Luach Cothaitheach Feamainne ~ Nutritional Value of Seaweeds



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USES OF SEAWEED: FOCUS ON FOOD

Laver bread (*Porphyra* sp.)

Nori (*P. tenera*) sushi rolls

Wakame salad -Undaria pinnatifida

Sugar kelp (*Saccharina lattisma*); Kombu (*Laminaria digitata*) crisps

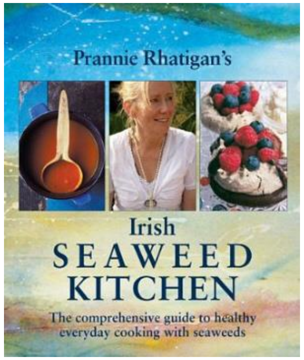
Nori (*P. tenera*) biscuits

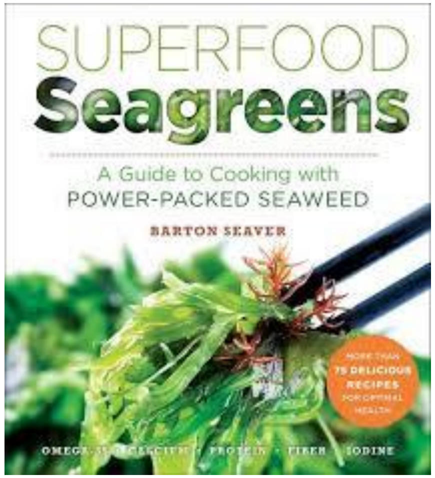
Dulse snack & chocolate & bacon alternative *(Palmaria palmata)*

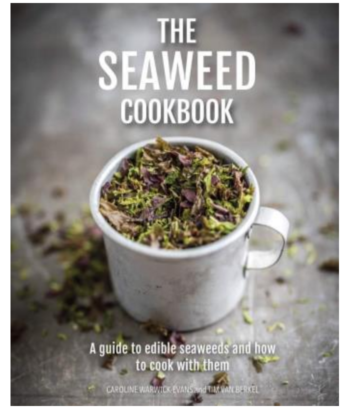
Seaweed pasta & flour

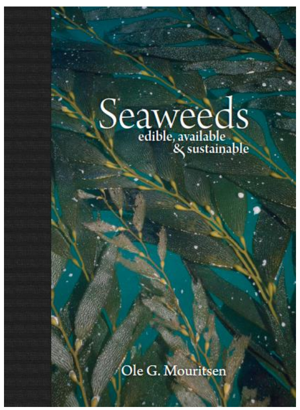
Kombu infused (*Laminaria digitata*) gin

