Ulisses

UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

MICROALGAE BIOMASS AS A SUSTAINABLE FOOD SOURCE

anabraymundo@isa.ulisboa.pt

SESSION III - Microalgae as important sources of bioactive compounds for food and pharmaceutical applications

ulisses.ulisboa.pt

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

Co-funded by the Erasmus+ Programme of the European Union

SESSION II - Microalgae as important sources of bioactive compounds for food and pharmaceutical applications

SUMMARY

Microalgae as important sources of bioactive compounds for food and pharmaceutical applications

Microalgae are one of the renewable sources for pharmaceutical compounds

Why the use of microalgae biomass as a food ingredient is really important?

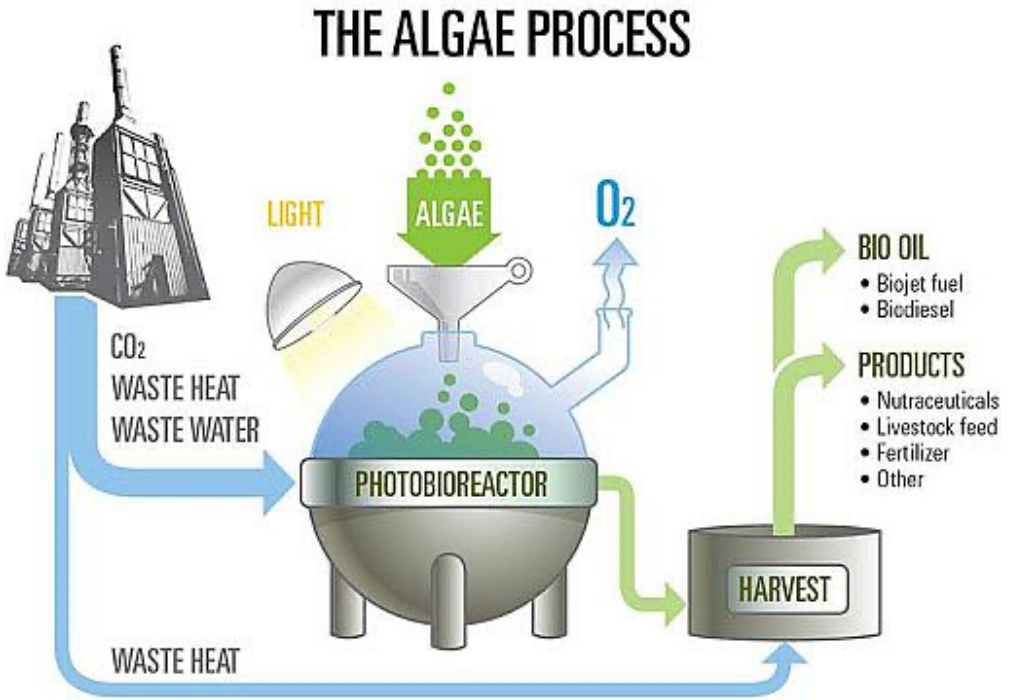
Microalgae as a source of protein and bioactives for food products

