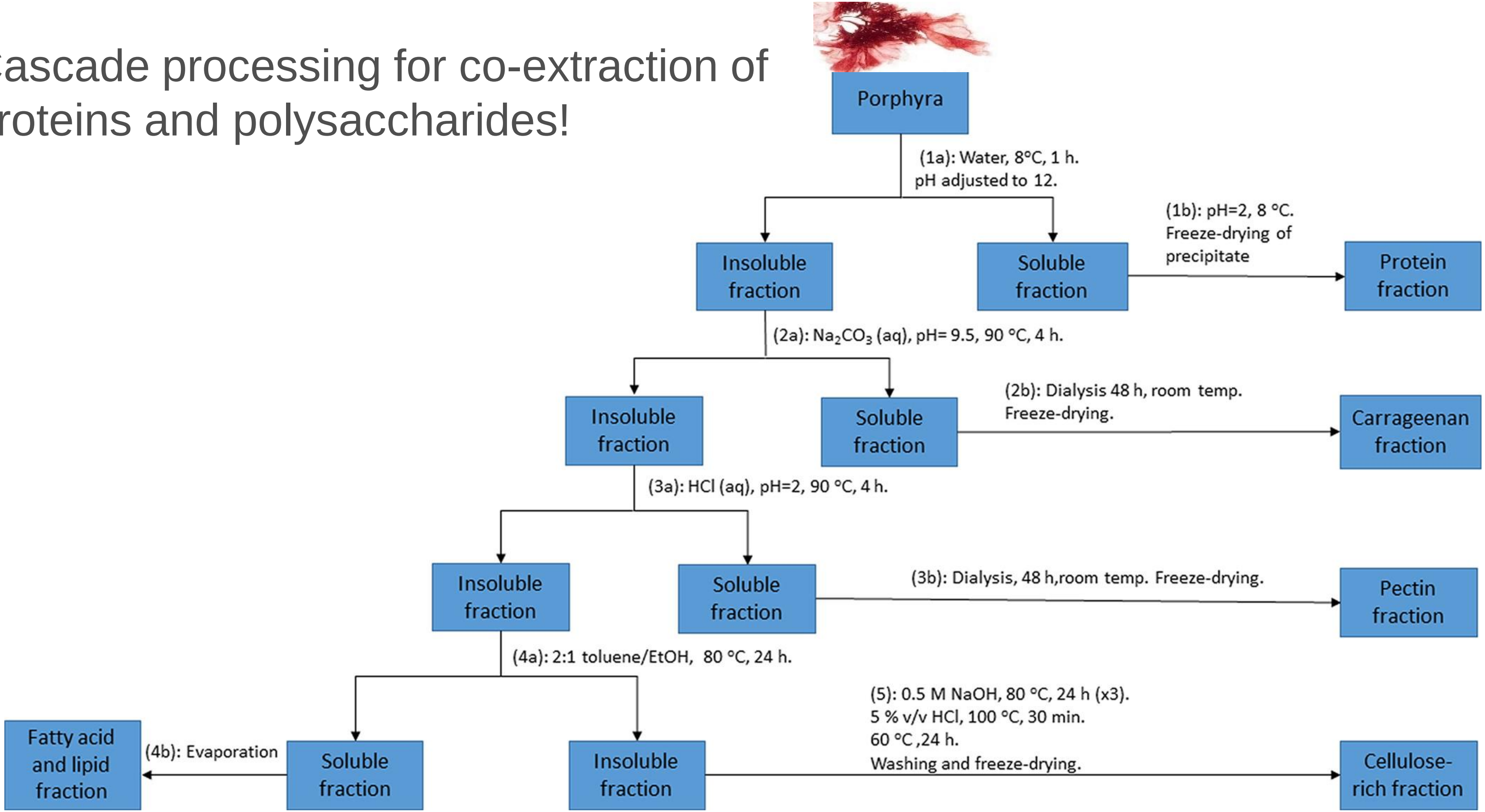
Cascade processing for co-extraction of proteins and polysaccharides!

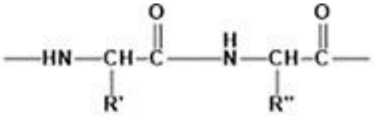


Wahlström et al. Ind. Eng. Chem. Res. ***2018****, 57, 42-53*

BIOREFINING

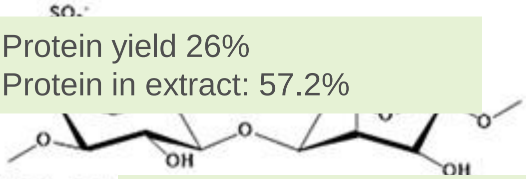
Porphyra umbilicalis

PROTEINS



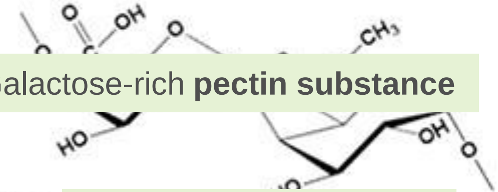
- Protein yield 26%
- Protein in extract: 57.2%

