Mogelijkheden voor zeewier/microalgen in voeding
Opportunities for Seaweed/Microalbgae in food

Hoe algen de smaak van de Europese consument kunnen veroveren?
How can algae discover the taste of European Consumer?

Johan ROBBENS

AlgenEvent 'Mei is AlgenMaand'
4Mei 2022

Vlaanderen
is landbouw & visserij

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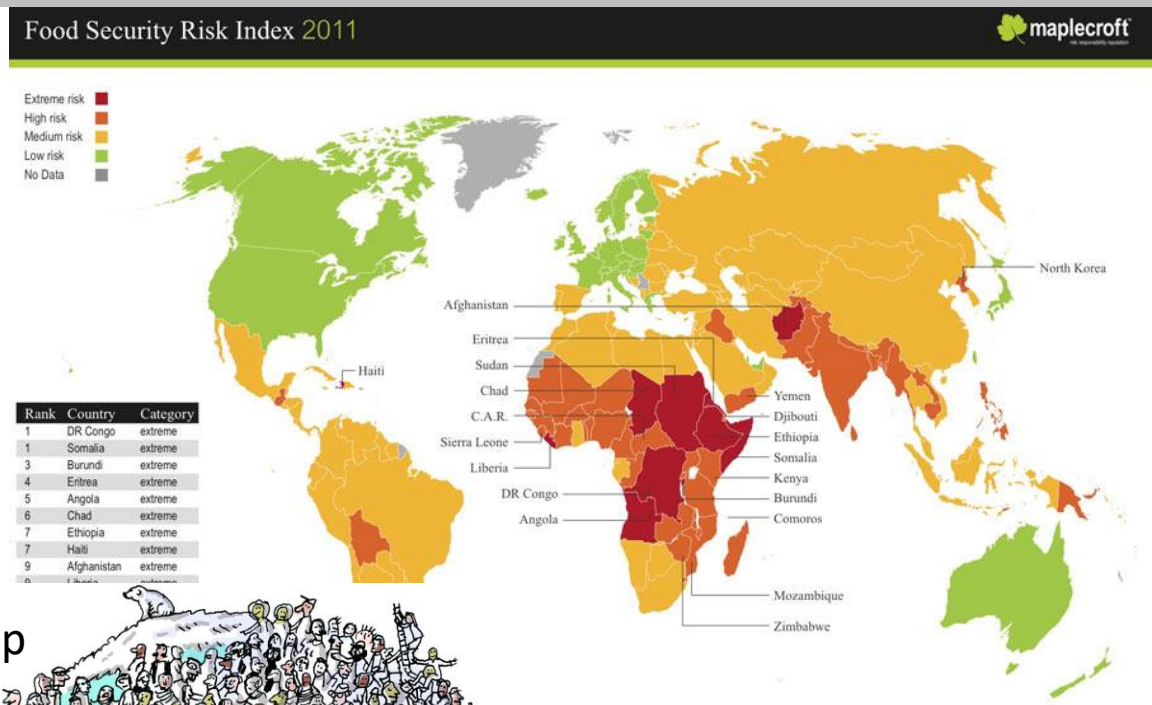
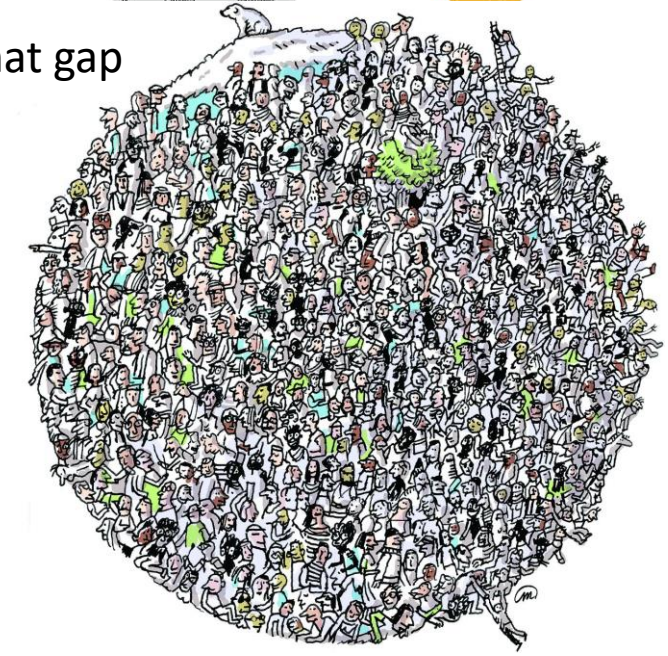
Algae - Food of the Future?

- ➢ Food Security→ Feeding the world
- ➢ Protein transition → Shift away from animal proteins
- Search for alternative sources
- ➢ New niche and more demand for vegetarian and vegan products



Rank	Country	Category
1	DR Congo	extreme
1	Somalia	extreme
3	Burundi	extreme
4	Eritrea	extreme
5	Angola	extreme
6	Chad	extreme
7	Ethiopia	extreme
7	Haiti	extreme
9	Afghanistan	extreme

- Algae 'Micro/Macro algae' offer opportunity to fill that gap



- Why?
- Several reasons:
- High diversity of species
  - →Protein rich, lipid rich, high nutritional value….
  - →Sustainable production

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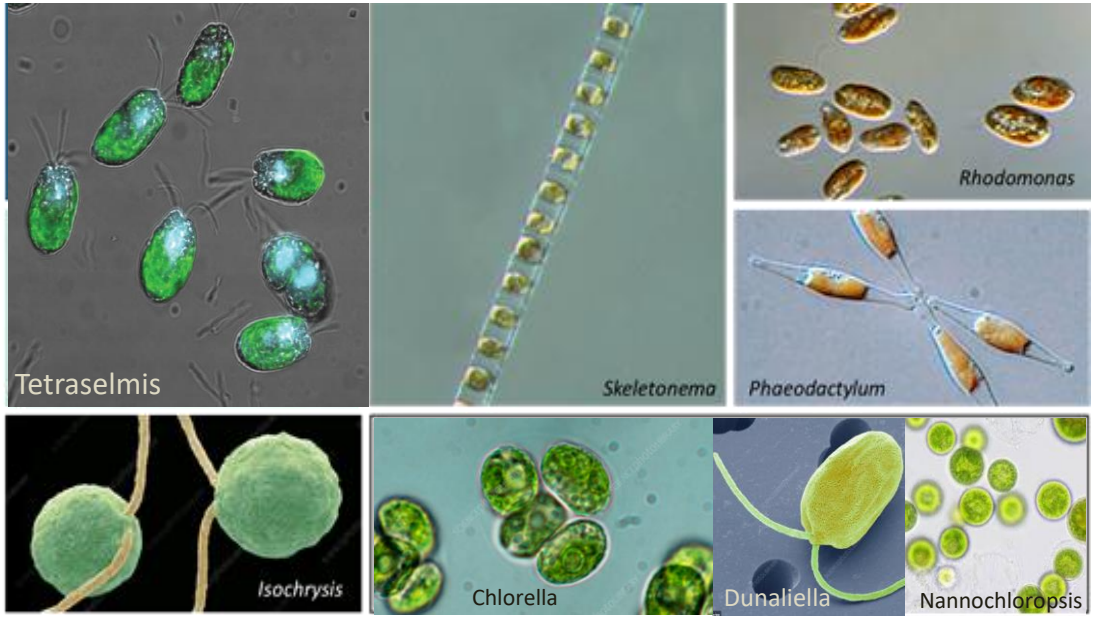
Interreg 2 Seas Mers Zeeën ValgOrize
European Regional Development Fund

Algae! What?

Microalgae: Unicellular

200.000 to 800.000 different species



Macroalgae: Multicellular- Seaweed

Green macroalgae- Chlorophyta (Ulva)

Brown macroalgae- Phaeophyta (Saccharina)

Red macroalgae- Rhodophyta (Dulse)

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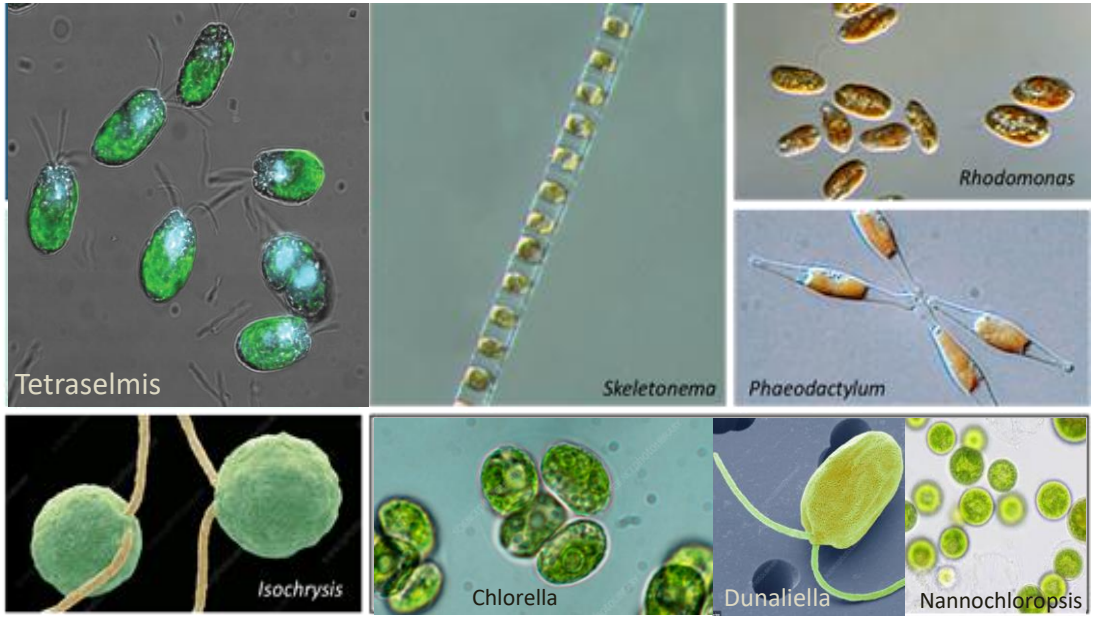
Algae! What?

Microalgae: Unicellular

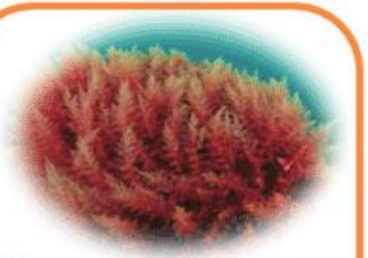
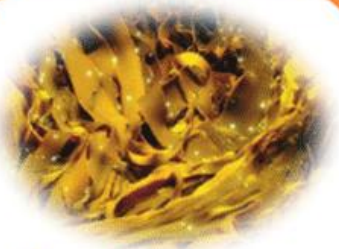
Number 200.000 to 800.000 species



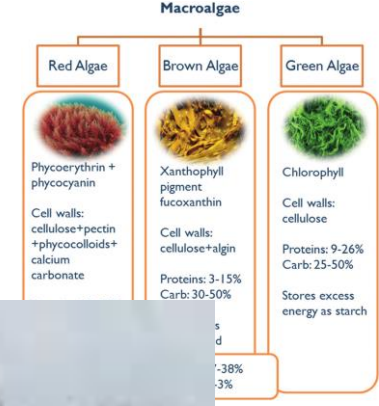
Algae! What?

Macroalgae: Multicellular- Seaweed
Green macroalgae- Chlorophyta (Ulva)
(4000 species)
Brown macroalgae- Phaeophyta (Saccharina)
(2000 species)
Red macroalgae- Rhodophyta (Dulse)
(6500 species)

Macroalgae

Red Algae	Brown Algae	Green Algae
		
Phycoerythrin + phycocyanin	Xanthophyll pigment fucoxanthin	Chlorophyll
Cell walls: cellulose+pectin +phycocolloids+ calcium carbonate	Cell walls: cellulose+algin	Cell walls: cellulose
Proteins: 10-47% Carb: 30-60%	Proteins: 3-15% Carb: 30-50%	Proteins: 9-26% Carb: 25-50%
Floridean starch as stored food	Mannitol as stored food	Stores excess energy as starch
	Minerals: 7-38% Lipids: 1-3%	

Algae! What?