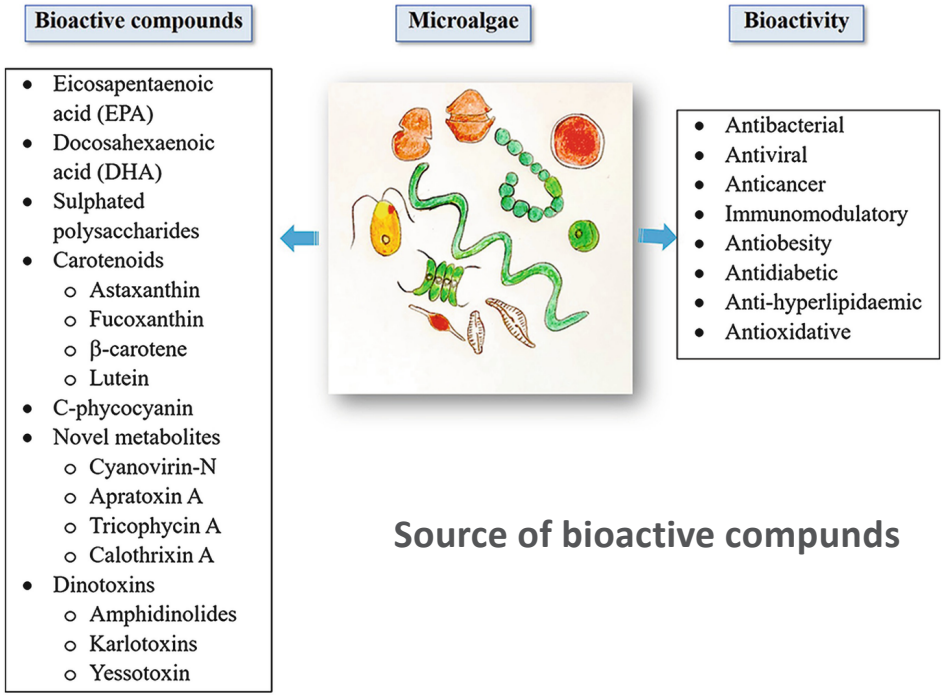
Microalgae – a tool for Food Innovation

Major challenges to the incorporation of microalgae in food

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

SESSION III - Microalgae as important sources of bioactive compounds for food and pharmaceutical applications





Source of bioactive compunds

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Microalgae are one of the renewable sources for pharmaceutical compounds

https://onlinelibrary.wiley.com/doi/abs/10.1002/cben.201600023

Cyanobacteria (spirulina) - source for antibiotics and pharmacologically active compounds
A large number of **antibiotic compounds**, many with novel structures, have been isolated and characterised.

Cyanobacteria – production of antiviral and antineoplastic compounds.

A range of pharmacological activities have also been observed with **extracts of microalgae**, however the active principles are as yet unknown in most cases.

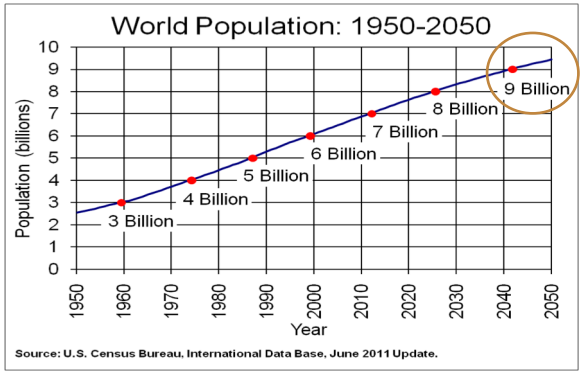
Several of the bioactive compounds may find application in human or veterinary medicine or in agriculture. Others should find application as research tools or as structural models for the development of new drugs. The microalgae are particularly attractive as **natural sources of bioactive molecules** since these algae have the potential to produce these compounds in culture which enables the production of structurally complex molecules which are difficult or impossible to produce by chemical synthesis.

https://link.springer.com/article/10.1007/BF00003544

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

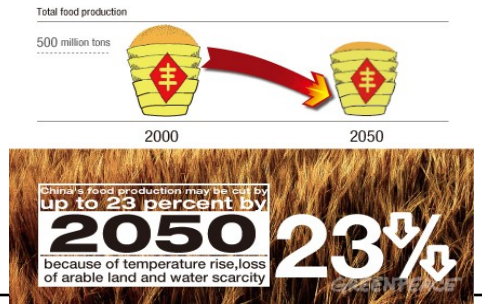
Why the use of microalgae biomass as a food ingredient is really important?

In 2050 there will be 9 billion people on the planet!



Sharp population growth

Resource scarcity



Food in the future?

Thomas Malthus (1798) - At that time he realized that the supply of food did not keep pace with population growth.

In the XXI century, food production is scarce and food prices assume significant increases

FAO estimates the production will have to rise by up to 70%, in order to have food available for all…

Efficiency of agricultural production systems
Scarcity of water resources and arable land
Climate change
Protein shortage

What is the role of microalgae?

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Food and Agriculture Organization of the United Nations

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA
Hinc Patriam Sustinet
Universidade de Lisboa