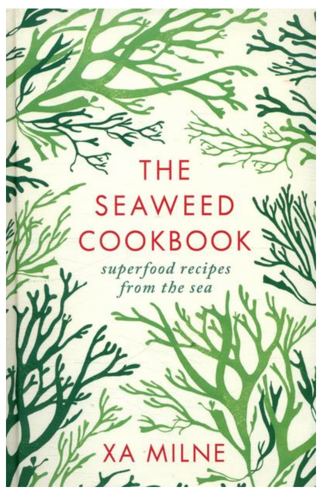
SEAWEED COOK BOOKS

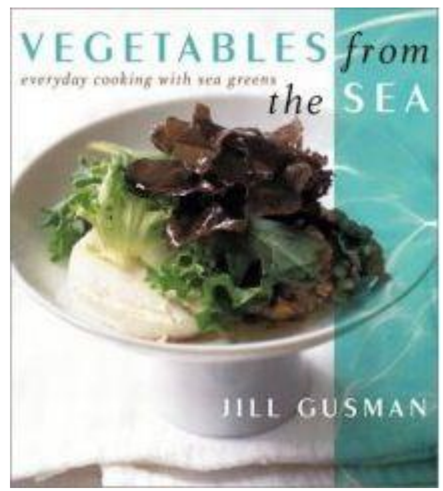


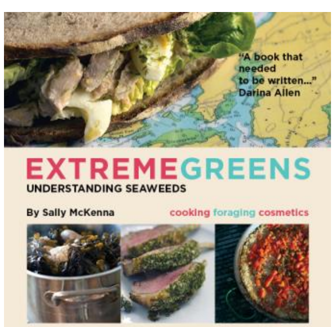




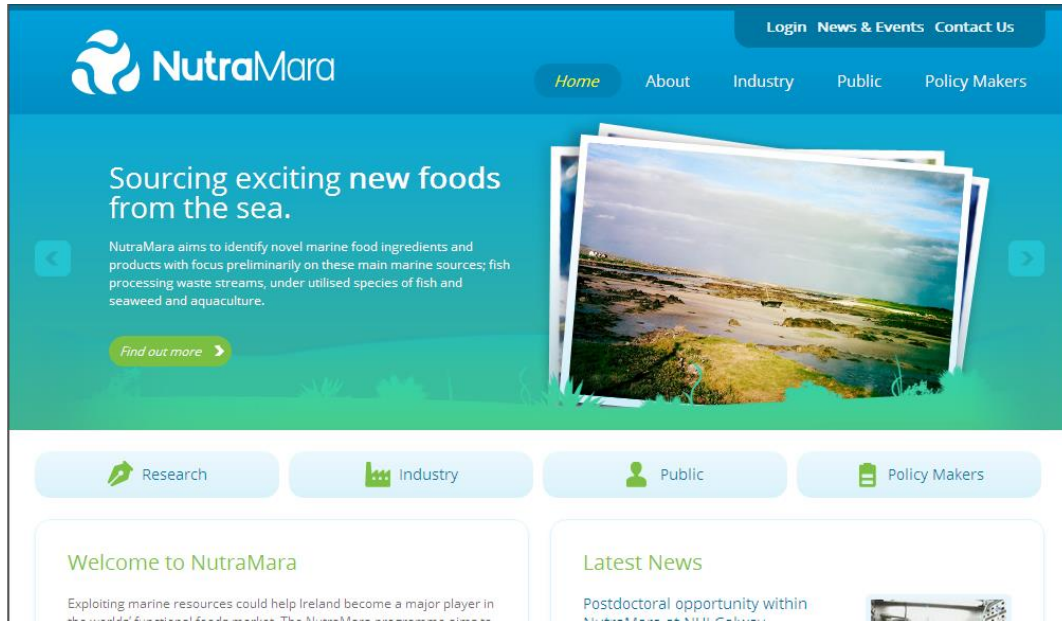




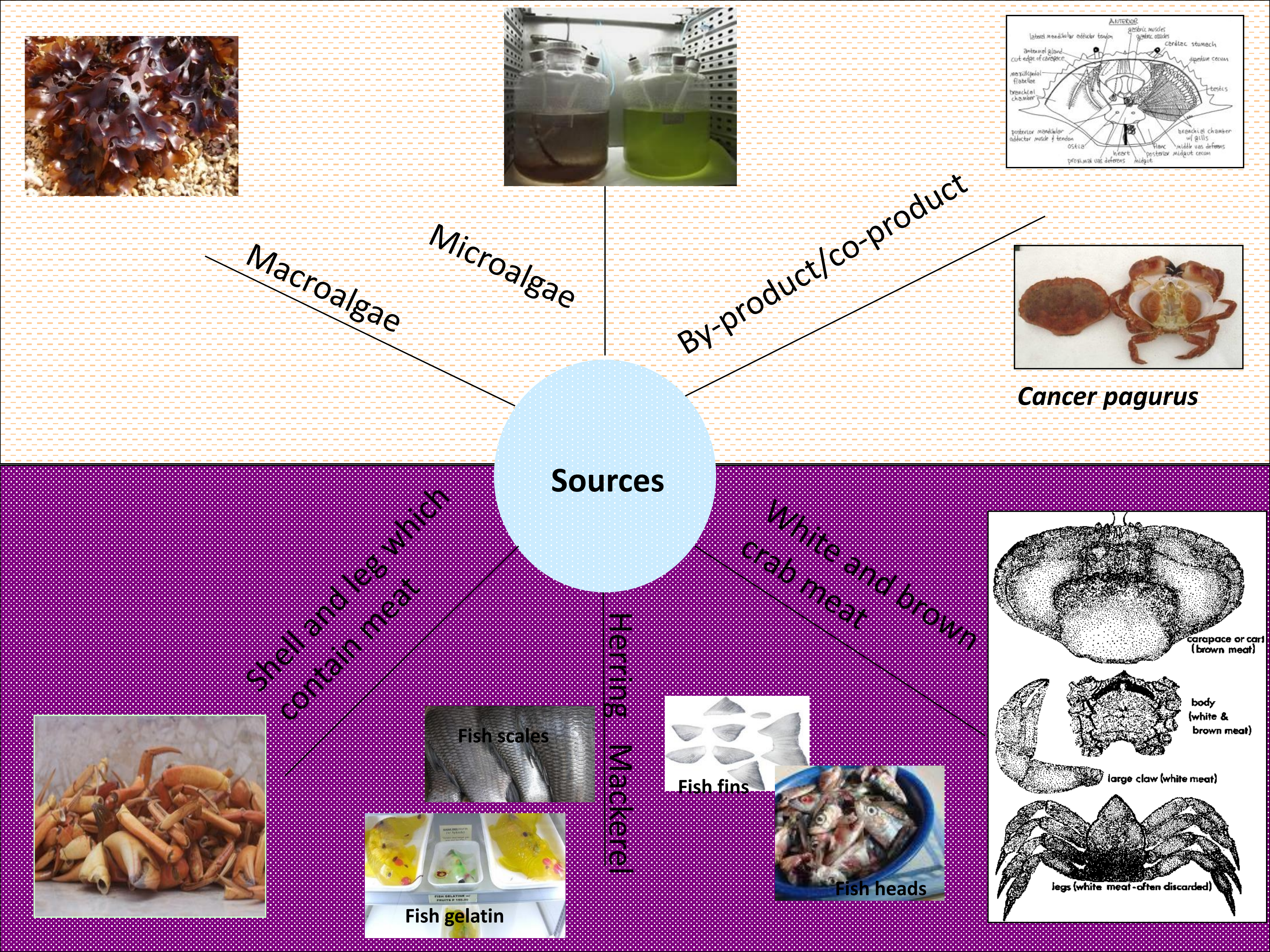




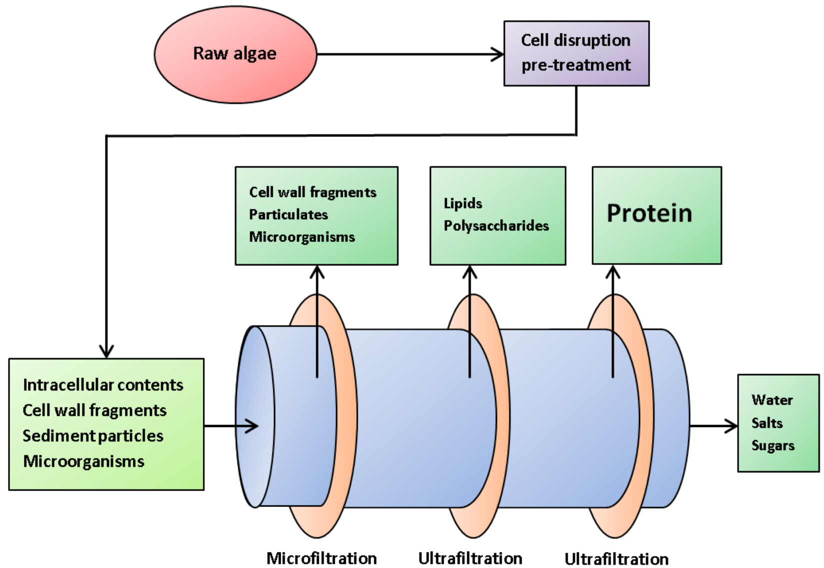
THE MARINE FUNCTIONAL FOOD RESEARCH INITIATIVE



https://www.teagasc.ie/media/website/publications/2018/NutraMara-Report-Troy-et-al-2017.pdf


Macroalgae
Microalgae
By-product/co-product
Cancer pagurus
Sources
Shell and leg which contain meat
Herring Mackerel
White and brown crab meat
Fish scales
Fish gelatin
Fish fins
Fish heads
carapace or cart (brown meat)
body (white & brown meat)
large claw (white meat)
legs (white meat - often discarded)

BIO ALGAE: APPLICATION OF DAIRY PROCESSING TECHNOLOGIES TO SEAWEEDS (2018-present)



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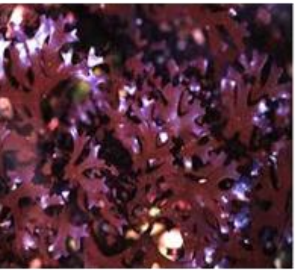
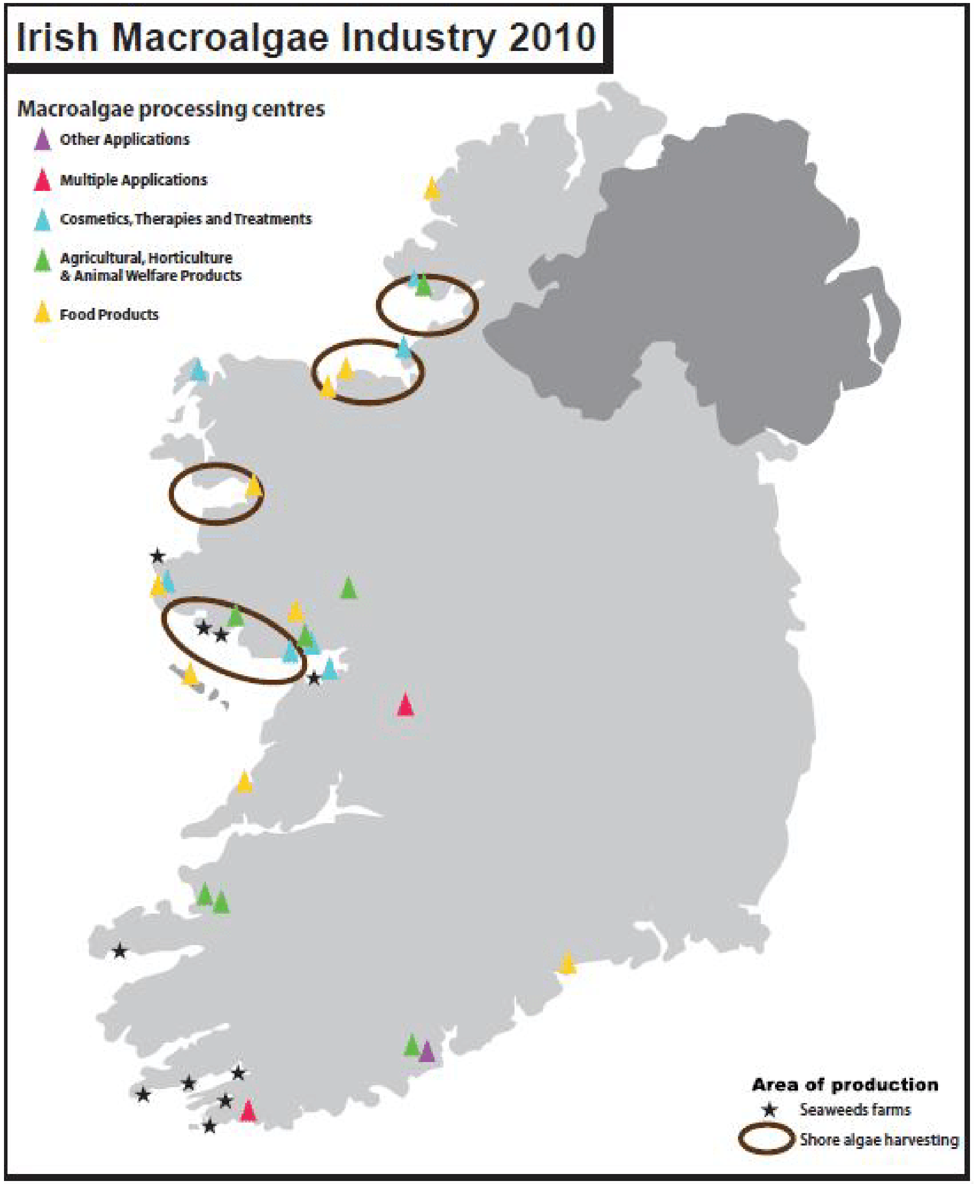
ALGAE AS A PROTEIN SOURCE