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Algae- Food of the future- different aspects

Aspects for Food

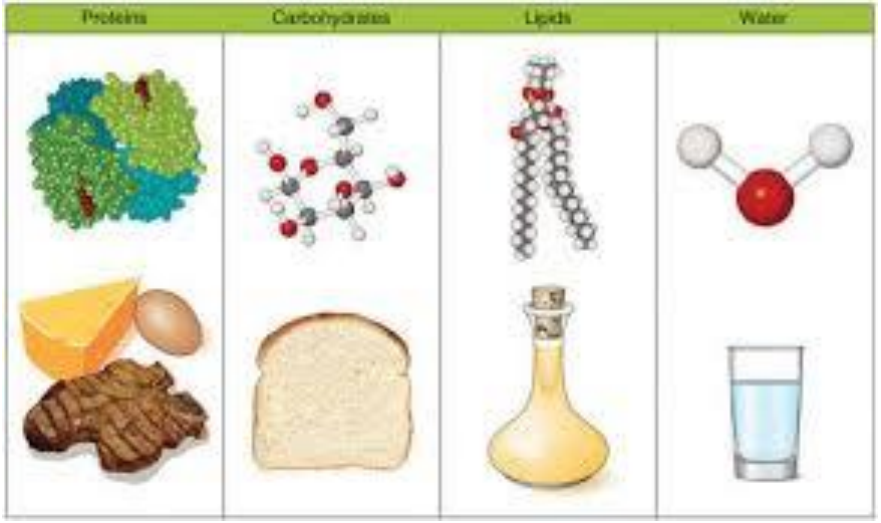
- Nutritional
- Functional-Techno-Functional aspects

- Taste/Flavour/Sensory aspects

Algae and Nutrition Food of the future- Nutrition

Macronutrient

- Protein
- Lipids
- Polysaccharides



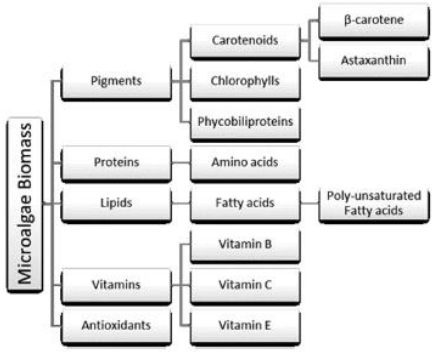


Table 1
Composition of microalgal species in percentage of dry biomass matter

Microalgae Species	Composition (%dry matter)			References
	Protein	Lipids	Carbohydrates	
Anabena cylindrica	43–56	4-7	25–30	[1]
Aphanizomenon flos-aquae	62	3	23	[2]
Chaetoceros calcitrans	36	15	27	[3]
Chlamydomonas rheinhardti	48	21	17	[4]
Chlorella vulgaris	51–58	14–22	12–17	[5]
Chlorella pyrenoidosa	57	2	26	[3]
Diacronema viktanum	57	6	32	[6]
Dunaliela salina	57	6	32	[3]
Dunaliela bioculata	49	8	4	[7]
Euglena gracilis	39–61	22–38	14–18	[3,7]
Haematococcus pluvialis	48	15	27	[6]
Isochrysis galbana	50–56	12–14	10–17	[3]
Porphyridium cruentum	28–39	9–14	40–57	[3,7]
Prymnesium parvum	28–45	22–38	25–33	[7]
Scenedesmus obliquus	50–56	12–14	10–17	[4,8]
Scenedesmus dimorphus	8–18	16–40	21–52	[3,7]
Scenedesmus quadricauda	47	1.9	21–52	[7]
Spirogyra sp.	6–20	11–21	33–64	[7]
Spirulina maxima	60–71	6–7	13–16	[3]
Spirulina platensis	46–63	4–9	8–14	[3]
Synechococcus sp.	63	11	15	[4]
Tetraselmis maculata	52	3	15	[7]

Table 2
Protein content in various food sources including microalgae. Adapted from [4]

Food origin	Protein content (% dry matter)
Beef	17.4
Fish	19.2–20.6
Chicken	19-24
Peanut	26
Wheat Germ	27
Parmesan Cheese	36
Skimmed Milk powder	36
Soybean flour	36
Beer Yeast	45
Whole egg	47
Chlorella sp.	50–60
Spirulina sp.	60–70

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Algae and Nutrition Food of the future- Proteins- Quantity!

Macronutrient
- Protein

Chicken: 20%
Egg: 47%
Beef: 17%
Macroalgae: 25%
Microalgae: 50%

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Whole egg	47
Chlorella sp.	50–60
Spirulina sp.	60–70

Macroalgae

Table 2 Crude protein and crude fiber proximate composition given in mean relative%, (average of n=2)

Species	Crude protein	Mean value	Crude fiber	Mean value
Rhodophyta				
Gelidium microdon	14.61	15.18	56.71	57.37
	15.75		58.02	
Osmundea pinnatifida	20.32	20.64	33.94	33.82
	20.97		33.69	
Porphyra sp.	25.64	25.80	43.09	40.98
	25.97		38.86	
Pterocladiella capillacea	20.56	20.52	52.96	52.08
	20.48		51.19	
Sphaerococcus coronopifolius	19.60	19.56	40.60	41.25
	19.51		41.91	
Phaeophyta				
Cystoseira abies-marina	6.94	6.81	56.26	56.34
	6.69		56.40	
Fucus spiralis	10.56	10.77	61.79	63.88
	10.97		65.97	
Chlorophyta				
Ulva compressa	27.52	26.62	40.24	41.16
	25.72		42.08	

Microalgae

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Algae and Nutrition Food of the future- Proteins- Quality

Macronutrient

- Protein
-

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Protein content in various food sources including microalgae. Adapted from [4]

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Beer Yeast	45
Whole egg	47
Chlorella sp.	50–60
Spirulina sp.	60–70

Table 3
Amino acids profile of conventional protein sources and microalgae (g/100g of dry matter). Adapted from [2,9–11]

Source	Egg	Chicken Breast	Soybean	*Chlorella sp.*	*Chlorella Vulgaris*	*Nannochloropsis sp.*	*Scenedesmus sp.*	*Scenedesmus obliquus*	*Dunaliella sp.*	*Du ba*
ESSENTIAL AMINO ACIDS										
Histidine	2.4	4.5	2.6	2.4	2.0	2.6	2.5	2.1	2.6	
Isoleucine	6.6	3.24	5.3	4.4	3.8	4.7	4.7	3.6	4.5	
Leucine	8.8	6.4	7.7	9.2	8.8	9.4	9.3	7.3	9.4	
Lysine	5.3	7.9	6.4	8.9	8.4	6.8	6.2	5.6	6.8	
Methionine	3.2	2.5	1.3	2.2	2.2	2.3	2.5	1.5	2.4	
Phenyl-alanine	5.8	3.2	5.0	5.5	5.0	5.5	6.0	4.8	5.5	
Threonine	5.0	3.7	4.0	4.7	4.8	4.8	5.0	5.1	4.9	
Tryptophan	1.7	-	1.4	-	2.1	-	-	0.3	-	
Valine	7.2	3.46	5.3	6.1	5.5	6.0	6.0	6.0	6.0	
NON-ESSENTIAL ACIDS										
Tyrosine	4.2	3.65	3.7	4.2	3.4	3.9	4.0	3.2	4.0	
Alanine	-	4.7	5.0	8.3	7.9	6.8	7.8	9.0	6.8	
Arginine	6.2	5.8	7.4	7.1	6.4	6.0	6.6	7.1	6.0	
Asparagine	11.0	7.8	1.3	9.4	9.0	9.1	10.5	8.4	9.2	
Glutamic	12.6	11.2	19.0	12.9	11.6	13.8	13.6	10.7	13.8	
Glycine	4.2	3.4	4.5	5.4	5.8	5.2	5.7	7.1	5.2	
Proline	4.2	3.2	5.3	4.8	4.8	8.3	4.9	3.9	8.3	
Serine	6.9	3.4	5.8	4.0	4.1	4.2	4.4	3.8	4.2	
Cystine	2.3	1.1	1.9	0.4	1.4	0.1	4.0	0.6	0.1	

Table 1
Dry matter, crude protein concentrations (mean ± SD[1]) and amino acids (AA) composition (mean) in dried and ground *Ascophyllum nodosum*, *Saccharina latissima* and *Ulva* sp.

	Ascophyllum nodosum	Saccharina latissima	Ulva sp. (June)	Ulva sp. (August)	Soybean meal[2]
Dry matter, (g/100 g)	93.2 ± 0.00	94.0 ± 0.00	92.8 ± 0.00	94.5 ± 0.16	
Crude protein, (g/100 g DM)	11.4 ± 0.18	15.2 ± 0.00	15.9 ± 0.27	13.3 ± 0.18	53.1 ± 1.14
EAA[3], (g/100 g CP)					
Arginine	4.58	4.25	4.74	4.46	7.21 ± 0.07
Histidine	1.42	1.41	1.29	0.96	2.70 ± 0.12
Isoleucine	4.00	3.87	3.61	3.86	4.50 ± 0.14
Leucine	6.02	6.07	5.87	5.48	7.60 ± 0.13
Lysine	4.92	4.61	3.89	3.40	6.12 ± 0.21
Methionine	1.85	1.47	1.32	1.54	1.34 ± 0.07
Phenylalanine	3.73	3.73	4.70	4.08	5.10 ± 0.10
Threonine	4.25	4.01	4.21	4.75	3.82 ± 0.14
Tryptophan	1.12	1.05	1.17	0.92	1.35 ± 0.06
Valine	4.73	4.65	4.94	5.40	4.81 ± 0.11
NEAA[4] (g/100 g CP)					
Alanine	5.34	6.01	6.81	7.67	4.25 ± 0.15
Aspartic acid	10.1	9.26	9.76	10.03	9.37 ± 3.04
Cysteine	1.85	1.80	1.24	1.65	1.41 ± 0.08
Glutamine	12.1	10.8	9.49	10.82	17.4 ± 0.55
Glycine	6.09	5.35	5.23	4.82	4.14 ± 0.10
Ornithine	0.10	0.09	0.09	0.11	
Proline	3.53	3.45	3.69	3.21	4.76 ± 0.19
Serine	4.14	4.10	4.59	4.75	4.71 ± 0.2
Σ EAA, (g/100 g CP)	36.62	35.12	35.74	34.85	44.2 ± 1.00
Σ NEAA, (g/100 g CP)	43.18	40.85	40.90	43.06	47.9 ± 3.36
EAA: NEAA	0.85	0.86	0.87	0.81	0.93 ± 0.05
Σ Total AA, (g/100 g CP)	79.8	76.0	76.6	77.9	92.1 ± 4.23

[1] Standard deviation over duplicate analysis of a representative seaweed sample.
[2] Average and SD over several studies (Hulshof et al., 2016; Lagos and Stein, 2017; Cowieson et al., 2019; Oliveira et al., 2020).
[3] Essential amino acids.
[4] Non-essential amino acids.

Protein quality of algae good profile

Not for other plants- Algae supplements and Vegan!

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Algae and Nutrition Food of the future- Lipids - Quantity and Quality

Macronutrient Lipids

- Quantity: Range

Fish: 1-20%
Beef: 5-15%
Egg: 10%
Microalgae: 5-40%
Macroalgae: 5-15%

Algae	Protein (%)	Carbohydrate (%)	Lipid (%)	Reference
Spirulina platensis	50–65	8–14	4–9	Venkataraman and Becker (1985), Becker (1994)
Chlorella sp.	51–58	12–17	14–22	(Trubachev et al. (1976), Aaronson et al. (1980), Becker (1994), Renaud et al. (1994)
Scenedesmus sp.	50–56	10–52	12–14	Hindak and Probil (1968), Becker (1984, 1994)
Dunaliella sp.	49–57	4–32	6–8	Eddy (1956), Parson et al. (1961)
Synechococcus sp.	63	15	11	Trubachev et al. (1976)
Euglena sp.	39–61	14–18	14–20	Collyer and Fogg (1955), Becker (1994)
Prymnesium sp.	28–45	25–33	22–38	(Ricketts 1966)
Anabaena sp.	48	25–30	4–7	Becker (1994)
Chlamydomonas sp.	43–56	2.9–17	14–22	Becker (19940, Renaud et al. (1994)
Porphyridium sp.	28–39	50–57		Becker (1994)
Spirulina maxima	60–71	13–16	6–7	Becker (1994)
Spirogyra	6–20	33–64	11–21	Becker (1994)
Tetraselmis	52	15	16–45	Becker (1994), Brown (1991)
Pavlova	24–29	6–9	9–14	Brown (1991), Becker (1994)
Enteromorpha intestinalis	6.15	30.58	7.13	Chakraborty and Santra (2008)
Rhizoclonium riparium	21.09	15.34	3.37	Chakraborty and Santra (2008)
Lola capillaris	40.87	22.32	4.05	Chakraborty and Santra (2008)
Ulva lactuca	8.44	35.27	4.36	Chakraborty and Santra (2008)
Catenella repns	8.42	28.96	5.29	Chakraborty and Santra (2008)
Polysiphonia mollis	16.59	25.81	5.79	Chakraborty and Santra (2008)

Algae and Nutrition Food of the future- Lipids – Quantity and Quality

Macronutrient Lipids

- Quality-,high quality
- PUFA
- high amount of Omega_3
  - EPA: C20:5, n-3) – algae, seaweed, fish
  - DHA: C22:6, n-3) – algae, seaweed, fish
  - ALA- nuts, seeds

Seaweed and algae are important sources of omega-3 for people on a vegetarian or vegan diet, as they are one of the few plant groups that contain DHA and EPA.