LEAF
LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

New perspective: Healthy and sustainable food

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Ulisses

SESSION III - Microalgae as sources of bioactive compounds for food

Microalgae - Food Innovation

UNDER-EXPLOITED RESOURCES

CIRCULAR ECONOMY
valorisation of by-products

Microalgae biomass

Seaweed
other marine resources
(underutilized species used in food)
Insects

Alternative sources of protein

unite! University Network for Innovation, Technology and Engineering

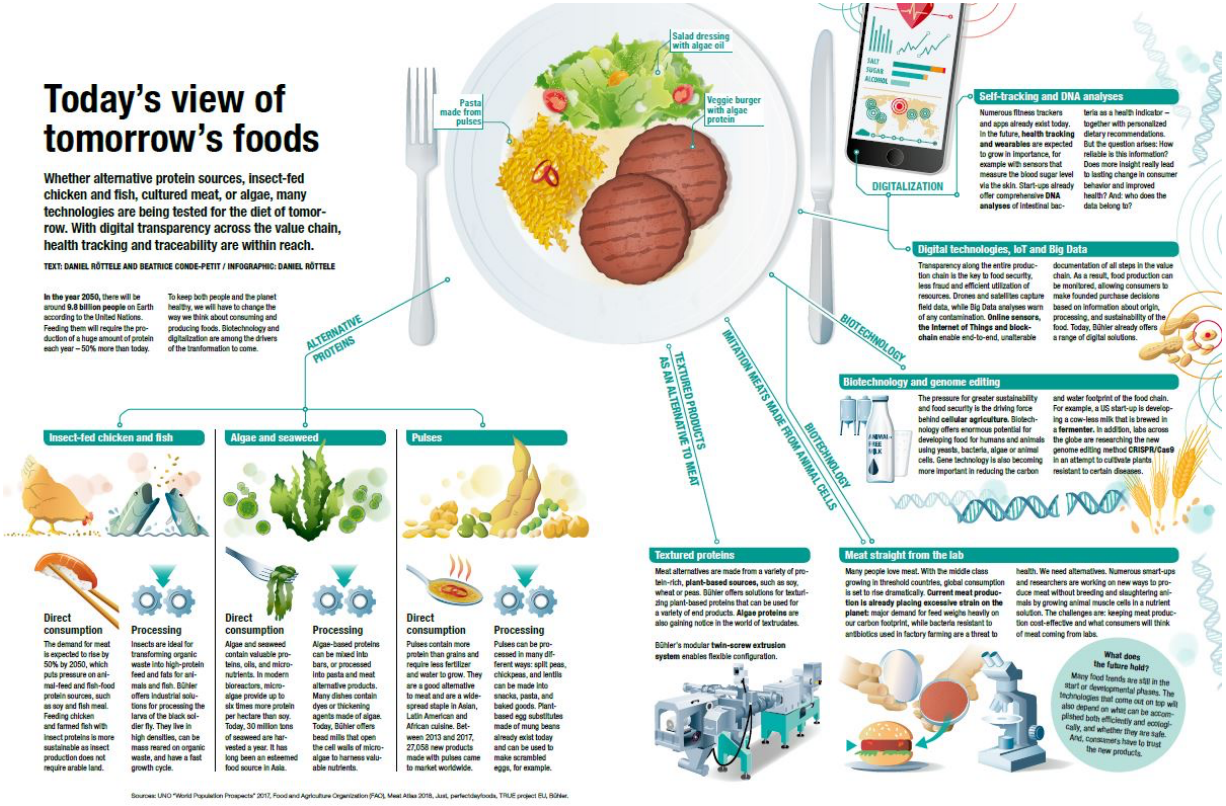
U LISBOA | UNIVERSIDADE DE LISBOA

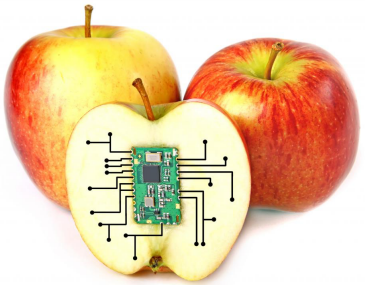
INSTITUTO SUPERIOR DE AGRONOMIA
Hinc Patriam Sustinet
Universidade de Lisboa

LEAF
LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

Microalgae - Food Innovation

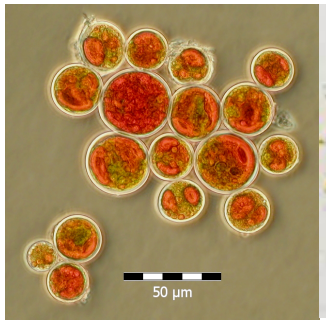




Major challenges to the incorporation of microalgae in food

MICROALGAE – FOOD FOR FUTURE?

New colours,
New textures
New flavours
Positive impact on health
Protein source
Modelling composition - production conditions





Technological challenge
Technological limit of incorporation
Sensory limit (consumer)
Overall cost of the product

How to engage the consumers?

Two distinct approaches with different technological and consumer impacts ...

A) Technological approach – Food engineering
B) Artistic Approach – Gastronomic science

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

MICROALGAE – FOOD FOR FUTURE?