CARRAGEENAN



- HMW-type, gelled with K^+

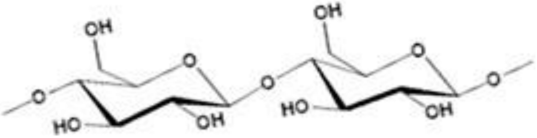
PECTINS



- Galactose-rich **pectin substance**

CELLULOSE

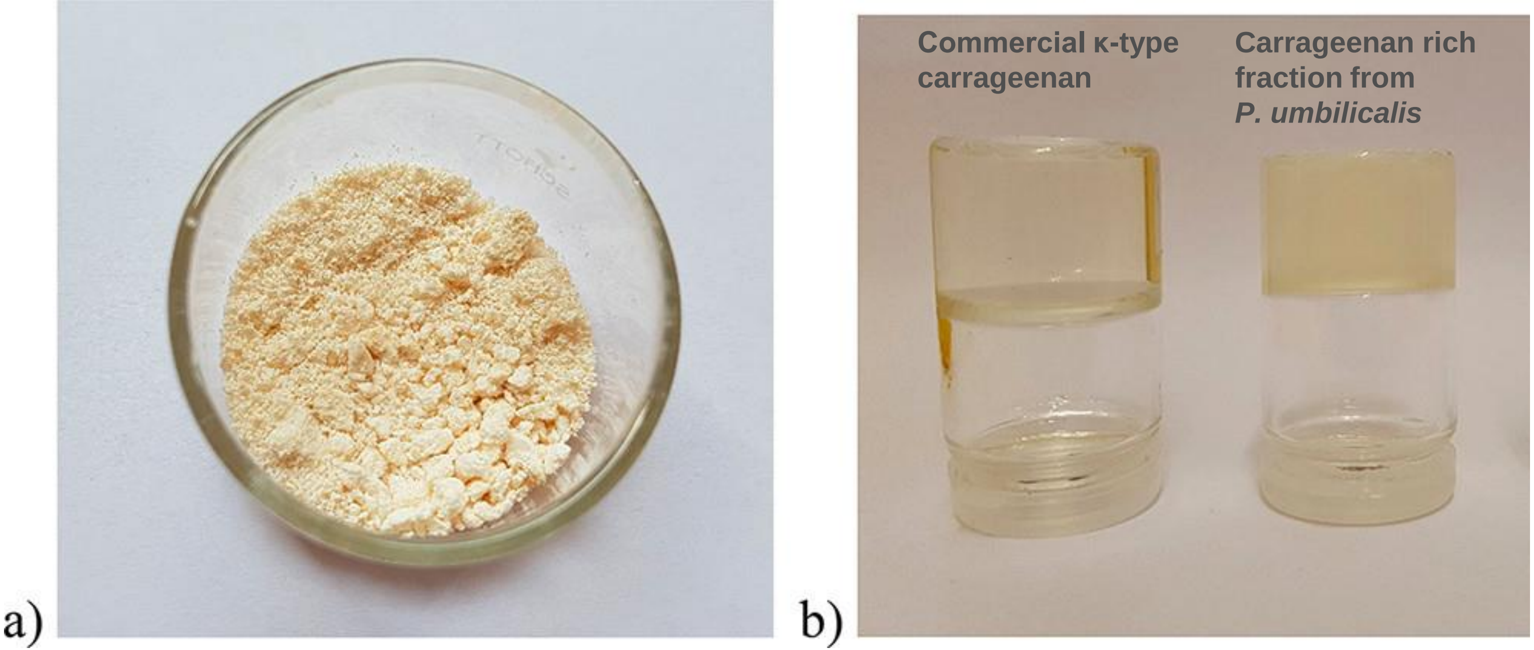
- Low yield



Changing the convential method for carrageenan extraction from red seaweed (alkali+heat+ethanol precipitation) allowed multiple product production!

Wahlström et al. Ind. Eng. Chem. Res. ***2018****, 57, 42-53*

Carrageenan from the pH-shift residue of *Porphyra*



We need scalable and food grade methods which efficiently yields a concentrated, multifunctional and highly bioavailable seaweed protein isolate which are applicable on both wet and dried seaweed biomass

- pH-shift processing promising→ concentrate with *≤71% protein & ≤ 30% protein yield*
- Precipitation more challenging than solubilization!
- Season and preservation affects yield
- Possibilities for co-extraction of polysaccharides

Thanks!

Ingrid Undeland, Chalmers