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Algae and Nutrition Food of the future- polysaccharide -Quantity and Quality

Quantity: 4-45%

Quality:

Macronutrient

- Polysaccharide- Important as dietary fiber

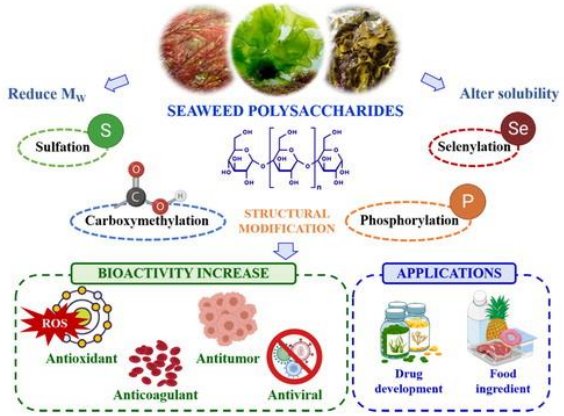
Soluble DF:

- Alginate, laminarin, fucoidan in brown seaweeds,
- Carrageenan, agar and agarose in red seaweed
- Ulvan of green seaweeds

Insoluble DF

- Cellulose, lignin, hemicellulose and starch

Health effects



Functionally important

Polyunsaturated FA (g/100 g FA)		37.9 ± 0.21	22.2 ± 0.51	20.6 ± 0.65	27.8 ± 0.81
C18:2n6	Linoleic acid	8.59 ± 0.05	5.34 ± 0.02	3.15 ± 0.08	5.70 ± 0.05
C18:3n6	γ-Linolenic acid	0.19 ± 0.00	0.65 ± 0.01	0.21 ± 0.04	0.37 ± 0.07
C18:3n3	α-Linolenic acid	3.72 ± 0.00	2.33 ± 0.01	6.15 ± 0.16	14.56 ± 0.06
C18:4n3	Stearidonic acid	3.30 ± 0.01	3.13 ± 0.04	6.78 ± 0.06	2.44 ± 0.03
C20:2n6	Eicosadienoic acid	1.91 ± 0.01	0.57 ± 0.12	0.46 ± 0.04	0.4 ± 0.16
C20:3n6	Dihomo-γ-linolenic acid	0.67 ± 0.01	0.2 ± 0.01	0.00 ± 0.00	0.49 ± 0.02
C20:4n6	Arachidonic acid	9.93 ± 0.03	4.09 ± 0.04	0.3 ± 0.01	1.2 ± 0.01
C20:3n3	Eicosatrienoic acid	0.45 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0;00
C20:5n3	Eicosapentaenoic acid	6.85 ± 0.04	4.67 ± 0.15	1.94 ± 0.02	1.41 ± 0.18
C22:5n6		0.18 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.41 ± 0.07
C22:5n3	Docosapentaenoic acid	0.15 ± 0.02	0.2 ± 0.01	1.07 ± 0.06	0.54 ± 0.14
C22:6n3	Docosahexaenoic acid	2.01 ± 0.02	1.03 ± 0.1	0.50 ± 0.17	0.27 ± 0.02
n6		21.3 ± 0.10	10.8 ± 0.2	4.12 ± 0.18	8.15 ± 0.32
n3		16.5 ± 0.08	11.4 ± 0.32	16.4 ± 0.47	19.2 ± 0.43
n-6:n-3		1.29	0.95	0.25	0.42

Polyunsaturated fatty acids (PUFA) are divided into 2 groups as omega (n); n-6 and n-3 groups, based on the position of the terminal double bond (Harris, 2018). Alpha-linolenic acid, EPA and docosahexaenoic acid (DHA) comprise the n-3 FA group. Linoleic acid and arachidonic acid comprise the n-6 FA group. The n-6:n-3 ratio is commonly used as an indicator of functional quality of a lipid source (Harris, 2018). Similar to the present study, van Ginneken et al. (2011) observed the highest concentration of α-linolenic acid (i.e. 20 % of total FAs) in *U. lactuca* among other studied seaweeds. These authors also observed similar concentrations of EPA in *U. lactuca* and *A. nodosum*. In addition, Peinado et al. (2014) observed similar concentrations of EPA and DHA in *A. nodosum*. Eicosapentaenoic acid, DHA and other unsaturated FAs in the diet are vital for improved health in humans (Calder and Yaqoob, 2009). Therefore, enrichment of food animal tissues (i.e. muscle, milk etc.,) with such FAs is beneficial.

Algae and Functional Food of the future

Algae and Functional food aspects

Techno-Functional Properties of Algae

Talk Geert Van Royen

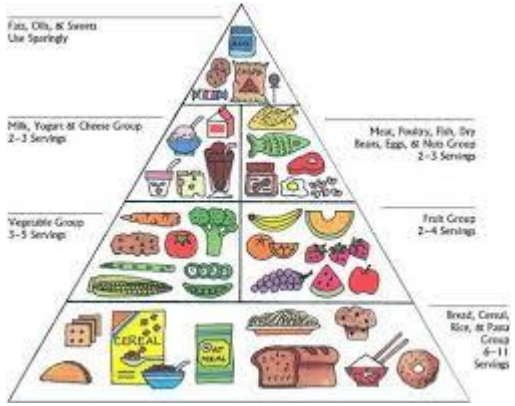
Algae and Food of the future

Considering

- Quality and quantity of macronutrient is excellent
- Functionality with high potential
- Micronutrient is excellent (vitamins, pigments, ions…- not covered here)
- Bioactive compounds (Anti-oxidant, anti-inflammatory, anti-microbial…- not covered here)

There is a high potential of algae for food of the future,

But…. The current market



Current Algae Market

Microalgae- limited species and limited amount
Spirulina 1- 2%
Chlorella 1 -2%

Macroalgae
2-10% seaweed (Saccharina)

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onderzoek

Algae

Current market

Microalgae- limited species and limited amount
Spirulina 1- 2%
Chlorella 1 -2%

Macroalgae
2-10% seaweed (Saccharina)

Table 6
Microalgae incorporation in food products

Type of product	Microalgae species	Addition	Benefit	Ref
Biscuits	*A. platensis*	1.63,3,5,7,8.36% w/w	Nutritional and Techno-functional properties (protein, fiber and anti-oxidative content)	[15]
	A. platensis, Phycocyanin Extract	0.3,0.6 and 0.9% w/w to wheat flour	Nutritional properties	[16]
	A. platensis, C. vulgaris, P. tricornutum and T. suecica	2 and 6% w/w	Nutritional and Techno-functional properties (anti-oxidative activity)	[17]
	I. galbana	1 and 3% w/w	Nutritional and Techno-functional properties (ω-3 PUFAs)	[18]
	A. fusiformis	1 and 3% w/w in the flour		[19]
	A. platensis	1.1% w/w in flour		[20]
Bread	*A. platensis (gluten free bread)*	2-5% w/w in flour		[21]
	A. platensis and C. amphiceon	2% w/w algal protein in flour	Nutritional and Techno-functional properties (proteins and mineral content)	[22]
	Arthrospira sp.	2,2.5 and 3% w/w in flour		[23]
	Dunaliella sp.	10% w/w with algal biomass, biomass without β-carotene and biomass without β-carotene and glycerol.		[22]
	I. galbana, N. gaditana, S. almeriensis, T. suecica	0.47% w/w in flour		[24]
Cookies	*C. vulgaris*	0.5, 1.0, 2.0 and 3.0 % w/w in flour	Colouring agent	[25]
	H. pluvialis	5, 10 and 15% astaxanthin in flour	Nutritional and Techno-functional properties (antioxidative activity)	[26]
Extruded snacks	*Arthrospira sp.*	0.4, 1.0, 1.8, 2.6 and 3.2% w/w	Nutritional and Techno-functional properties (proteins content)	[27]
Emulsions: Oil/water	Green and orange *C. vulgaris* (after carotenogenesis)	2% w/w	Techno-functional properties	[28]
	Green and orange *C. vulgaris* and red *H. pluvialis* (after carotenogenesis)	*C. Vulgaris*: 0.25-2.0% w/w *H. pluvialis*: 0.05-2.0% w/w	Colouring agent and nutritional properties (antioxidative activity)	[29]
Fermented milk	*A. platensis*	3 g/L	Nutritional properties	[30]
Frozen yogurt	*Arthrospira sp.*	2-8% w/w	Nutritional properties	[31]
	A. maxima, green and orange *C. vulgaris* after carotenogenesis	0.5, 1.0 and 2.0% w/w in flour	Nutritional and Techno-functional properties	[32]
Pasta	*A. platensis*	1-3% w/w in flour	Sensory quality and nutraceutical potential	[33]
		5, 10 and 20% w/w in flour	Nutritional and Techno-functional properties (antioxidative activity)	[34]
	D. salina	1-3% w/w in flour	Nutritional and Techno-functional properties	[35]
	D. vlkianum and *I. galbana*	0.5, 1.0 and 2% w/w in flour	Nutritional and Techno-functional properties (ω-3 PUFAs)	[36]
	S. platensis	5 and 10% w/w in flour	Nutritional and Techno-functional properties (protein enrichment)	[37]
Probiotic Yogurt	*A. platensis*	0.1-0.8% w/w	Nutritional and Techno-functional properties	[22]
Processed cheese	*Chlorella sp.*	0.5 and 1.0% w/w	Nutritional and Techno-functional properties	[38]
Vegetarian food gels	*A. maxima* and *D. vlkianum*	0.1- 1.0% w/w	Nutritional and Techno-functional properties (antioxidative activity, ω-3 PUFAs)	[39]
	A. maxima, C. vulgaris, D. vlkianum and *H. pluvialis*	0.75% w/w		[40]
	A. maxima and *H. pluvialis*	0.75% w/w		[41]
Yogurt	*Chlorella sp.*	Powder extract: 0.25% w/w Liquid extract: 2.5-10%	Nutritional and Techno-functional properties	[42]

A.K. Koyande et al. / Food Science and Human Wellness 8 (2019) 16–24

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Algae and Functional Food of the future-
Business

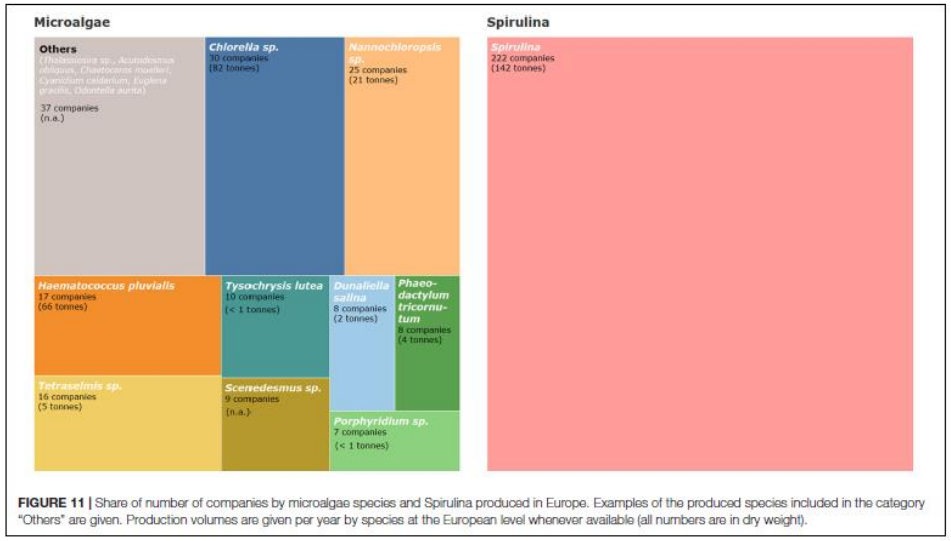

FIGURE 11 | Share of number of companies by microalgae species and Spirulina produced in Europe. Examples of the produced species included in the category "Others" are given. Production volumes are given per year by species at the European level whenever available (all numbers are in dry weight).

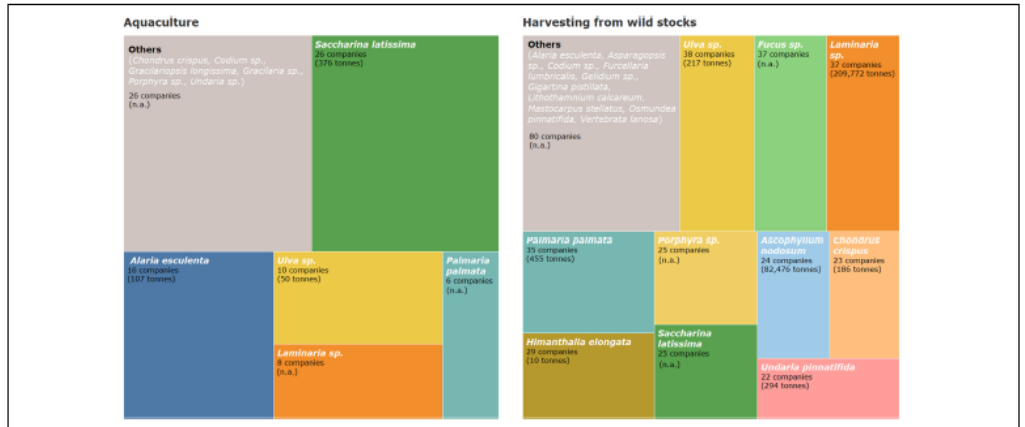

FIGURE 8 | Share of number of companies by macroalgae species produced in aquaculture and wild stock harvesting systems in Europe. Examples of the produced species included in the category "Others" are given. Production volumes per year by species are given whenever available (all numbers are in fresh weight). Volumes of production are estimated based on FAO (2020), national and regional statistics authorities and information from the industry.