The consumption of microalgae is an alternative to the lack of food that is expected for the next years, being an **excellent source of protein and functional ingredients**

The introduction of microalgae into high-consumption foodstuffs and diversified gastronomic productions is a decisive contribution to their **acceptance by consumers**

Microalgae present **varied nutritional profiles**, according to their origin and growth conditions, with different possibilities of incorporation into culinary preparations

Algal Research 2 (2013) 164–173

Contents lists available at SciVerse ScienceDirect

Algal Research

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

Comparison of microalgal biomass profiles as novel functional ingredient for food products

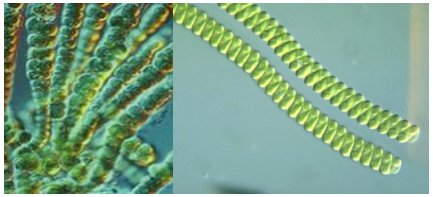
Ana Paula Batista [a,b,*], Luísa Gouveia [b], Narcisa M. Bandarra [c], José M. Franco [d], Anabela Raymundo [a]

[a] Núcleo de Investigação de Engenharia Alimentar e Biotecnologia (NIEAB), Instituto Piaget–ISEIT de Almada, Quinta da Arreinela de Cima, 2800-305 Almada, Portugal
[b] Laboratório Nacional de Energia e Geologia (LNEG)–Unidade de Bioenergia, Estrada do Paço do Lumiar, Edifício G, 1649-038 Lisboa, Portugal
[c] Divisão de Aquacultura e Valorização, Instituto Português do Mar e da Atmosfera, Av. Brasília 1449-006 Lisboa, Portugal
[d] Universidad de Huelva, Facultad de Ciencias Experimentales, Dpto. Ingeniería Química. Campus de Excelencia Internacional Agroalimentario, ceiA3. Campus del Cármen, 21071 Huelva, Spain

Bioactive compounds with health impact
+
Complex macromolecules

→ **Impact on physical, nutritional and sensory properties of developed products**
Food production costs with microalgae incorporation

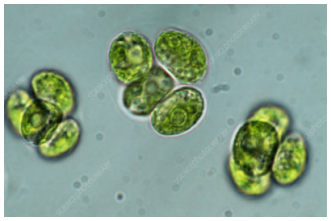
Role of regulators in relation to novel foods ...



Spirulina maxima/ Arthrospira platensis (cyanobacteria)

Health benefits - stimulation of the immune system, reduction of cholesterol levels and blood pressure, anti-carcinogenic, detoxifying effect.

Phycocyanin (blue phycobiliprotein): antioxidant, anti-inflammatory, neuroprotective effect…
High protein content (≈65%) and balanced amino acid profile
Essential fatty acids (γ-linoleic acid)
High Vitamin B12 and **Fe** content - vegetarian supplements



Chlorella vulgaris

Health benefits - strengthening of the immune system, detoxifying - stimulates tissue growth and repair - protection against UV radiation; retardation of aging phenomena. Prevention of atherosclerosis, hypercholesterolemia and as an antitumor agent.

High levels of β-1,3-glucan: active immune stimulator, which acts in the elimination of free radicals and as a blood lipid reducer and **vitamin B12**.

High chlorophyll content

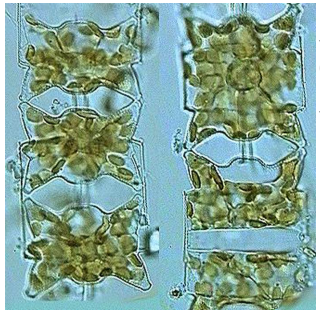
unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Role of regulators in relation to novel foods ...

Tetraselmis chuii

fitoplancton marino

Odontella aurita



Flavoured pasta, fish soups, sea food terns, broth preparations, salt crackers, frozen breaded fish; Incorporation levels range from 0.5% to 1.5%.