3- 4 %

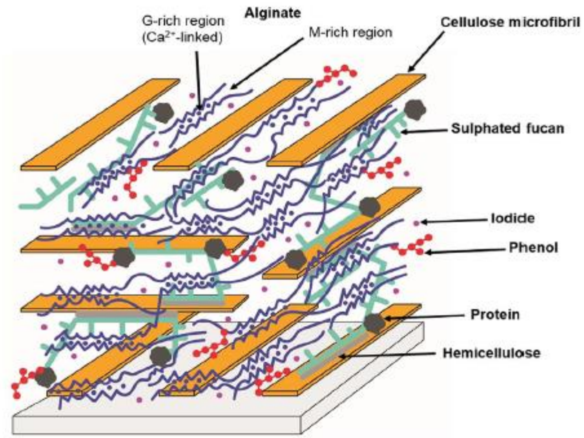


Algal species	Protein content (% dry weight)
Rhodophyta	
Porphyra sp.	24
	33-47
	44
	37
	33
	25
Chondrus crispus	20
Gracilaria sp	21
	24
	20-26
	12-22
	19
	10
	31-45
Palmaria sp.	14
	14-30
Chlorophyta	
Ulva sp.	9-33
	11
	21
	7
	7
Ulva lactuca	27
	29
	7-12
	17
	11
	17-20



SEAWEED STRUCTURE & ACCESS TO PROTEINS

- *Fucus vesiculosus* (Brown seaweed)
- *Alaria esculenta* (Brown seaweed)
- *Palmaria palmata* (Red seaweed)
- *Chondrus crispus* (Red seaweed)



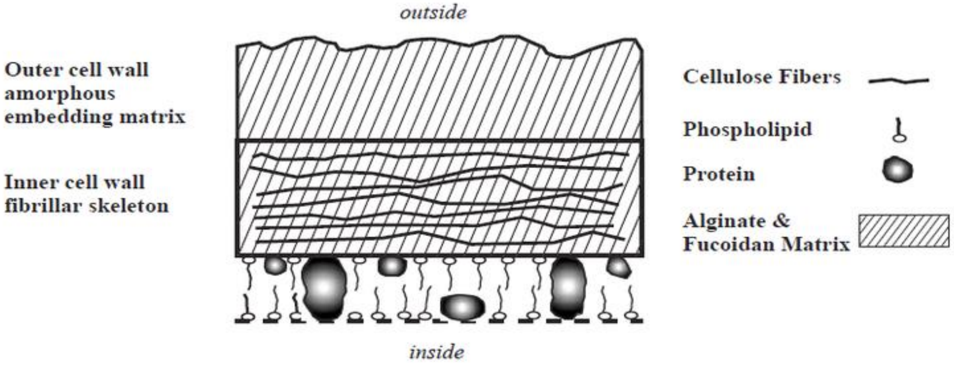


Figure 1 – Cell wall structure of brown algae (left) and red algae (right). Adapted from the studies of Charoensiddhi et al. (2017) and Khan et al. (2013).

PHYSICAL & CHEMICAL TREATMENT STRATEGIES

Traditional protein extraction method

- Uses sonication to caused localised cavitation to the Algal cell walls
- This method was the only one which used a precipitation step with ammonium sulphate, and additional cell wall damage due to freeze thaw method .


High Pressure Processing (HPP)

- It is usually used as a method, to lyse bacterial cells and an alternative to other more taste altering technique of preservation

Autoclave

- It has been observed that using heat for 30 minutes improves the bio accessibility of the amino acids from 86-109% in *P. palmata*
- Its main disadvantage is denaturing any natural proteins of interest

Microwave

- MAE uses oscillating electric fields which causes the heat to throughout the whole cell wall matrix. The quick heating of the matrix encourages the ions to collide. The pressure and heat caused by theses collisions and vibrations causes the cell wall to breakdown(Grosso *et al.*, 2015)

Electroporation

- This uses high energy electric fields, these cause pores to form in the cell wall. If the electric field is strong enough then the pores can be irreversibly left open.
- It has been mainly used in he past before in the extraction of lipids.

Enzyme

- This has too look at two steps: one look at the specific hydrocolloid that makes up the matrix of the cell wall (agar, carrageenan, Xylan and alginate)
- Secondly using cellulase to break down the structural part of the cell wall (cellulose microfibrils)

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Protein yields from seaweeds following physical treatments**

Species	Percentage of extracted protein obtained following pre-treatment application (mean ± SD, *n*=3)			
	F. vesiculosis	*A. esculenta*	*P. palmata*	*C. crispus*
Traditional	35.1 ± 9.1 (A)	18.2 ± 5.3 (A)	12.5 ± 2.3 (A)	35.2 ± 3.9 (B)
HPP	23.7 ± 2.1 (A)	15.0 ± 2.9(A)	14.9 ± 1.1 (A)	16.1 ± .5 (A)
Autoclave	24.3 ± 1.5 (A)	17.1 ± 1.5 (A)	21.5 ± 1.4 (B)	21.9 ± 3.3(A)

The three physical extractions are compared only against each other for each specific macroalgae species to see which method, if any, resulted in a significant increase in protein yield. Data with the same letter in () indicates that no significant difference in protein yield was observed, while different letters show a significant difference in protein yields obtained.

O' Connor, J., Meaney, S., Williams, G., **Hayes, M.(2020). Extraction of protein from four different seaweeds using three different physical pre-treatment strategies, Molecules (submitted).