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Algae and Functional Food of the future-
Algae and Functional aspects

Most of them are infant formulae containing *Schizochytrium*-derived docosahexaenoic acid (DHA) or astaxanthin-rich oleoresin from *Haematococcus pluvialis*, a carotenoid available as dietary supplement, food additive, or pigment (Enzing et al., 2014; Lafarga, 2019). The incorporation of microalgal biomass into conventional food products, because of their nutritional properties, is a global trend that fostered the launch of several products worldwide. Once again, the majority of these products contain either *Arthrospira* or *Chlorella*, mainly because of their long history of use and protein content (Lafarga, 2019; Nova et al., 2020). The very low concentrations used in some products suggest that microalgal biomass is mostly applied as a colouring agent or for marketing purposes focused on vegan consumers as well as on consumers who decide to purchase organic or ecologic products, rather than for the nutritional or technological advantages of microalgae as a food ingredient (Lafarga, 2019). In fact, several authors evaluated the effect of macroalgae and microalgae biomass incorporation into foods. In general, authors reported that higher algae concentrations (depending on algae species and end product) resulted in negative effects on colour and flavour of the final product, which decrease consumers' acceptance (Arufe et al., 2018; Batista et al., 2013; Jiménez-Colmenero et al., 2010). Protein extracts would allow improving consumers' acceptance, at least from a sensorial point of view. For this reason, the effect of different protein processing methods on yield, digestibility, bioactivity, colour, and flavour of the resulting protein extract needs to be evaluated, in view of the final application (Grossmann et al., 2018; Schwenzfeier et al., 2012).

Authors reported that higher algae concentrations (depending on algae species and end product) resulted in negative effects on colour and flavour, which decrease consumers' acceptance

Algae and negative connotation with taste/flavour and consumer acceptance

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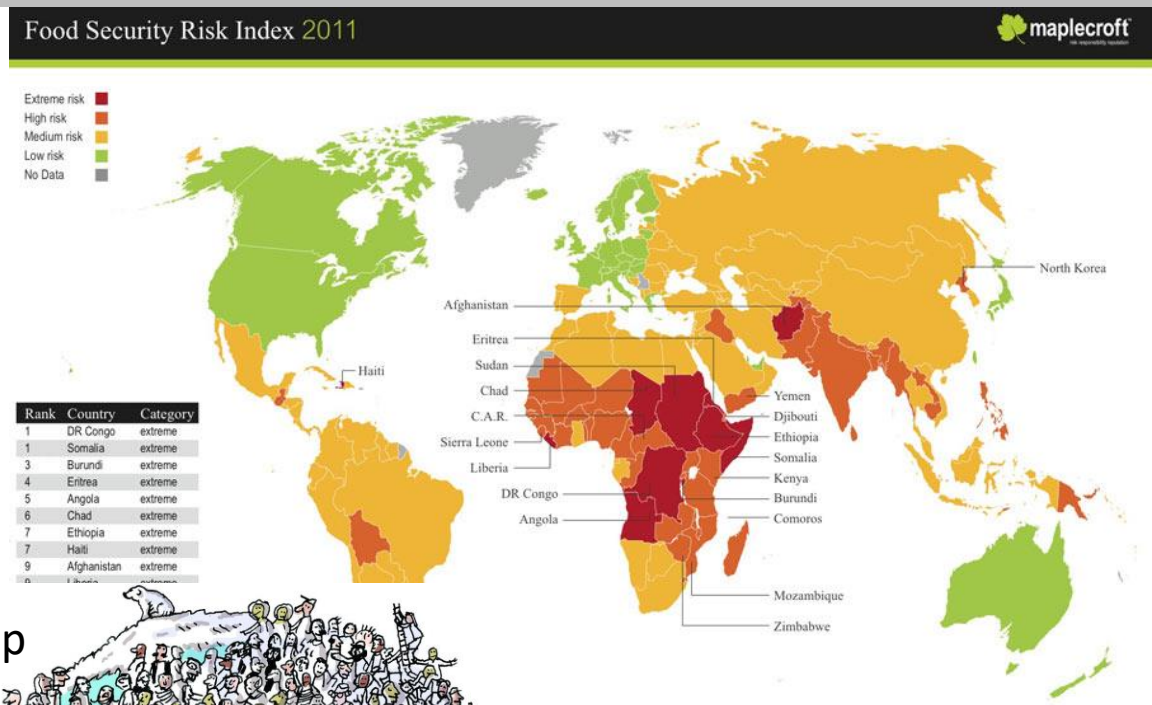
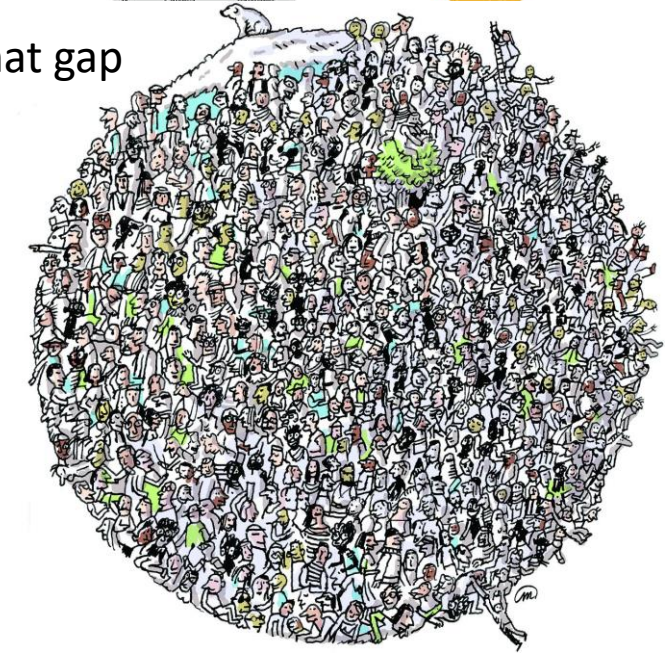
Algae - Food of the Future?

- ➢ Food Security→ Feeding the world
- ➢ Protein transition → Shift away from animal proteins
- Search for alternative sources
- ➢ New niche and more demand for vegetarian and vegan products



Rank	Country	Category
1	DR Congo	extreme
1	Somalia	extreme
3	Burundi	extreme
4	Eritrea	extreme
5	Angola	extreme
6	Chad	extreme
7	Ethiopia	extreme
7	Haiti	extreme
9	Afghanistan	extreme

- Algae 'Micro/Macro algae' offer opportunity to fill that gap



- Why?
- Several reasons:
- High diversity of species
  - →Protein rich, lipid rich, high nutritional value….
  - →Sustainable production

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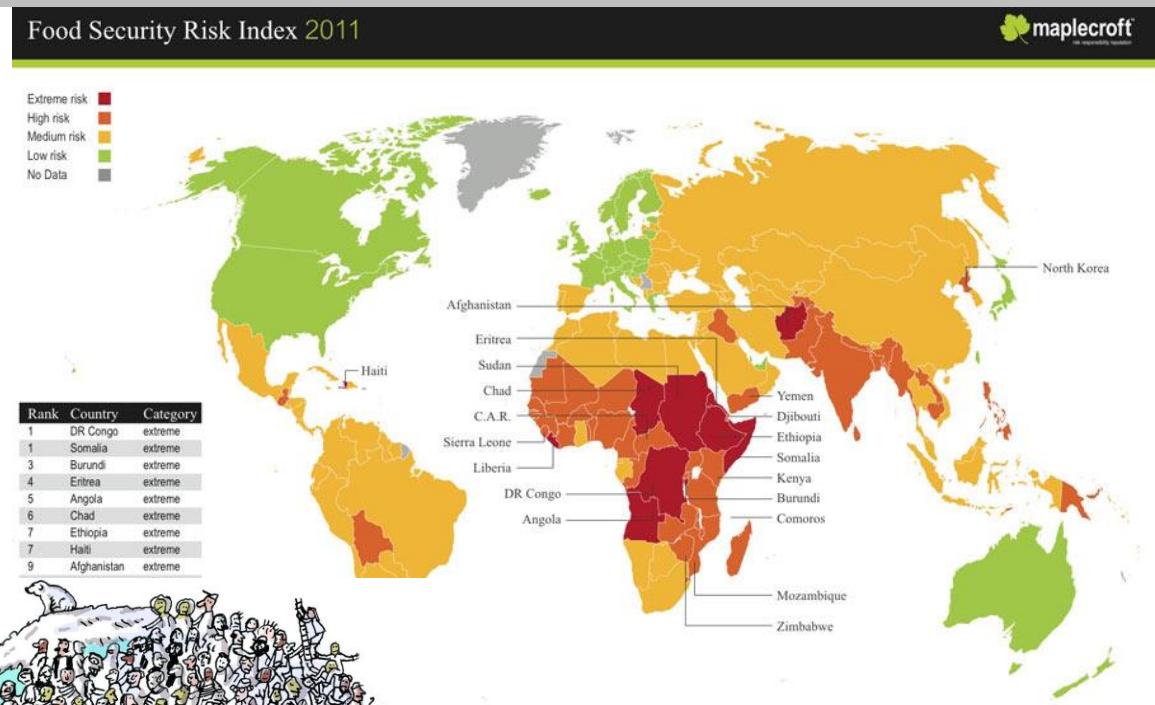
European Regional Development Fund

European Biomass

Food Security→ Feeding the world

- Protein transition
- Search for alternative sources

- Algae ‘Micro/Macro algae’ offer opportunity to fill that gap
  → Protein rich, lipid rich, high nutritional value



Rank	Country	Category
1	DR Congo	extreme
1	Somalia	extreme
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4	Eritrea	extreme
5	Angola	extreme
6	Chad	extreme
7	Ethiopia	extreme
7	Haiti	extreme
9	Afghanistan	extreme

However so far Algae are NOT a part of ‘our’ (European) food basket

- EU consumers are not used to consume algae
- Often a negative connotation

How to convince?
→ Taste

Within ValgOrize we want to sustainably produce algae with a good flavour/taste that is appreciated by the European consumer ‘European Taste/Flavour’.

Interreg
2 Seas Mers Zeeën
ValgOrize
European Regional Development Fund

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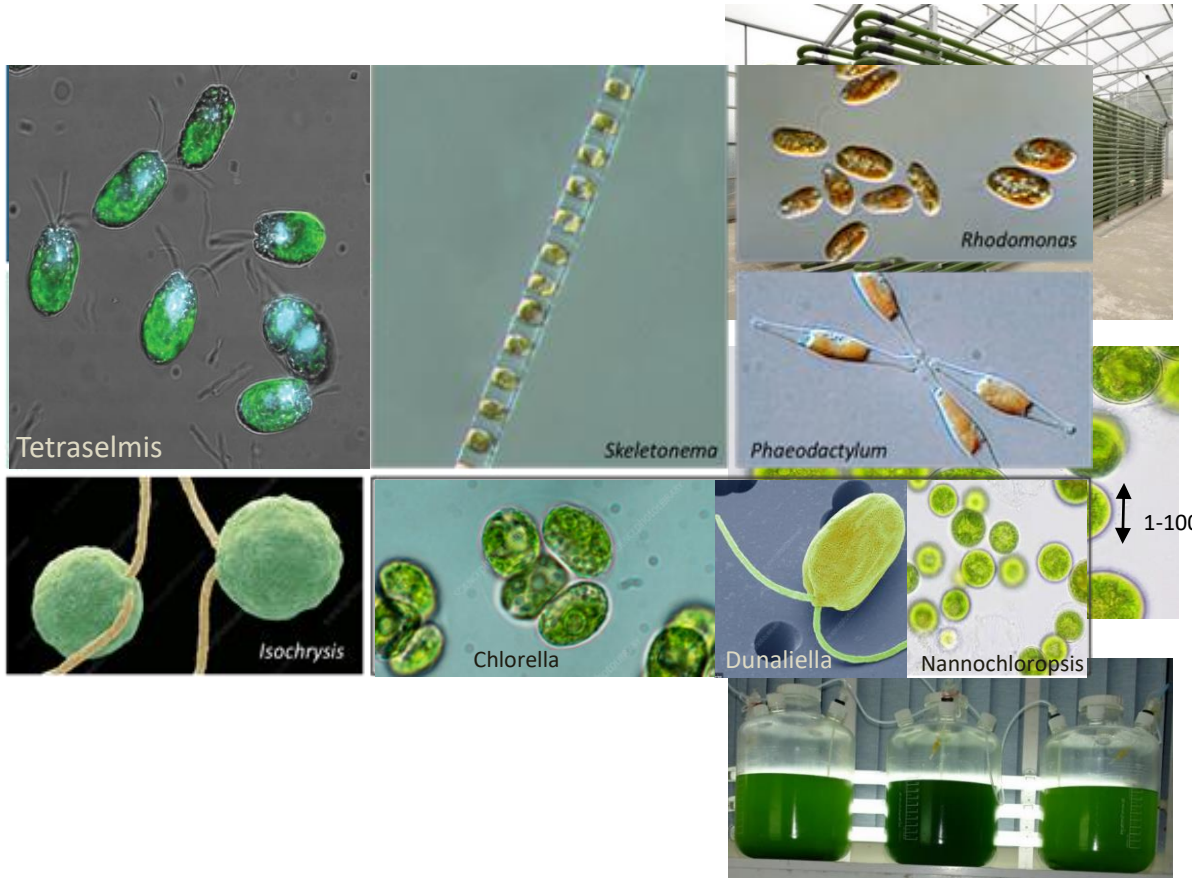
European Biomass - Macroalgae and Microalgae