COMMISSION IMPLEMENTING REGULATION (EU) 2017/2470

of 20 December 2017

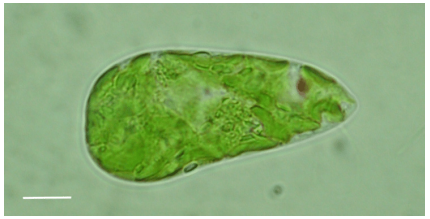
establishing the Union list of novel foods in accordance with Regulation (EU) 2015/2283 of the European Parliament and of the Council on novel foods

(Text with EEA relevance)

(OJ L 351, 30.12.2017, p. 72)

	Specified food category	*Maximum levels*	
Dried *Tetraselmis chuii* microalgae	Sauces	20 % or 250mg/day	The designation of the novel food on the labelling of the foodstuffs containing it shall be 'Dried microalgae *Tetraselmis chuii*' or 'Dried microalgae *T. chuii*'
	Special salts	1 %	Food supplements containing dried microalgae *Tetraselmis chuii* shall bear the following statement: 'Contains negligible amounts of iodine'
	Condiment	250 mg/day	
	Food Supplements as defined in Directive 2002/46/EC	250 mg/day	

Euglena gracilis



3.12.2020 PT Jornal Oficial da União Europeia L 406/29

REGULAMENTO DE EXECUÇÃO (UE) 2020/1820 DA COMISSÃO

de 2 de dezembro de 2020

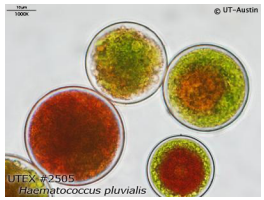
que autoriza a colocação no mercado de *Euglena gracilis* desidratada como novo alimento ao abrigo do Regulamento (UE) 2015/2283 do Parlamento Europeu e do Conselho e que altera o Regulamento de Execução (UE) 2017/2470 da Comissão

(Texto relevante para efeitos do EEE)

unite! University Network for Innovation, Technology and Engineering
LISBOA UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Another promising microalgae as food ingredients....

Haematococcus pluvialis

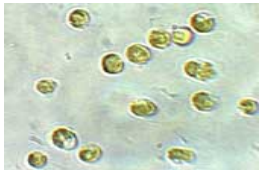


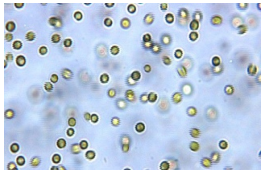
Largest natural source of **astaxanthin** - accumulation capacity of about 0.2-2% dry biomass after carotenogenesis

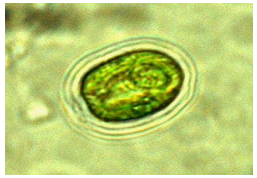
Carotenoids are accumulated and have an important free radical scavenging effect - a more significant antioxidant effect than β-carotene, vitamin C and vitamin E

The combination of carotenoids confers special **use as antioxidant**, with beneficial effect in the treatment of CNS pathologies

Isochrysis galbana e *Diacronema vlkianum*







Common in European seas, particularly in the North Atlantic and Irish coast.

Important source of PUFA's - EPA (20: 5-3) and DHA (22: 6-3), which may be an alternative to fish oils.

Important sources of sterols: sitosterol and tocopherols - **antioxidants**

The production of these metabolites depends on the growth conditions of the microalga...

Already farmed for the production of aquaculture feeds.

MICROALGAE BIOMASS AS A FOOD INGREDIENT - SUMMARY

Important source of **bioactive compounds** with positive **impact on health** - healthy diet
Sustainable food source
Important **source of protein**
Large-scale controlled production facility - **reasonable costs**

From the technological point of view

Impact of microalgae on the **food structure** (macromolecules and polysaccharides)
Impact of processing levels (different thermal treatments severity) on the **degradation of the bioactive compounds**
Food processing has a determinant impact on **bioaccessibility** and it should be optimised in order to reduce the degradation of the bioactive compounds