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Protein Quality – Essential amino acid content

Amino acid profile of the crude macroalgae and macroalgal derived protein extracts (percentage of the Total amino acids)

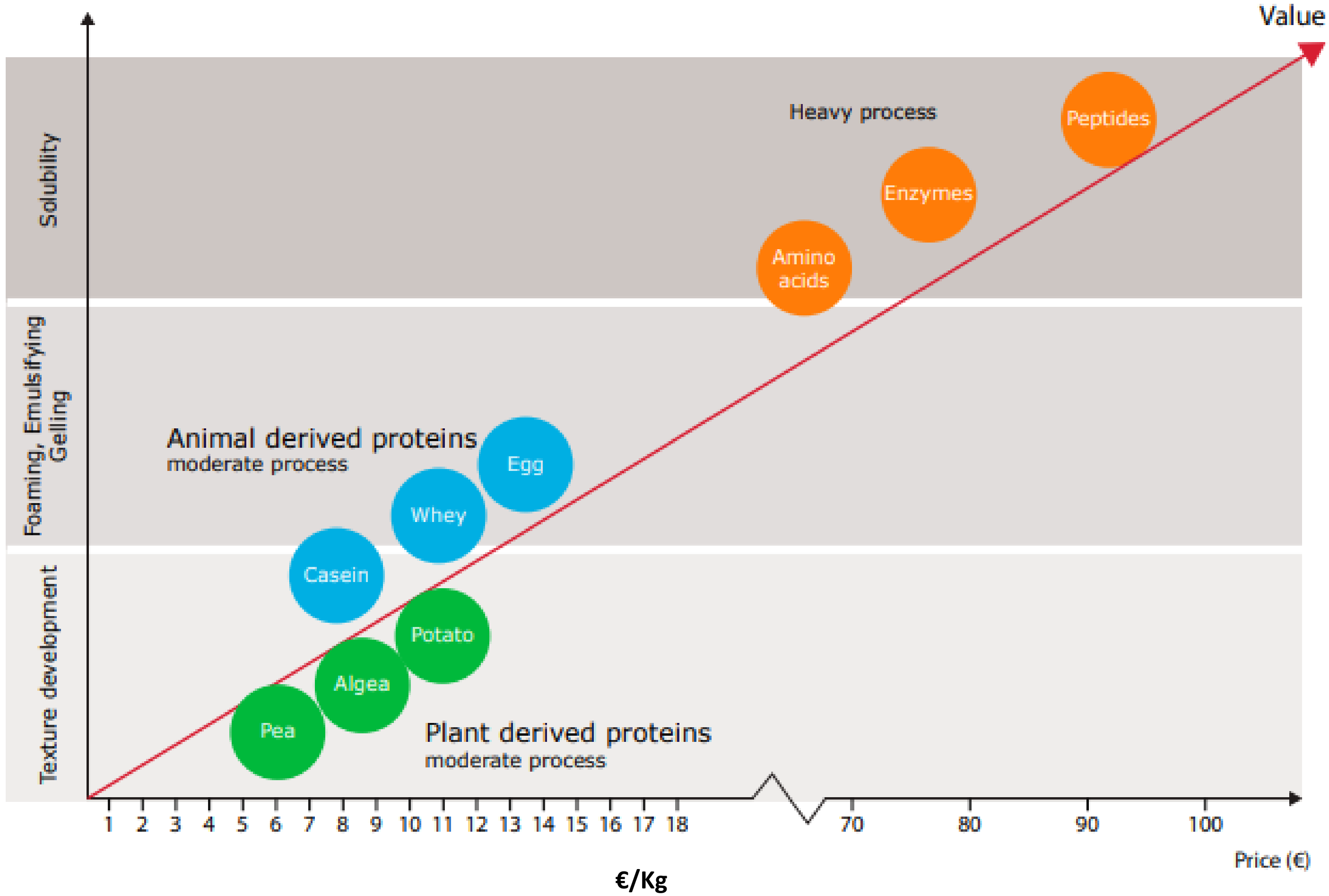
Amino Acids	*Fucus vesiculosis*				*Alaria esculenta*				*Palmaria palmata*				*Chondrus crispus*				Cow*
	Crude	Trad	HPP	Auto	Crude	Trad	HPP	Auto	Crude	Trad	HPP	Auto	Crude	Trad	HPP	Auto	Casein
Threonine	1.51	2.59	4.09	4.57	4.63	5.79	4.54	3.56	4.71	4.89	3.67	3.66	4.57	5.54	2.82	3.86	4.4
Valine	1.23	2.53	4.33	3.69	5.41	6.63	3.34	3.71	6.15	7.39	4.17	3.94	3.69	6.25	3.74	4.37	6.5
Isoleucine	1.20	1.64	2.22	1.89	4.31	4.54	1.59	1.43	3.64	4.59	3.11	2.15	1.89	4.51	2.34	3.12	5.5
Leucine	0.60	3.25	4.13	2.71	7.09	7.27	2.32	1.56	5.91	7.73	3.83	3.68	2.71	6.93	3.23	4.98	8.3
Phenylalanine	0.77	2.27	3.27	2.47	4.58	4.67	2.95	2.50	3.84	4.91	2.61	2.66	2.47	4.29	0.40	4.49	4.5
Histidine	5.70	4.45	2.90	1.47	5.04	2.28	5.26	3.33	4.65	2.57	5.26	2.95	1.47	2.15	3.06	3.55	2.8
Lysine	1.75	2.44	2.10	4.16	5.28	5.22	0.96	1.65	5.58	6.40	3.22	3.67	4.16	5.31	4.14	4.58	7.4
Methionine	0.00	1.66	1.84	4.61	2.85	3.46	0.99	2.30	2.70	3.17	0.80	2.34	4.61	3.29	0.83	2.59	2.5
Arginine	1.20	2.12	2.66	2.52	7.00	5.88	2.05	1.63	5.96	6.32	2.87	2.98	2.52	6.48	2.77	5.09	3.7
∑EAA(%)	12.77	25.45	25.6	26.55	39.32	41.99	21.96	20.27	37.68	43.76	26.66	25.20	26.55	40.94	25.10	31.70	45.1
TAA (g/kg)	44.30	57.82	17.6	19.72	61.12	93.70	31.34	37.62	112.1	73.10	35.23	59.68	137.4	226.2	73.40	69.05	





O' Connor, J., Meaney, S., Williams, G., **Hayes, M.(2020). Extraction of protein from four different seaweeds using three different physical pre-treatment strategies, Molecules (submitted).

Functionality of protein - €€€



Functionality or performance of proteins and prices (adapted from Hart, 2015*)

*Hart, P., 2015 "https://www.slideshare.net/ PaulHart1/lant-proteins-wtg-03-0315-london-em."