Seaweed/Macroalgae

Microalgae



Algae for a 'European flavour'

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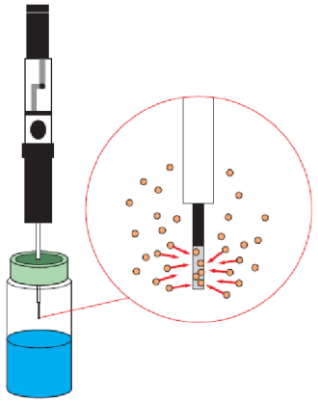
Flavour/Palatability = combined Aroma, Taste, Mouth Feeling (and colour)

Assessing compounds

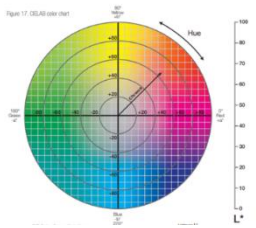


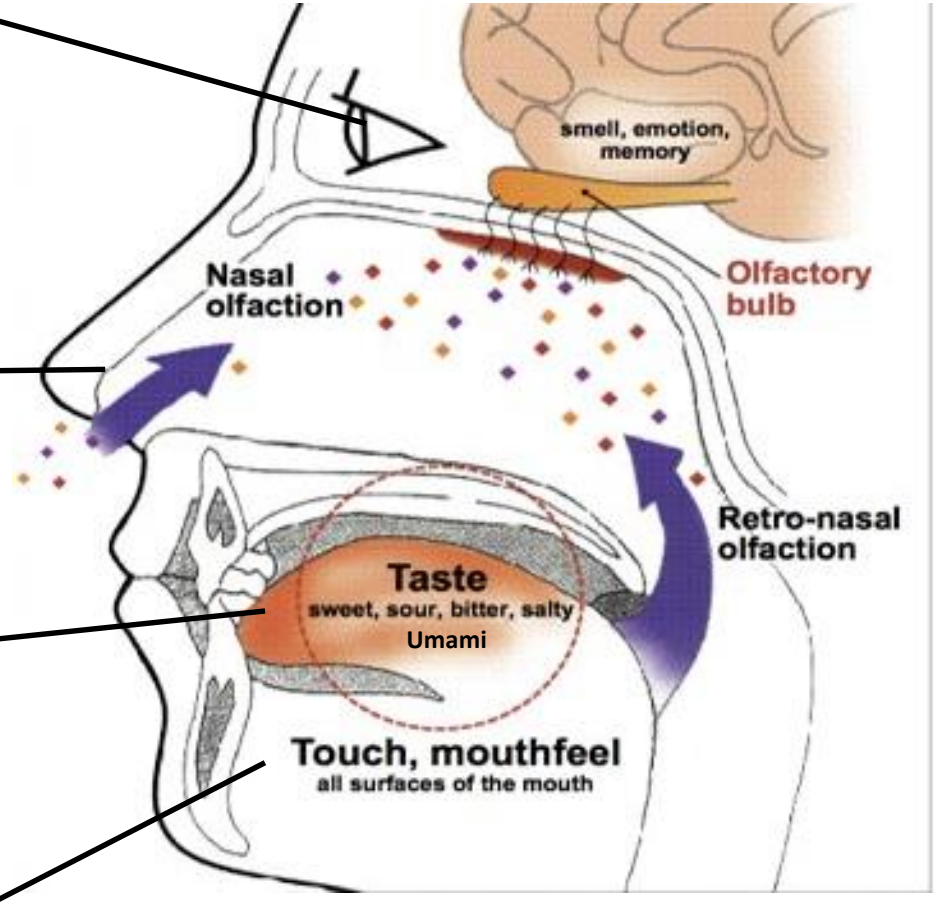
Aroma

volatile compounds

Colour

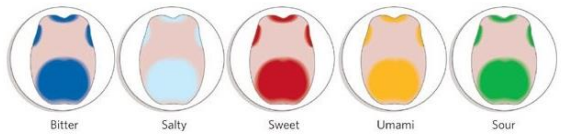
pigments





Taste: different basic tastes

free AA, ribonucleotides, sugar, salt



Mouth Feeling

texture: polysaccharides

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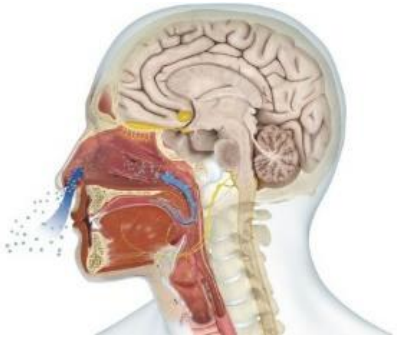
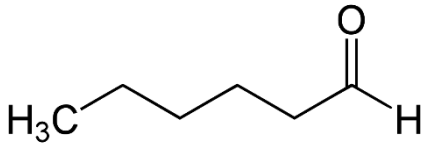
FLAVOUR =

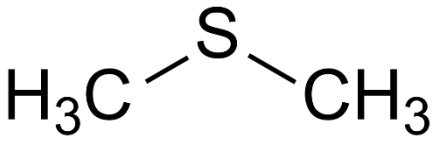
Aroma



Hexanal



Dimethyl sulphide

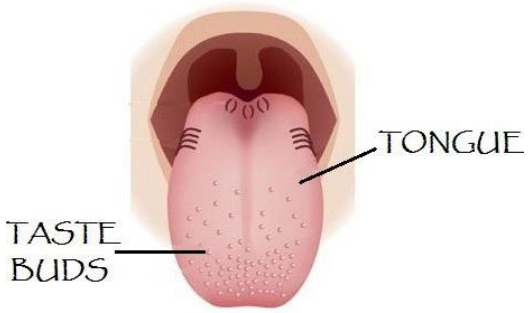


Volatiles

Fatty Acids
Sulfur-compounds

+

Taste



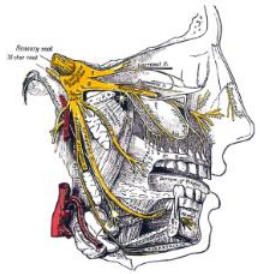
Umami, Sweet, Bitter, Salt

Free amino acids
Ribonucleotides

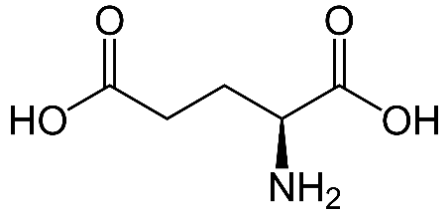
Protein

+

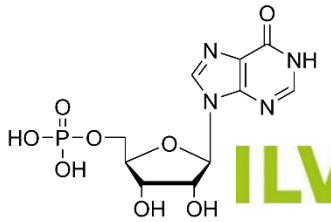
Textural mouthfeel



Glutamic acid



Inosine monophosphate (IMP)



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Molecules for a good taste!

FAA	Taste attribute	Chl	Dun	Iso	Nan	Pha	Rho	Ske	Tet	Pal	Lam	Sac	Ulv	Und	Cod fish	Crab extr	Shrimp extract	Lobster	Lobster extract	Mussel	Shrimp extract	Coal fish
Phenylalanine	Bitter (-)			1.4		1.9		0.6								1.4	1.0	0.5	1.3		1.1	
Tyrosine	Bitter (-)			2.5		3.0		1.8								2.2	1.2	0.8	1.3	1.0	1.0	
Leucine	Bitter (-)					2.3				0.8	0.8					1.3	1.0		1.3		0.7	
Methionine	Bitter/sweet/umami (-)					0.5										1.4	0.9		1.3		0.8	
Isoleucine	Bitter (-)			3.0		2.9		0.8		1.4												
Valine	Sweet/bitter (-)	1.8		9.9		9.3	0.5	3.3	0.9													
Histidine	Bitter (-)	0.5		1.9		1.7		0.6	1.2													
Arginine	Bitter/sweet (+)	1.1		15.1		7.5	2.6	7.4	25.2	6.5												
Tryptophan	Bitter (-)			0.5		0.7																
	TAV (Bitter)	**3.6**	**0**	**32.4**	**0**	**31.2**	**3.2**	**13.3**	**27.5**	**8.6**												
Threonine	Sweet (+)			0.8		1.3		1.6														
Serine	Sweet (+)			2.5		3.8	1.5	1.2														
Alanine	Sweet (+)	5.8		13.3		14.6	2.3	12.7	3.5	0.9												
Proline	Sweet/bitter (+)			0.7		9.3																
Glycine	Sweet (+)			0.7		0.7		0.5														
Lysine	Sweet/bitter (-)	3.1		3.2		2.5	0.7		2.8													
	TAV(Sweet)	**5.9**	**0**	**16.5**	**0**	**22.7**	**3.1**	**12.9**	**4.3**	**0.6**												
Glutamic acid	Umami (+)	8.1	0.1	8.6	1.6	38.1	3.0	23.9	18.9	1.8												
Aspartic acid	Umami (+)	0.7		2.8		0.9	0.5	1.2	1.1	0.1		0.2	0.1	0.2	0.2	0.2	0.3	0.3	0.3	1.7	0.2	0.1

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Molecules for a good taste!

FAA	Taste attribute	Chl	Dun	Iso	Nan	Pha	Rho	Ske	Tet	Pal	Lam	Sac	Ulv	Und	Cod fish	Crab extr	Shrimp extract	Lobster	Lobster extract	Mussel	Shrimp extract	Coal fish
Phenylalanine	Bitter (-)			1.4		1.9		0.6								1.4	1.0	0.5	1.3		1.1	
Tyrosine																	1.2	0.8	1.3	1.0	1.0	
Leucine																	1.0		1.3		0.7	
Methionine	Bitter																0.9		1.3		0.8	
Isoleucine																						
Valine	Sv																					
Histidine																						
Arginine	Bi																					
Tryptophan																						
Threonine																						
Serine	Sweet (+)			2.5		3.8	1.5	1.2														
Alanine	Sweet (+)	5.8		13.3		14.6	2.3	12.7	3.5	0.9												
Proline	Sweet/bitter (+)			0.7		9.3																
Glycine	Sweet (+)			0.7		0.7		0.5														
Lysine	Sweet/bitter (-)	3.1		3.2		2.5	0.7		2.8													
	TAV(Sweet)	**5.9**	**0**	**16.5**	**0**	**22.7**	**3.1**	**12.9**	**4.3**	**0.6**												
Glutamic acid	Umami (+)	8.1	0.1	8.6	1.6	38.1	3.0	23.9	18.9	1.8												
Aspartic acid	Umami (+)	0.7		2.8		0.9	0.5	1.2	1.1	0.1		0.2	0.1	0.2	0.2	0.2	0.3	0.3	0.3	1.7	0.2	0.1

Future Foods 5 (2022) 100139

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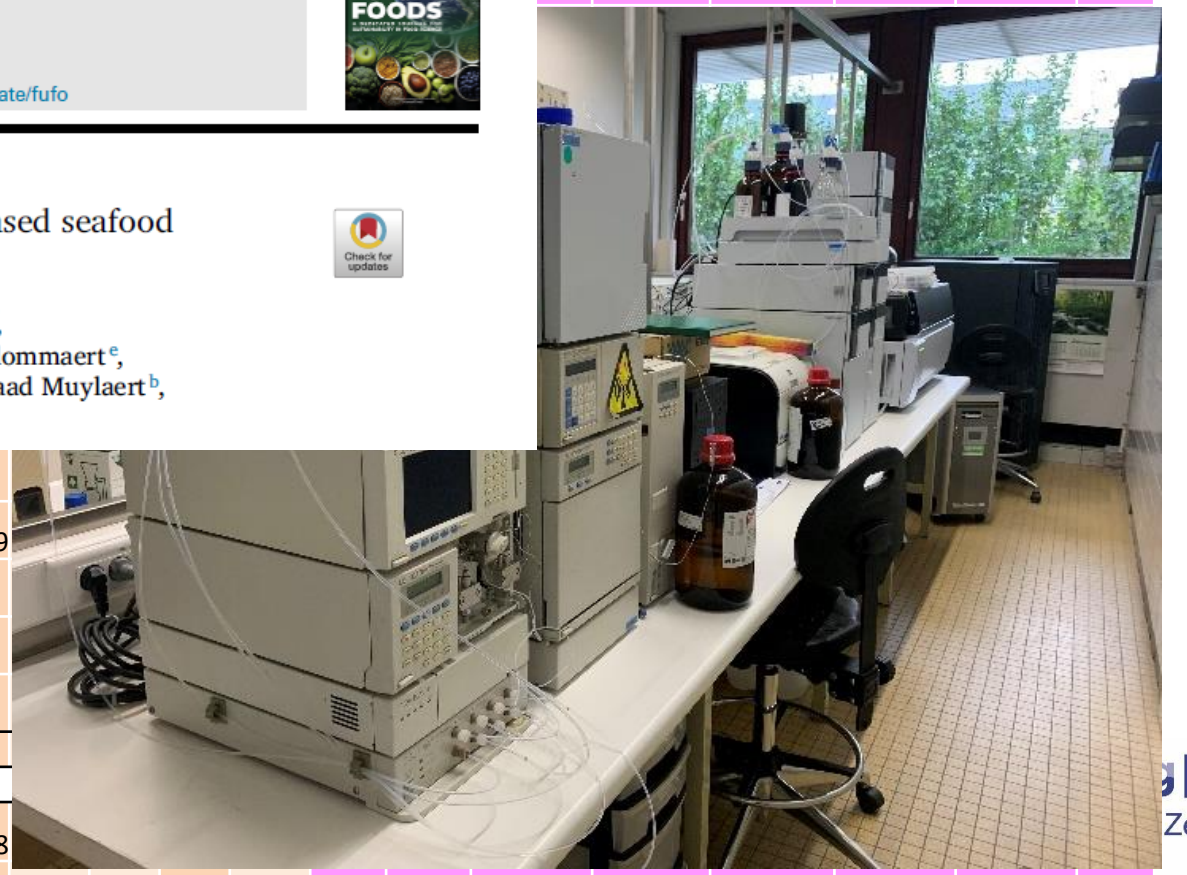
journal homepage: www.elsevier.com/locate/fufo

Potential of microalgae as flavoring agents for plant-based seafood alternatives

Bert Coleman[a,b,*], Christof Van Poucke[c], Bavo Dewitte[a], Ann Ruttens[f], Tanja Moerdijk-Poortvliet[d], Christos Latsos[d], Koen De Reu[c], Lander Blommaert[e], Barbara Duquenne[c], Klaas Timmermans[e], Jasper van Houcke[d], Koenraad Muylaert[b], Johan Robbens[a]



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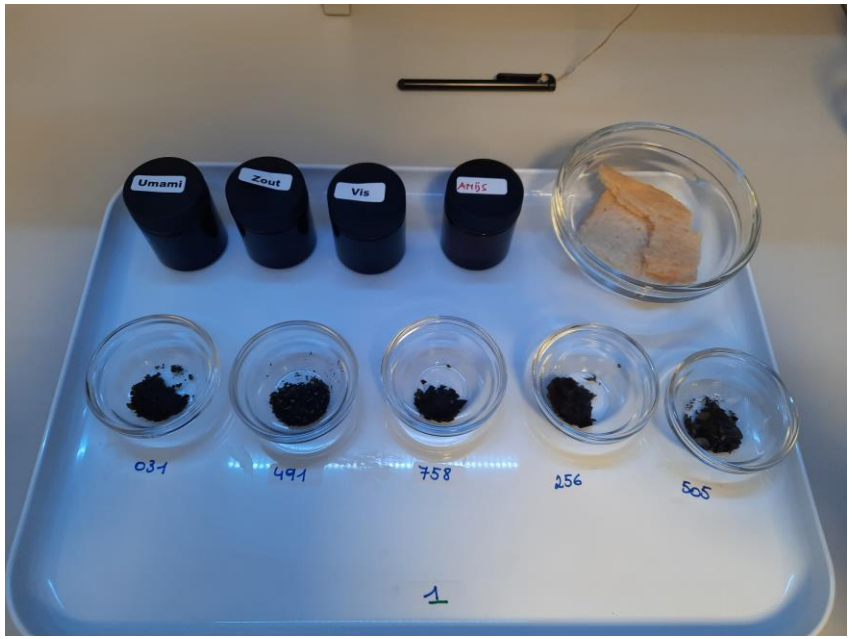
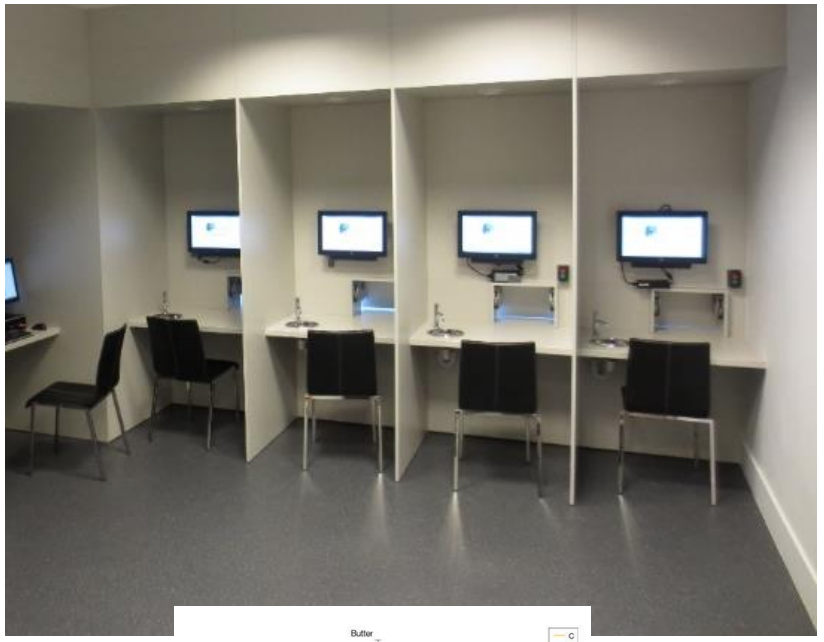
Expert Taste Panel

Trained expert taste panel

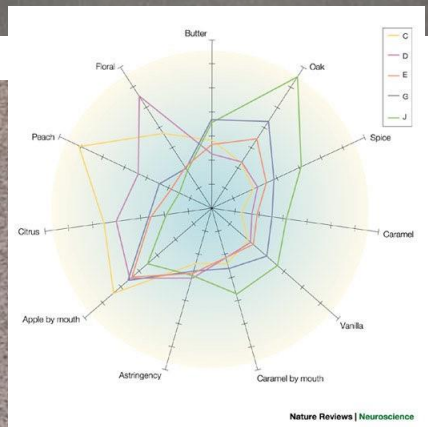
- Scoring of taste
- Scoring of descriptors/attributes





Approved by ethical commitee, based on in depth analysis for food safety (microbial, contaminants)

Tasting of (micro)algae with high potential but that are so far not approved as Novel Food

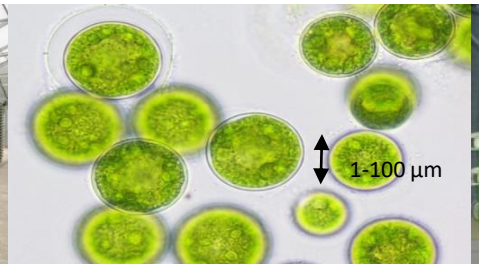


Evaluation of algae biomass – Chemical analysis

Saccharina latissima

Alaria esculenta

Ulva sp.



Volatile compounds

	RT	RI
Aldehydes		
Hexanal	16.551	1080
Heptanal	21.604	1170
Octanal	26.057	1286
2-Heptenal	27.426	1326
Nonanal	30.022	1404
2-Octenal	31.328	1512
2,4-Heptadienal	32.529	1531
Alcohols		
1-Penten-3-ol	20.321	1148
1-Octen-3-ol	31.795	1520
2-ETHYL-1-hexanol	33.142	1541
4-Hepten-1-ol	33.596	1549
Esters		
Ethyl acetate	7.623	692
Ketones		
4-Methyl-2- Heptanone	22.534	1187
1-Octen-3-one	26.532	1301
6-Methyl-5-hepten-2-one	27.927	1341
Acids		
Acetic acid	32.154	1525
4-Hydroxy butanoic acid	37.994	1642
2-Ethyl hexanoic acid	46.424	1900
Aromatic compounds		
Methylene chloride	9.131	927
Benzaldehyde	33.014	1539
Phenol	34.589	1565

Chemical analysis

- Volatile compounds
- Taste compounds
  - Umami
  - Bitter
  - …

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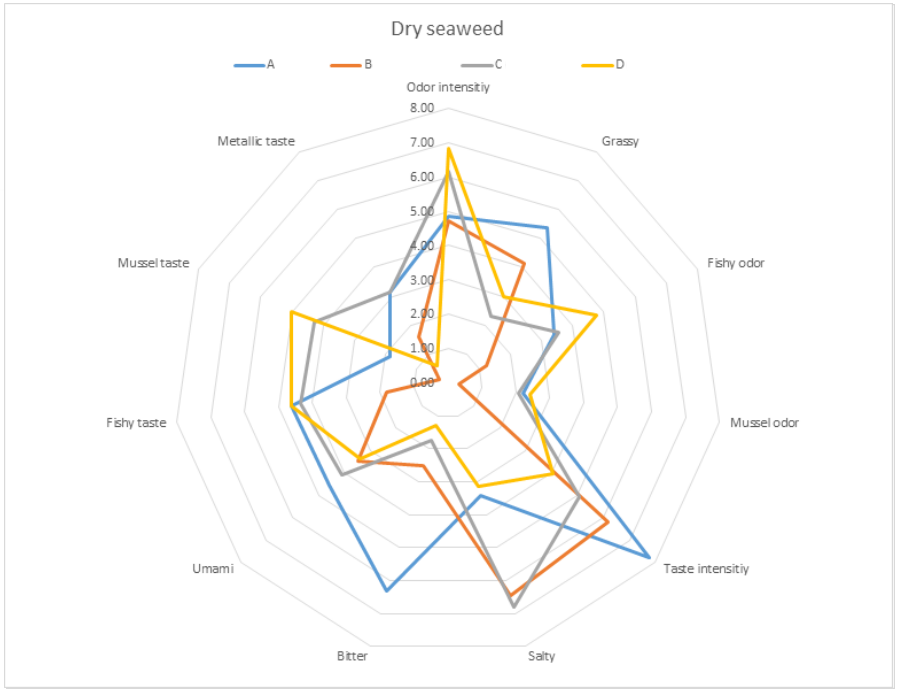
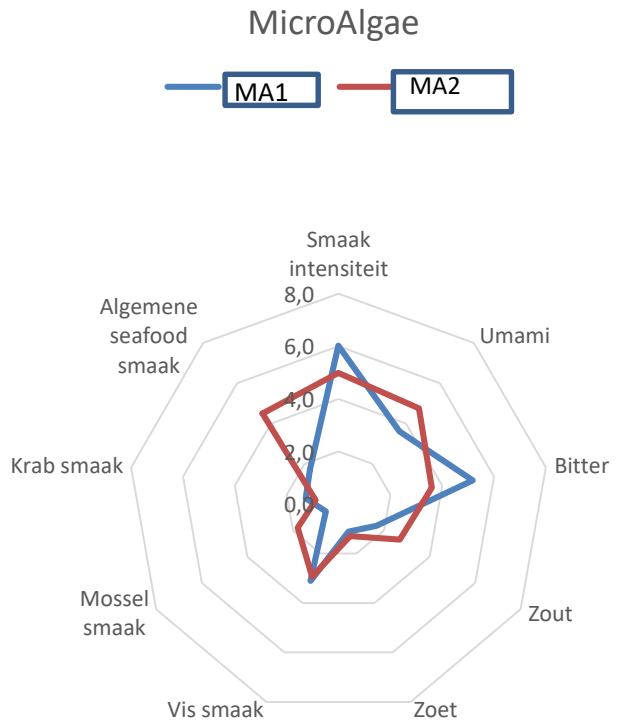
Evaluation of algae biomass by taste panel

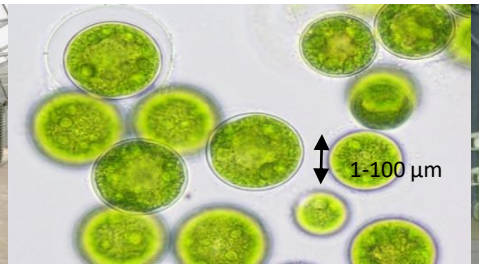
Saccharina latissima

Alaria esculenta

Ulva sp.