Technofunctional applications

Marine protein

Gelation

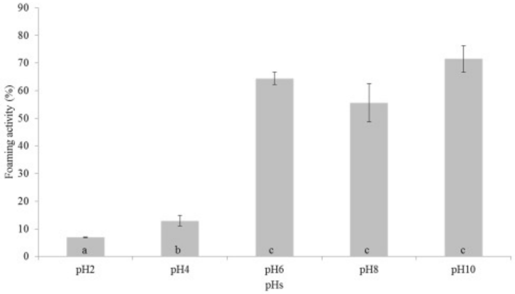
Water binding

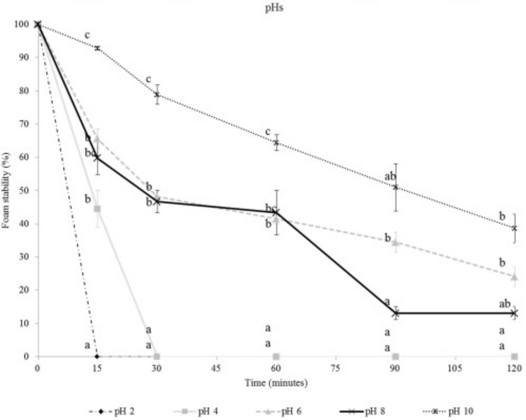
Solubility

Foaming

Emulsification

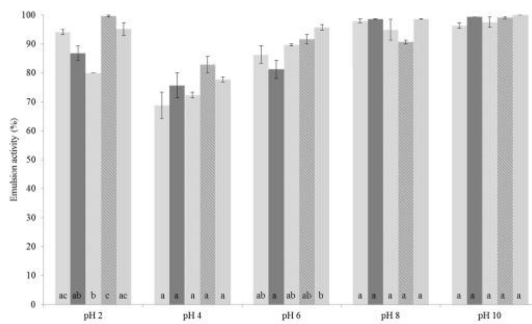
Technofunctional applications of seaweed proteins

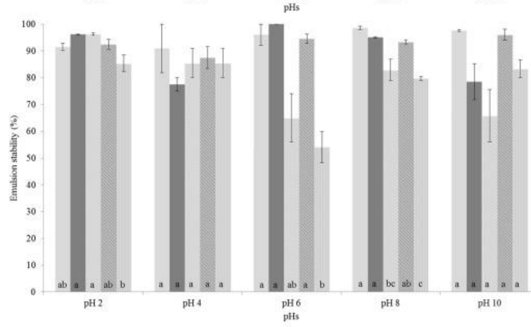




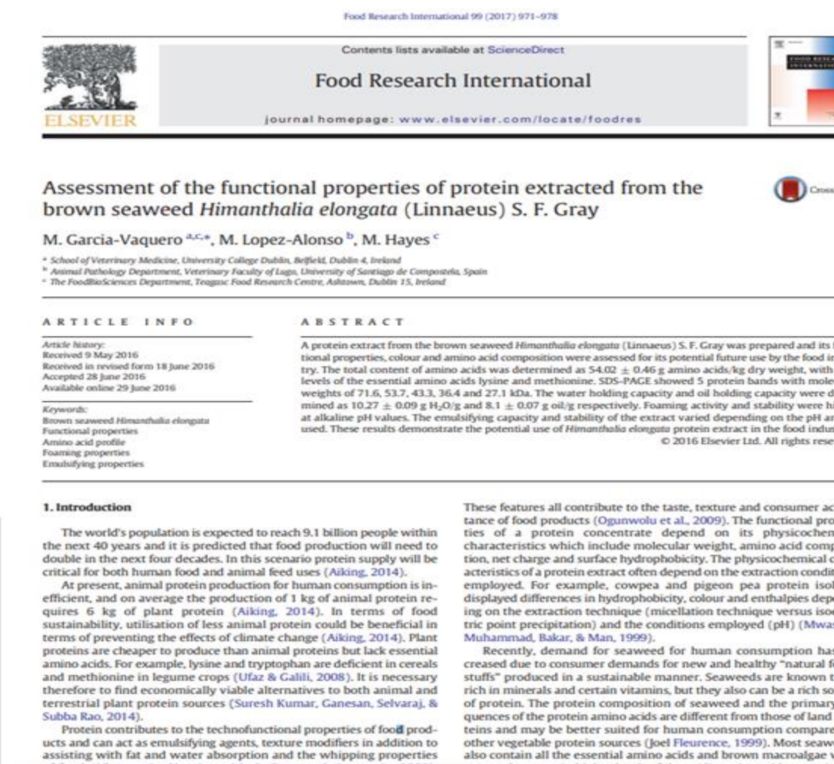
Different letters indicate statistically significant differences (p<0.05) in FC and FS between the different pHs.

Himanthalia elongata
(Sea spagetti)





Different letters indicate statistically significant differences (p<0.05) in EA and ES between the different oils at the same pH.



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Assessment of the functional properties of protein extracted from the brown seaweed *Himanthalia elongata* (Linnaeus) S. F. Gray

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Brown seaweed *Himanthalia elongata*
Functional properties
Amino acid profile
Foaming properties
Emulsifying properties

ABSTRACT

A protein extract from the brown seaweed *Himanthalia elongata* (Linnaeus) S. F. Gray was prepared and its
tional properties, colour and amino acid composition were assessed for its potential future use by the food i
try. The total content of amino acids was determined as 54.02 ± 0.46 g amino acids/kg dry weight, with
levels of the essential amino acids lysine and methionine. SDS-PAGE showed 5 protein bands with mole
weights of 71.6, 53.7, 43.3, 36.4 and 27.1 kDa. The water holding capacity and oil holding capacity were d
mined as 10.27 ± 0.09 g H_2O/g and 8.1 ± 0.07 g oil/g respectively. Foaming activity and stability were h
at alkaline pH values. The emulsifying capacity and stability of the extract varied depending on the pH a
used. These results demonstrate the potential use of *Himanthalia elongata* protein extract in the food indu

1. Introduction

The world's population is expected to reach 9.1 billion people within the next 40 years and it is predicted that food production will need to double in the next four decades. In this scenario protein supply will be critical for both human food and animal feed uses (Aiking, 2014).

At present, animal protein production for human consumption is inefficient, and on average the production of 1 kg of animal protein requires 6 kg of plant protein (Aiking, 2014). In terms of food sustainability, utilisation of less animal protein could be beneficial in terms of preventing the effects of climate change (Aiking, 2014). Plant proteins are cheaper to produce than animal proteins but lack essential amino acids. For example, lysine and tryptophan are deficient in cereals and methionine in legume crops (Ufaz & Galili, 2008). It is necessary therefore to find economically viable alternatives to both animal and terrestrial plant protein sources (Suresh Kumar, Ganesan, Selvaraj, & Subba Rao, 2014).

Protein contributes to the technofunctional properties of food products and can act as emulsifying agents, texture modifiers in addition to assisting with fat and water absorption and the whipping properties

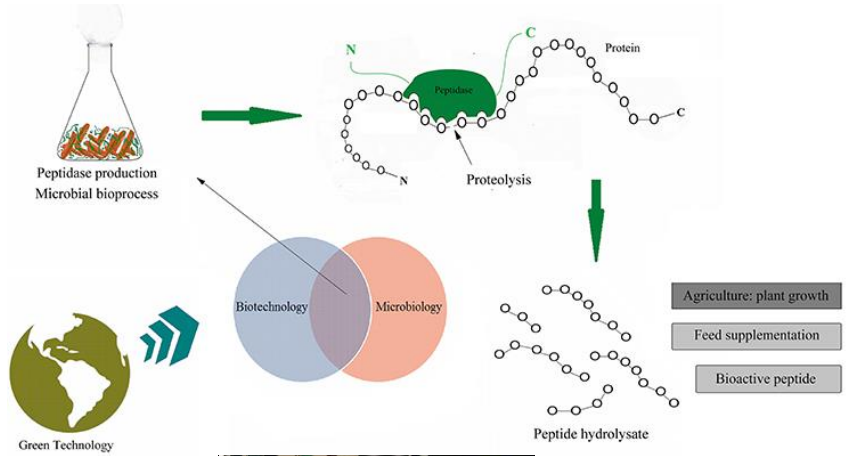
These features all contribute to the taste, texture and consumer ac
tance of food products (Ogunwolu et al., 2009). The functional pro
ties of a protein concentrate depend on its physicochem
characteristics which include molecular weight, amino acid com
tion, net charge and surface hydrophobicity. The physicochemical c
acteristics of a protein extract often depend on the extraction condi
employed. For example, cowpea and pigeon pea protein iso
displayed differences in hydrophobicity, colour and enthalpies dep
ing on the extraction technique (micellation technique versus iso
tric point precipitation) and the conditions employed (pH) (Mwa
Muhammad, Bakar, & Man, 1999).