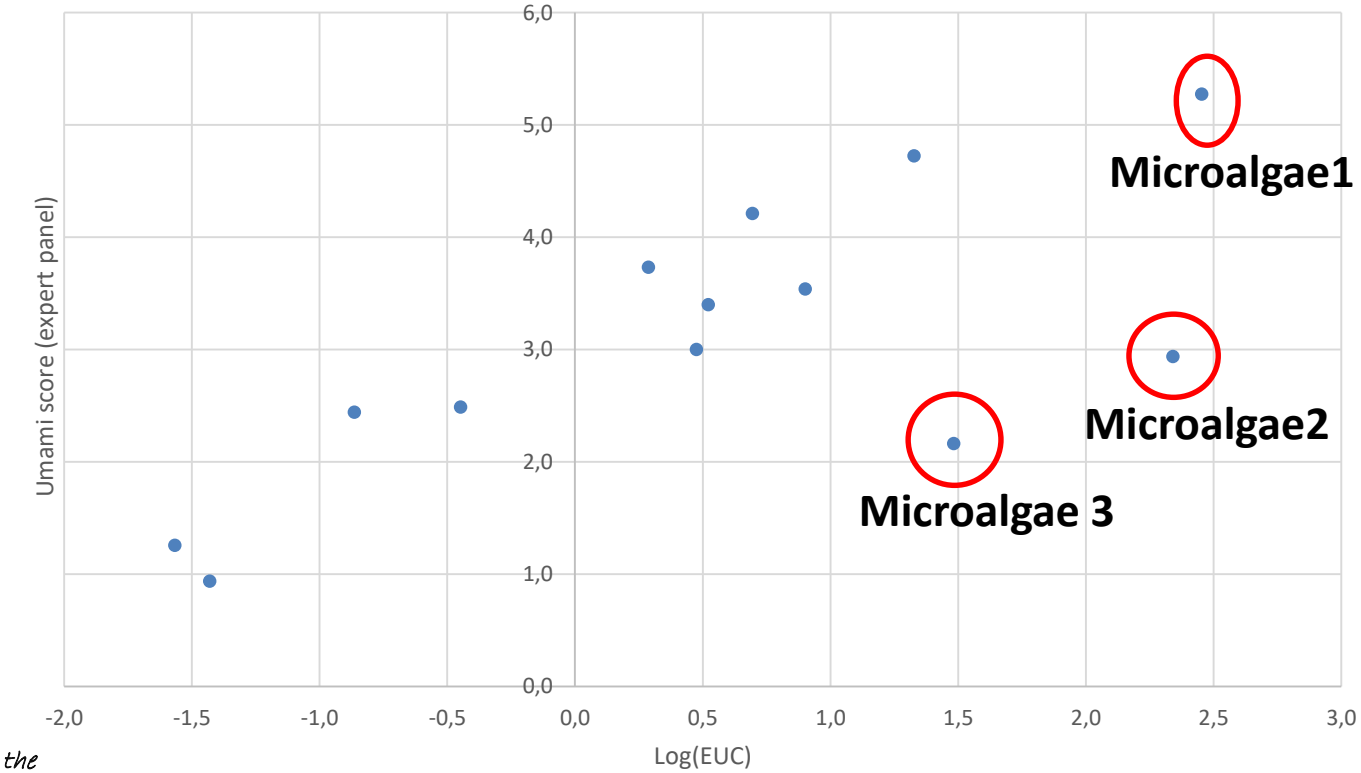


Link umami score and chemical umami markers (EUC)

Sample	EUC	Umami Score	Bitter Score
MicroAlgae1	284	5	3.5
MicroAlgae2	219	3	6
MicroAlgae3	30	2	4
MicroAlgae4	21	5	3
MicroAlgae5	8	3.5	2
MicroAlgae6	5	4	1

Analytics

Expert Panel



EUC: Equivalent Umami Concentration
is the quantitative parameter introduced to describe umami intensity in food, based on the concentration of umami amino acids and 5'-nucleotides

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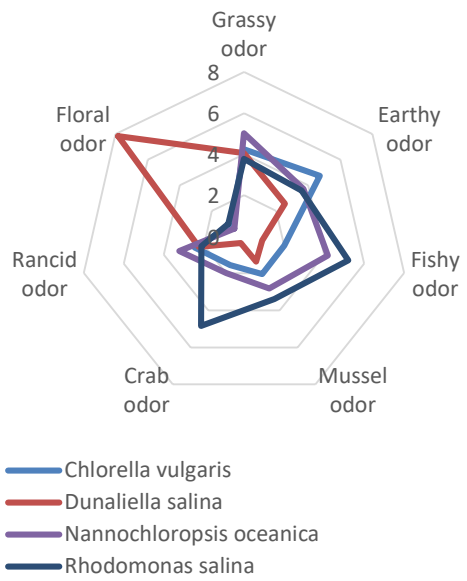
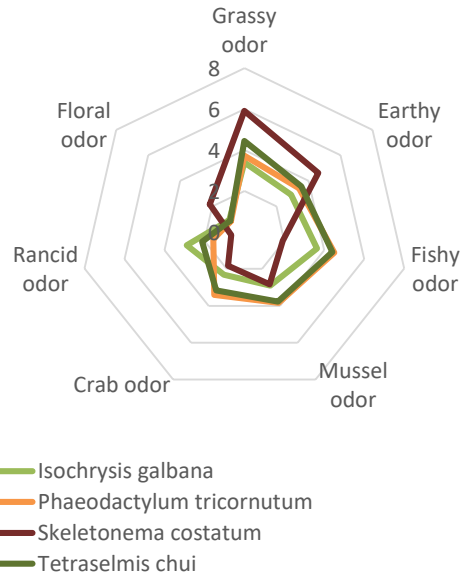
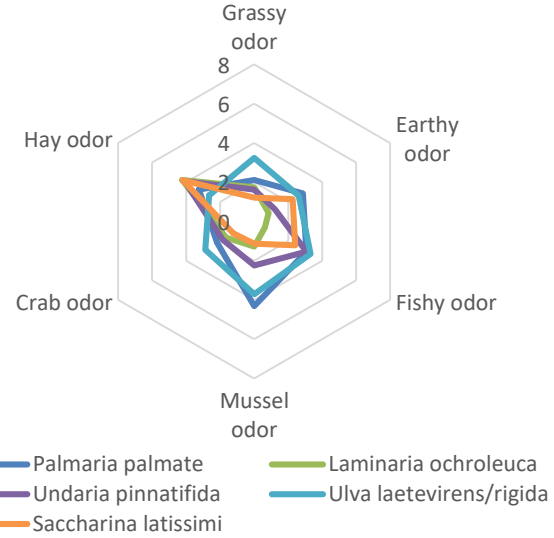
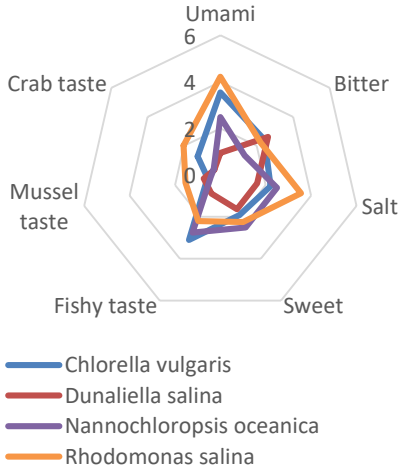
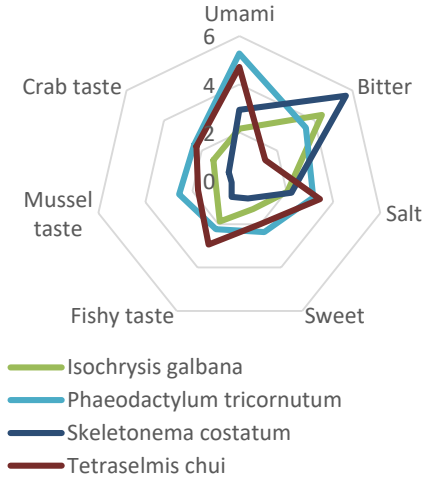
Evaluation of algae biomass by taste panel

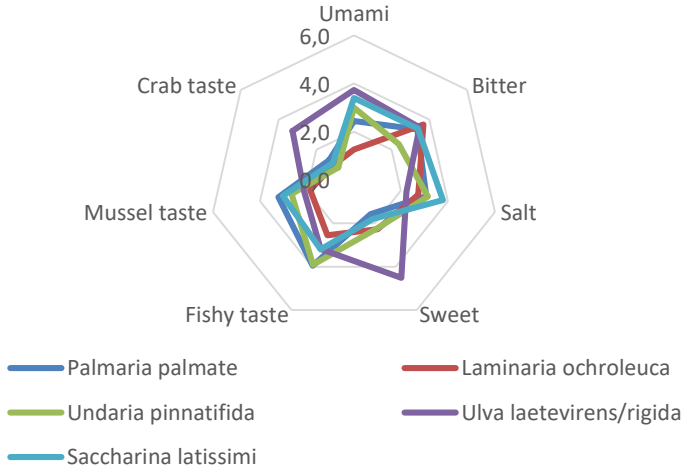




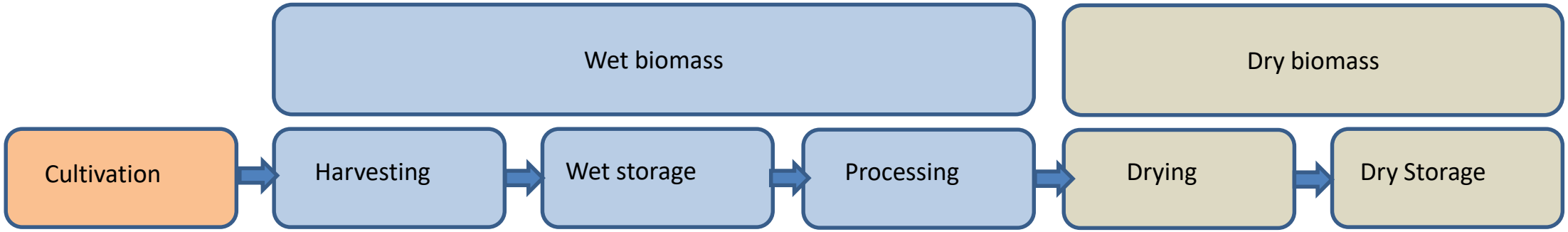


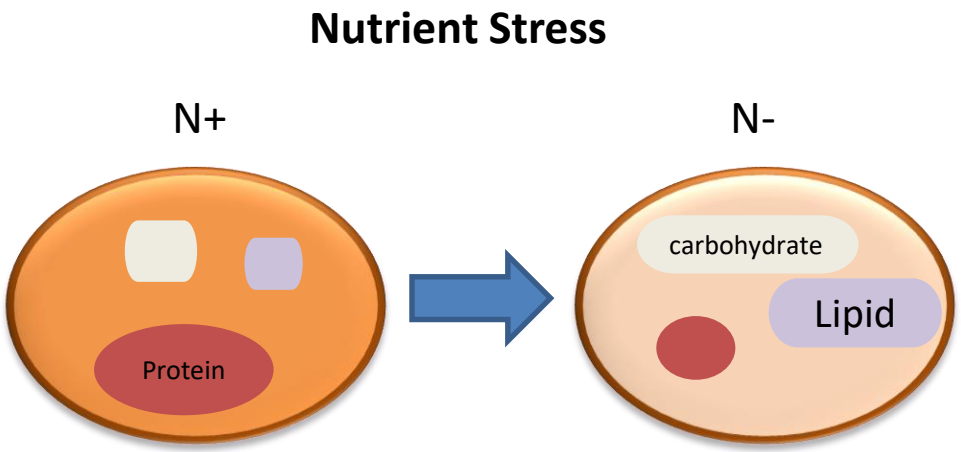






Effect of cultivation on flavour of microalgae?





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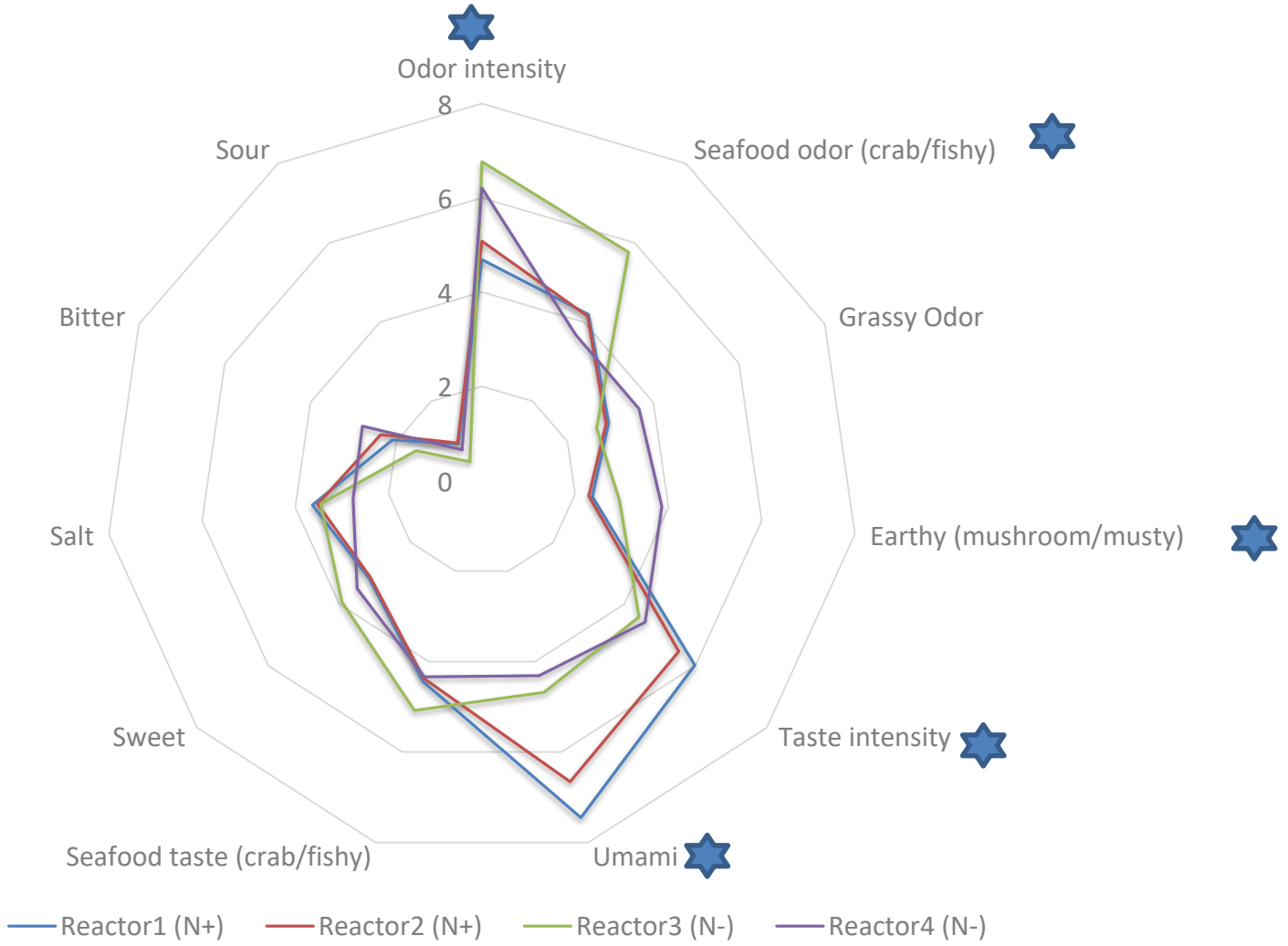
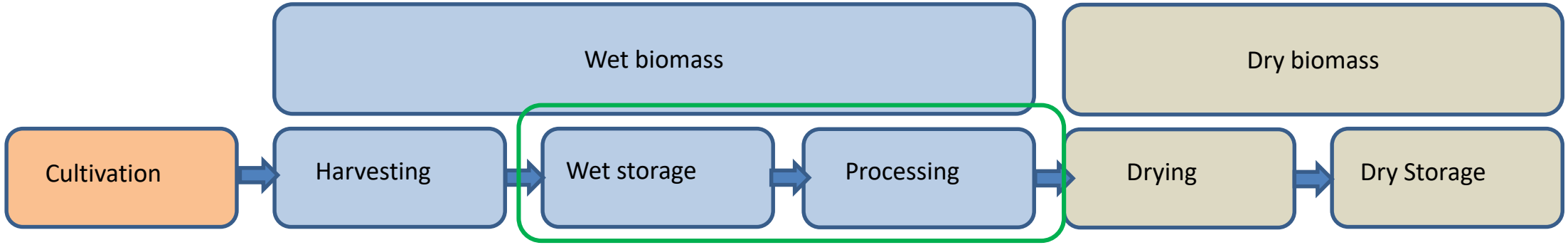
Sensory Evaluation

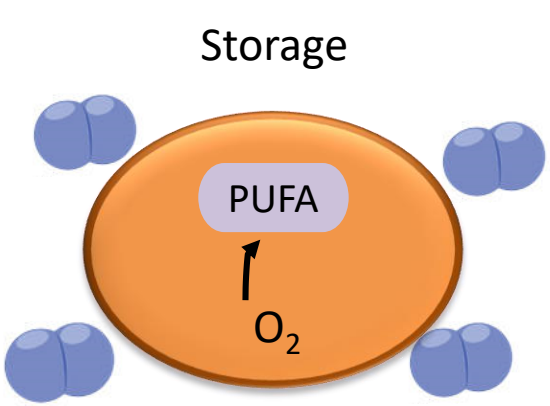
N-stress for optimized (umami)taste
Nutriënt Stress
(PhD Bert Coleman)

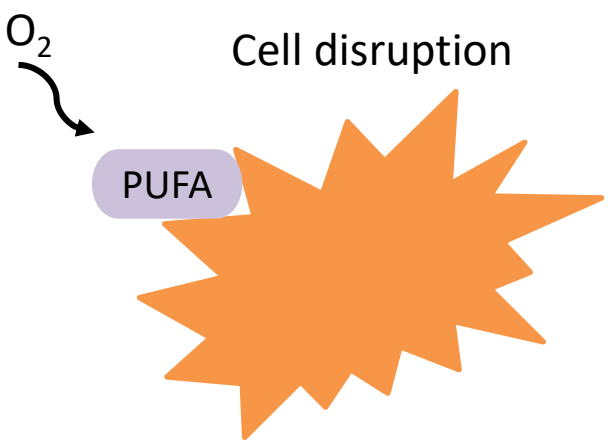
Light stress- cfr Rhodomonas work of Christos Latsos

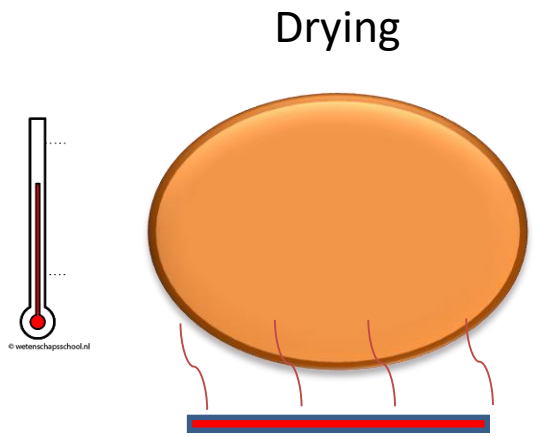


Effect of processing and storage on flavour of microalgae?









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Effect of processing and storage on flavour *Nannochloropsis*

Cell-disruption

Drying technique

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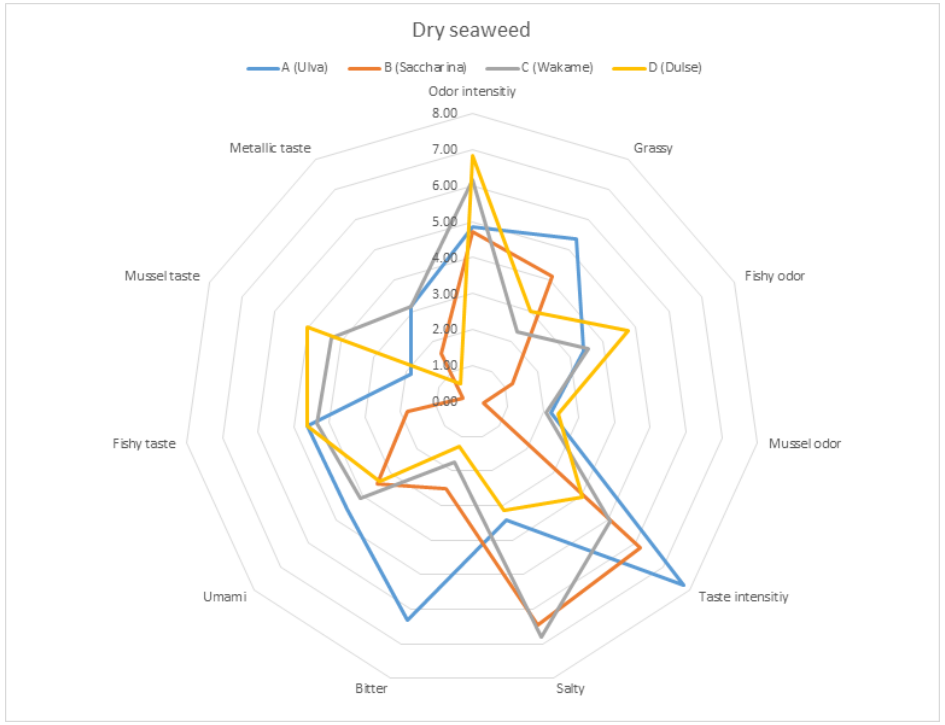
Evaluation of algae biomass- taste profiles

MacroAlgae



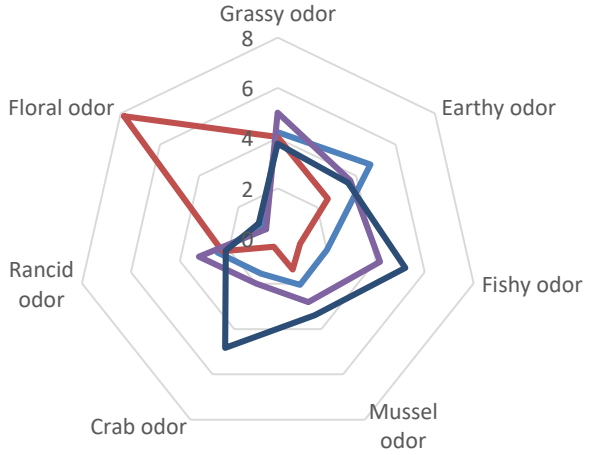
Saccharina latissima

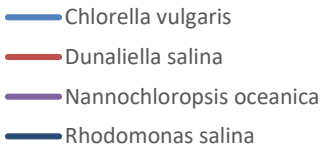
Alaria esculenta

Ulva sp.

Cultivation, processing, storage- What is the impact on the taste profile

MicroAlgae





Rhodomonas salina (HZ)

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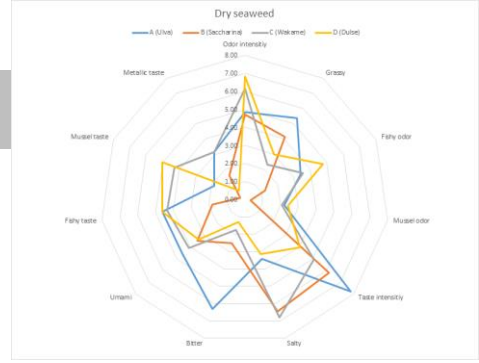
Algae in food?!

Product development in ValgOrize



Session
Room Pasteur

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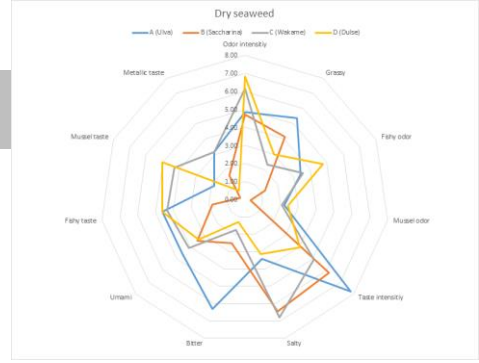
Algae in food? What is next?



Collaboration ValgOrize/ILVO and Donald

Interactive Session Donald

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Algae in food? What is next? !

Co-creatie session with consumers

Alice
DOWN THE RABBIT HOLE

Talk Charlotte/Veerle

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European Regional Development Fund

Algae in food? What is next? !

ILVO-Algen Event: Woensdag 4 Mei

Kennistransfer van ValgOrize naar de (Vlaamse) voedingsindustrie
Kennisoverdracht en eventuele begeleiding voor co-creatie door ILVO

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2 Seas Mers Zeeën
ValgOrize
European Regional Development Fund

Thanks

A lot of people have contributed….

- Special thank to Liesbet Colson and Bert Coleman for slides
- Special thank to Valentina Casciaro, Kaitlyn Vanhoutte for lab work
- Special thank to Liesbet Colson, Bert Coleman, Valentina Casciaro, Geert Van Royen, Barbara Duquenne, Kathleen van de Walle for the organisation of taste panel
- Special thank to Louise Pauwels, Greet Riebels for communication
- Special thank to all consortium partners for the nice collaboration
- Special thank to Interreg 2 Seas for funding

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Thanks!

Further questions?

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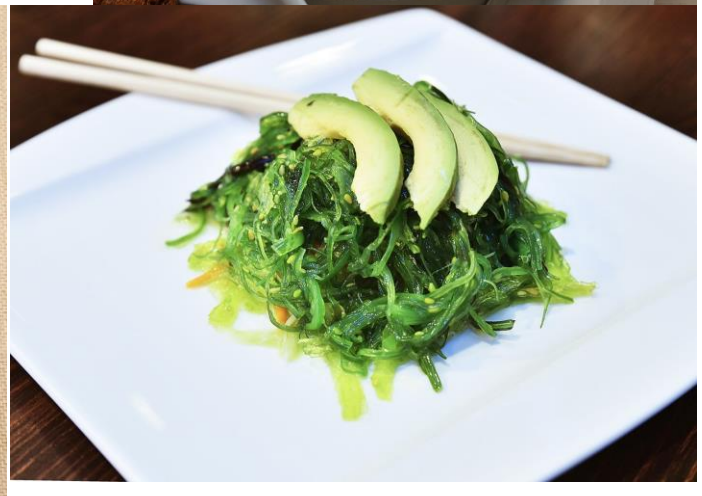
Conclusion

Is Algae- food of the future??

MICROALGAE

Explore the big diversity of microalgae/macroalgae
Taste can be an important driver
Produce ‘European quality’
Align with food producers during cultivation/harvesting



Conclusion

Algae- food of the future??

Yes….

Explore the big diversity of microalgae/macroalgae
Taste can be an important driver
Produce ‘European quality’
Align with food producers during cultivation/harvesting

Yes, Algae the food of the future!!