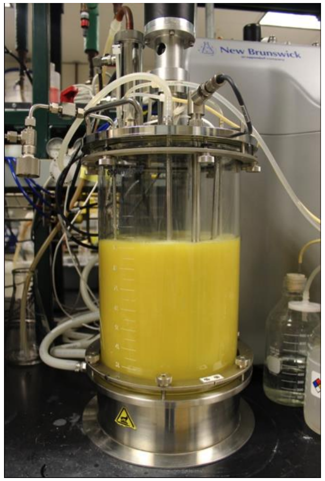
Recently, demand for seaweed for human consumption ha
creased due to consumer demands for new and healthy "natural f
stuffs" produced in a sustainable manner. Seaweeds are known t
rich in minerals and certain vitamins, but they also can be a rich so
of protein. The protein composition of seaweed and the primar
quences of the protein amino acids are different from those of land
teins and may be better suited for human consumption compare
other vegetable protein sources (Joel Fleurence, 1999). Most seaw
also contain all the essential amino acids and brown macroalgae

- Sausages,
- Breads, and cakes
- Soups
- Salad dressing

HYDROLYSATE TECHNOLOGIES

- Hydrolysate technology can offer smaller processors a cost effective method to handle seafood processing by-products.
- Produce high quality oils and protein for food, feed and fertilisers.
- Produces bioactive peptides.
- Reduces allergenicity.
- Sports nutrition, foods for the elderly, infant nutrition, pet health.





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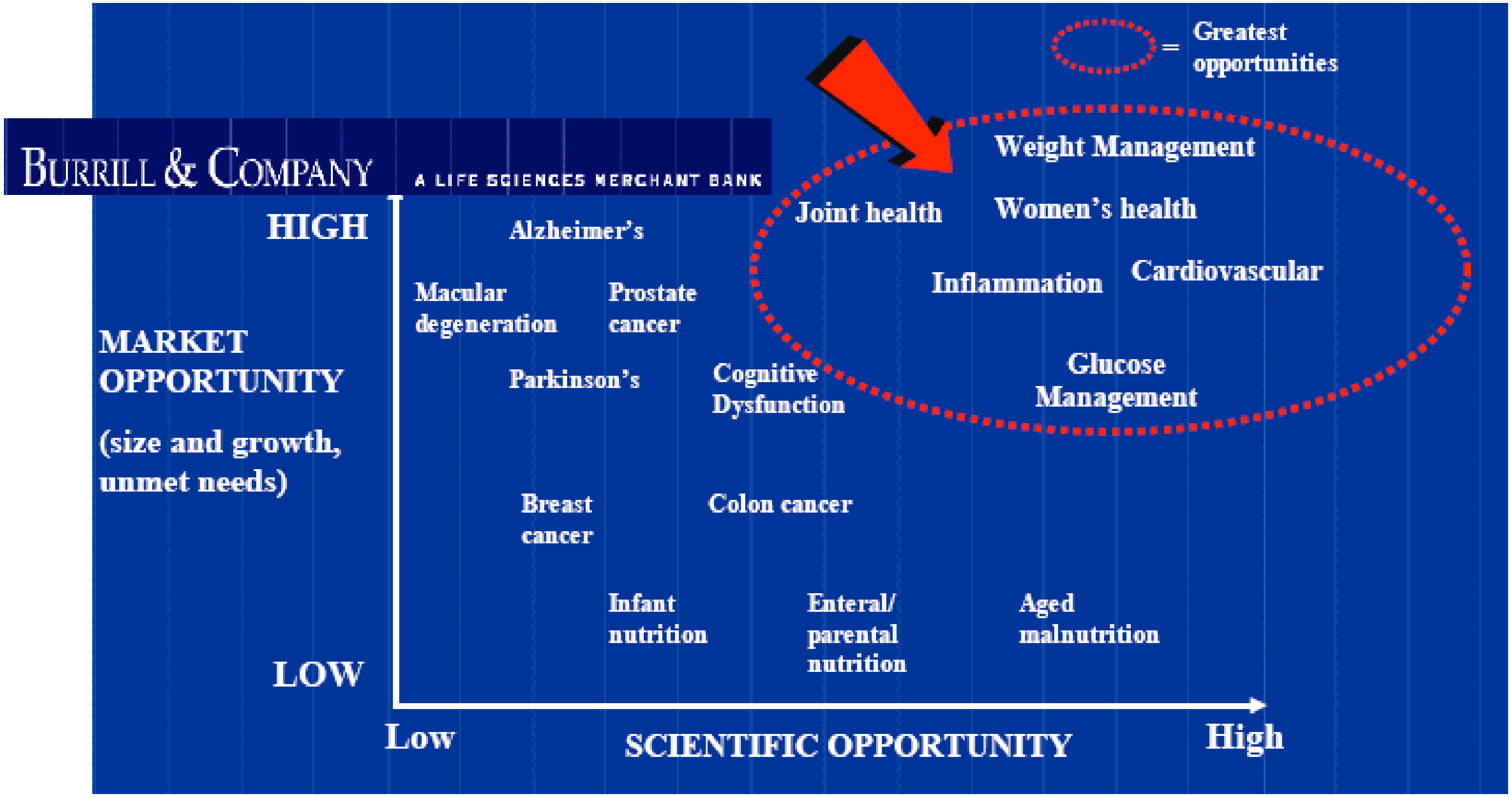
Key Areas based on Market and Scientific Opportunity



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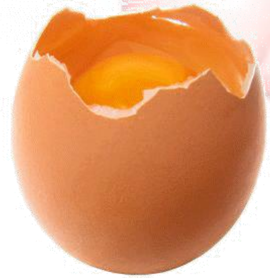
Bioactive peptides sources









Marine by-products and algal sources.....

Generation of bioactive peptides

Extraction of macroalgal, microalgal or marine by-product proteins

Freeze-dry

↓

Hydrolysis
with proteolytic enzymes

Freeze-dry

Test hydrolysates for PAF-AH, PEP, ACE-I and renin inhibition

↓

UF 10kDa MWCO/3kDa MWCO

↓

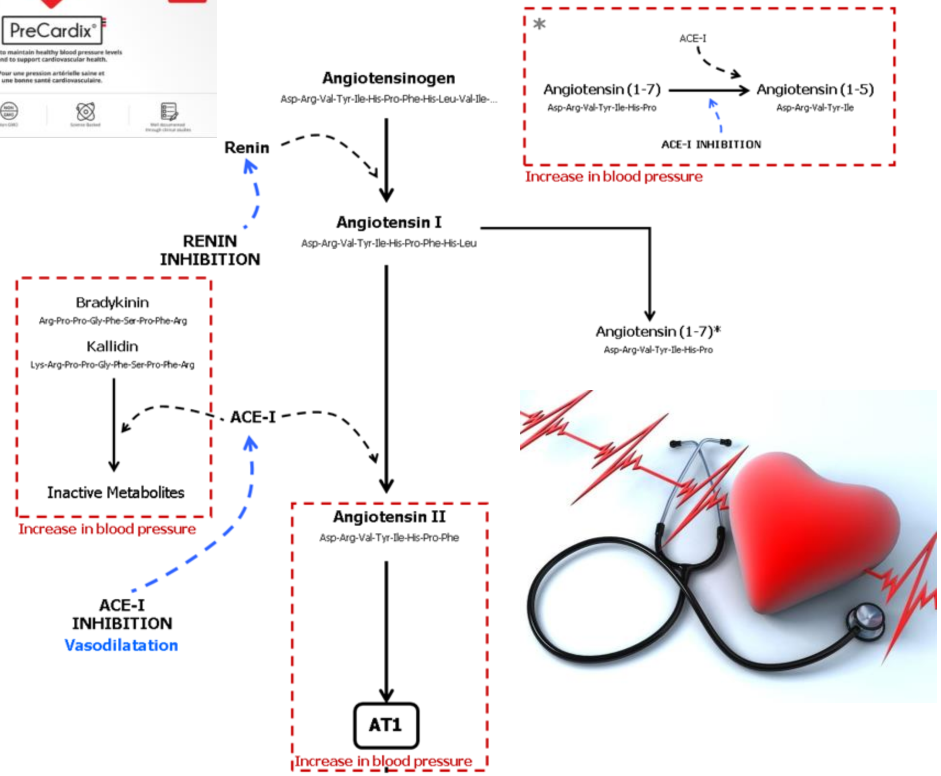
Purification RP-HPLC

↓

Characterisation – UPLC & MS

Health benefits of protein hydrolysates & peptides

Type 2 diabetes,
Coronary heart disease, mortality,
Cardiovascular disease,
Obesity,
Impaired glucose metabolism,
Hyperlipidemia,
Hypertension,
Osteoporosis,
Muscle soreness,
Depression,
Brain activity,
Infection control,
Bowel movement,
Irritable bowel syndrome,
Osteoporosis
Muscle soreness post training



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European Food Safety Authority

EMFF OPERATIONAL PROGRAMME 2014-2020

European Union
European Maritime and Fisheries Fund

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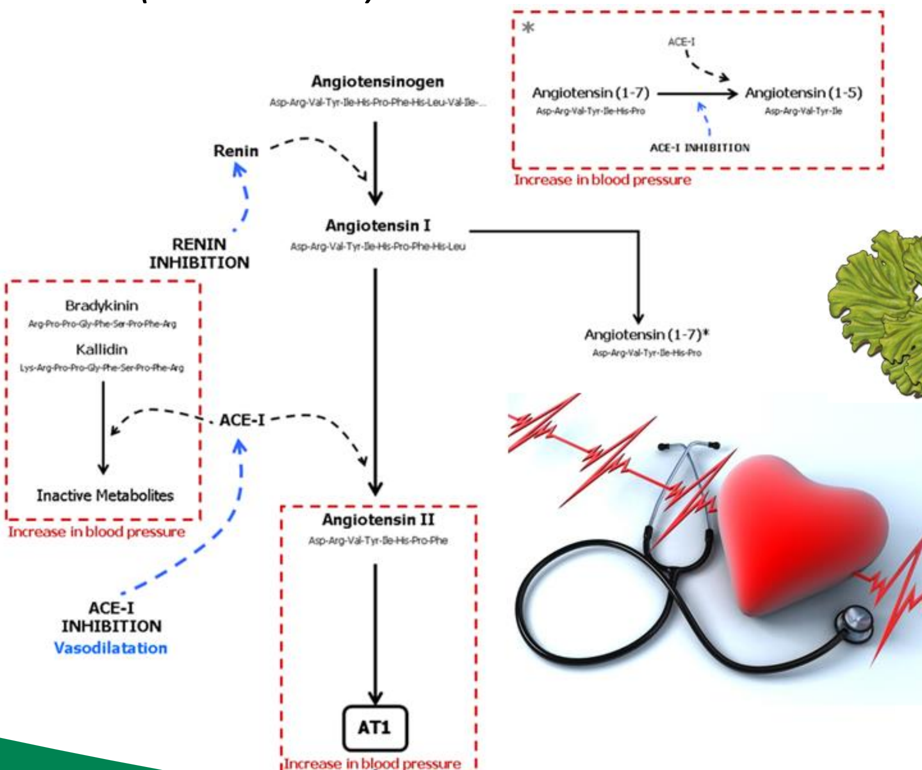
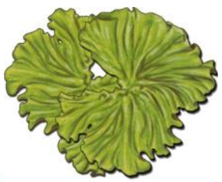
BIOACTIVITIES FOR HEART HEALTH

Ulva lactuca
(Sea lettuce)





marine drugs

MDPI

Article

In Vitro and In Silico Approaches to Generating and Identifying Angiotensin-Converting Enzyme I Inhibitory Peptides from Green Macroalga *Ulva lactuca*

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Abstract: A protein extract was generated from the macroalga *Ulva lactuca*, which was subsequently hydrolysed using the food-grade enzyme papain and angiotensin-converting Enzyme I and renin inhibitory peptides identified using a combination of enrichment strategies employing molecular weight cutoff filtration and mass spectrometry analysis. The generated hydrolysates with the most promising in vitro activity were further purified using preparative RP-HPLC and characterised. The 1 kDa hydrolysate (1 kDa-UFH), purified and collected by preparative RP-HPLC at minutes 41-44 (Fr41-44), displayed statistically higher ACE-I inhibitory activities ranging from 96.91% to 98.06%. A total of 48 novel peptides were identified from these four fractions by LC-MS/MS. A simulated gastrointestinal digestion of the identified peptide sequences was carried out using in silico enzyme cleavage simulation tools, resulting in 86 peptide sequences that were further assessed for their potential activity, toxicity and allergenicity using multiple predictive approaches. All the peptides obtained in this study were predicted to be non-toxic. However, 28 out of the 86 novel peptides released after the in silico gastrointestinal digestion were identified as potential allergens. The potential allergenicity of these peptides should be further explored to comply with the current labelling regulations in formulated food products containing *U. lactuca* protein hydrolysates.

Keywords: seaweed protein; protein hydrolysate; ACE-I; renin; allergenicity; in silico analysis; functional food; bioactive peptide; bioinformatics

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BIOACTIVITIES FOR HEART HEALTH

Palmaria palmata (Linneaus) Weber & Mohr

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

REVIEW

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Heart Health Peptides from Macroalgae and Their Potential Use in Functional Foods

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ABSTRACT: Macroalgae have for centuries been consumed whole among the East Asian populations of China, Korea, and Japan.

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Article

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Isolation and Characterization of Bioactive Pro-Peptides with *in Vitro* Renin Inhibitory Activities from the Macroalga *Palmaria palmata*

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JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Article

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Potential of a Renin Inhibitory Peptide from the Red Seaweed *Palmaria palmata* as a Functional Food Ingredient Following Confirmation and Characterization of a Hypotensive Effect in Spontaneously Hypertensive Rats

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ABSTRACT: This work examined the resistance of the renin inhibitory, tridecapeptide IRLIIVLMPILMA derived previously from a *Palmaria palmata* papain hydrolysate, during gastrointestinal (GI) transit. Following simulated GI digestion, breakdown products were identified using mass spectrometry analysis and the known renin and angiotensin I converting enzyme inhibitory dipeptide IR was identified. In vivo animal studies using spontaneously hypertensive rats (SHRs) were used to confirm the antihypertensive effects of both the tridecapeptide IRLIIVLMPILMA and the seaweed protein hydrolysate from which this peptide was isolated. After 24 h, the SHR group fed the *P. palmata* protein hydrolysate recorded a drop of 34 mm Hg in systolic blood pressure (SBP) from 187 (±0.25) to 153 (± 0.64) mm Hg SBP, while the group fed the tridecapeptide IRLIIVLMPILMA presented a drop of 33 mm Hg in blood pressure from 187 (±0.95) to 154 (±0.94) mm Hg SBP compared to the SBP recorded at time zero. The results of this study indicate that the seaweed protein derived hydrolysate has potential for use as antihypertensive agents and that the tridecapeptide is cleaved and activated to the dipeptide IR when it travels through the GI tract. Both the hydrolysate and peptide reduced SHR blood pressure when administered orally over a 24 h period.

KEYWORDS: *in vitro simulated gastrointestinal digestion, spontaneously hypertensive rats, renin inhibitory peptides, red macroalga*

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Teagasc
AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

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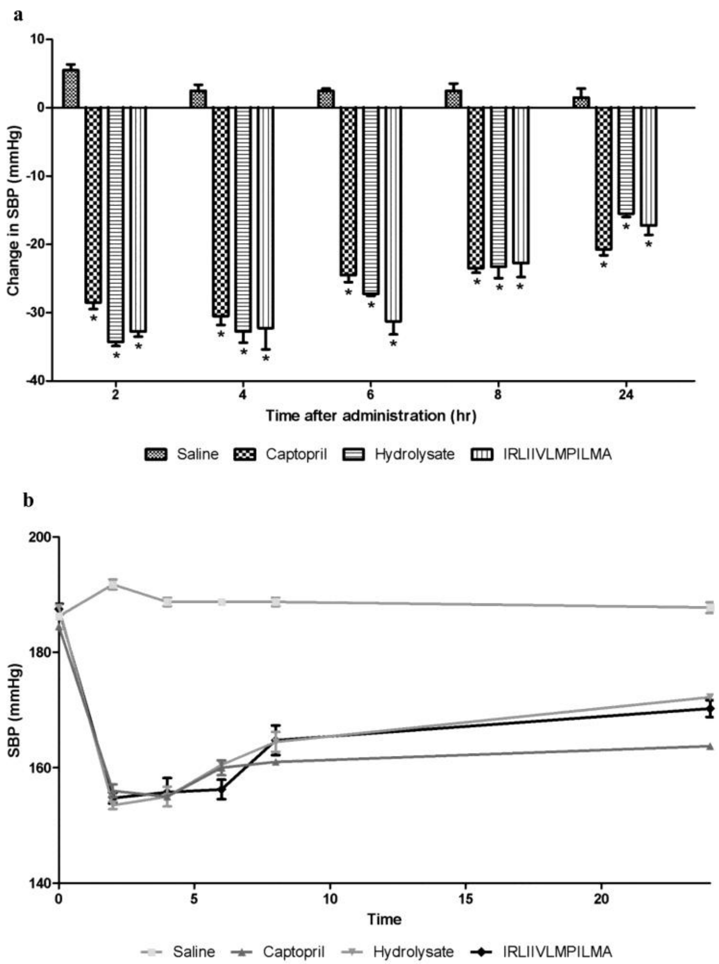
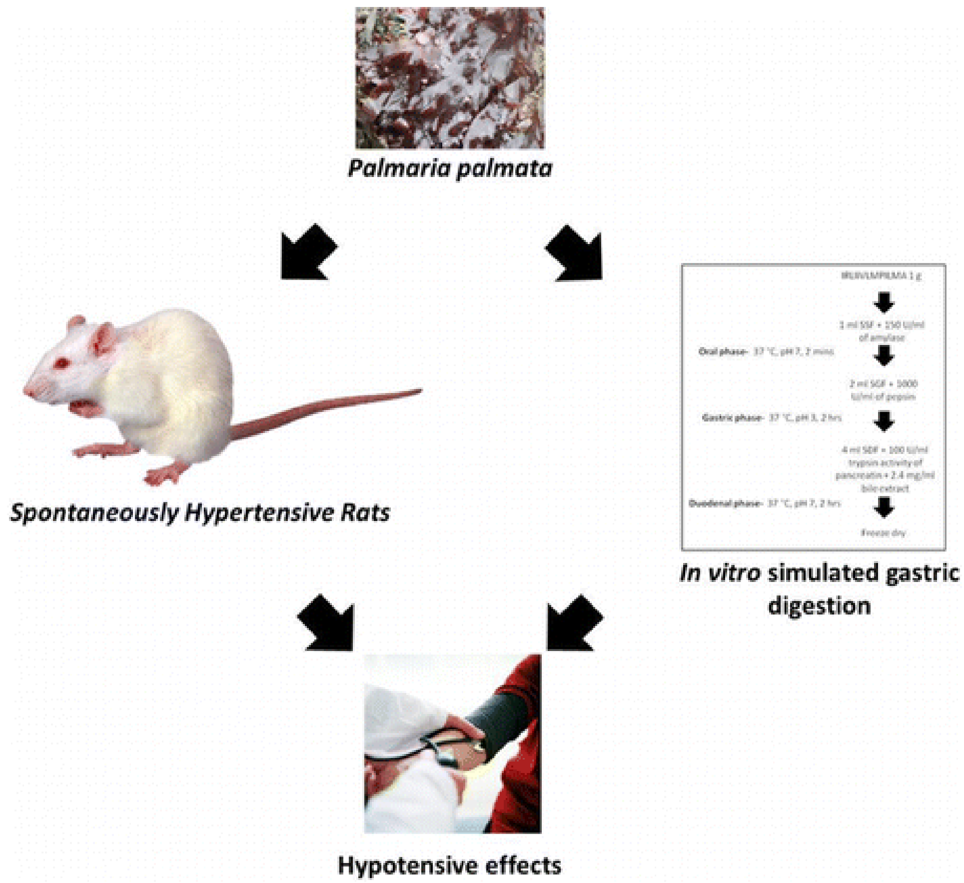
Renin inhibitory hydrolysate and peptide : *in vivo*





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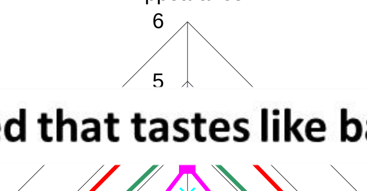
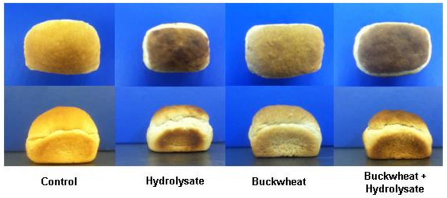
Bioactive peptides from Macroalgae: Heart Health

BITTERNESS & SENSORY ISSUES – USE CORRECT FOOD VEHICLES

The higher the value, the more the flour absorbs water





Dulse – The seaweed that tastes like bacon!

A high value corresponds to high dough stability in mixing

A high value corresponds to high gluten resistance to heating

A high value corresponds to high dough viscosity during heating

Go raibh mhaith agaibh go léir

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