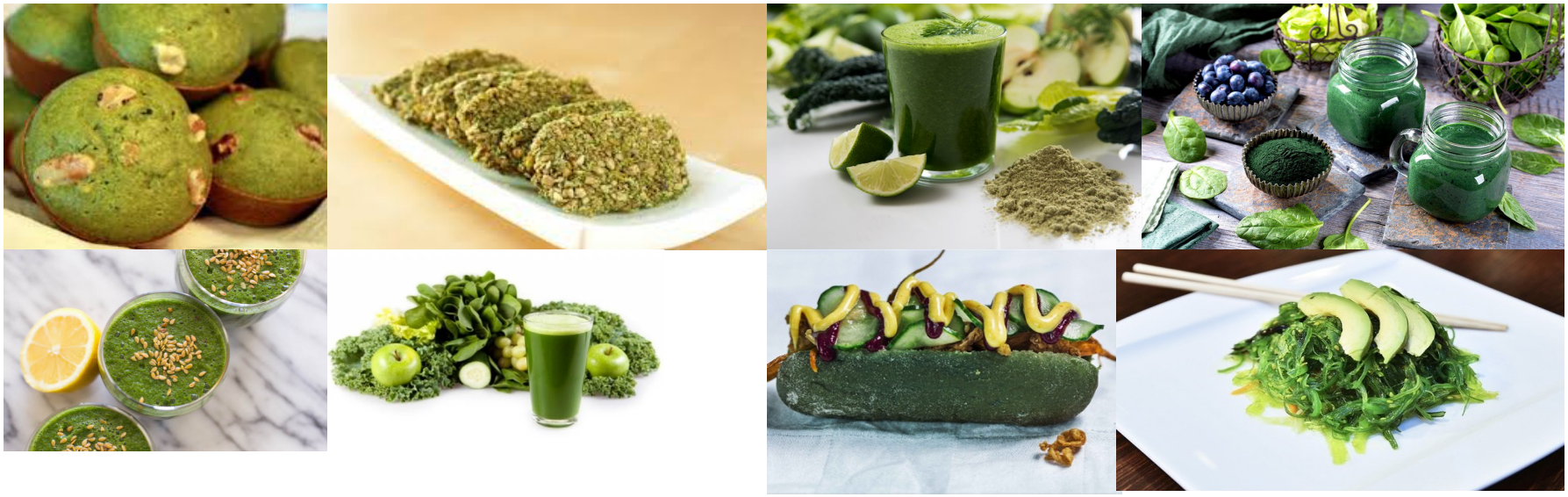
From the consumer point of view

BUT...

Colour - colours not common (green bread?)
Flavour - Sea and fish flavour may be relevant
Cost (even)

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Sharp increase in microalgae consumption from domestic scale to industrial food production?...



Are the consumers prepared?

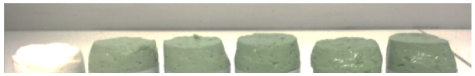
What can we do to engage the consumer?

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union

Ulisses

SESSION III - Microalgae as sources of bioactive compounds for food

Technological approach



Algal Research 50 (2020) 101998

ELSEVIER

Microalgae biorr
rheology, textur

Sheyma Khemiri[a,b,*]
Issam Smaali[a], Anat

[a] University of Carthage, INSAT, L
[b] LEAF – Linking Landscape, Envir
[c] LNEG-UB National Laboratory of
[d] University of Carthage, Higher Institute of Fisheries and Aquaculture, BP 15, Errimel, 20 7080 Bizerte, Tunisia

foods

Article

Tetraselmis c
Ingredient to
on Structure,

Maria Cristiana Nunes

LEAF—Linking Landsca
Universidade de Lisboa;
inesfsvasco@gmail.com (
* Correspondence: crnu

foo

Article

Microalga
Products:

Ana Paula Batista
Anabela Raymund

1 LEAF—Linking
Universidade d
ivana.bursic@gr
2 Department of A
Cascine 24, 5014
mario.tredici@u
3 Fotosintetica &
* Correspondence

Received: 31 March 2020; Accepted: 1 May 2020; Published: 4 May 202

ELSEVIER

Effect of *Arth*
and bioactive

Patrícia Fradinh
Mario R. Tredici

[a] LEAF–Linking Landscape, E
[b] Department of Agriculture,
[c] Fotosintetica & Microbiolog

More than 20 years on new food product development incorporating microalgae into different foods for different consumers!

GLUTEN FREE PRODUCTS

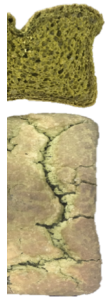
FRADINHO, P., NICCOLAI, A., SOARES, R., RODOLFI, L., BIONDI, N., TREDICI, M.R., SOUSA, I., RAYMUNDO, A. (2020). Effect of *Arthrospira platensis* (spirulina) incorporation on the rheological and bioactive properties of gluten-free fresh pasta. *Algal Res.*, 45, 101743.

SCIENTIFIC REPORTS
nature research

OPEN

Development of new microalgae-based sourdough "crostini": functional effects of *Arthrospira platensis* (spirulina) addition

Alberto Niccolai[1], Manuel Venturi[2*], Viola Galli[1], Niccolò Pini[1], Liliana Rodolfi[1,3], Natascia Biondi[1], Massimo D'Ottavio[1], Ana Paula Batista[4], Anabela Raymundo[4], Lisa Granchi[1] & Mario R. Tredici[1]



Impact of the addition of microalgae on nutritional, technological, sensory, digestibility and bioactivity properties - **systematic approach**

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa

LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

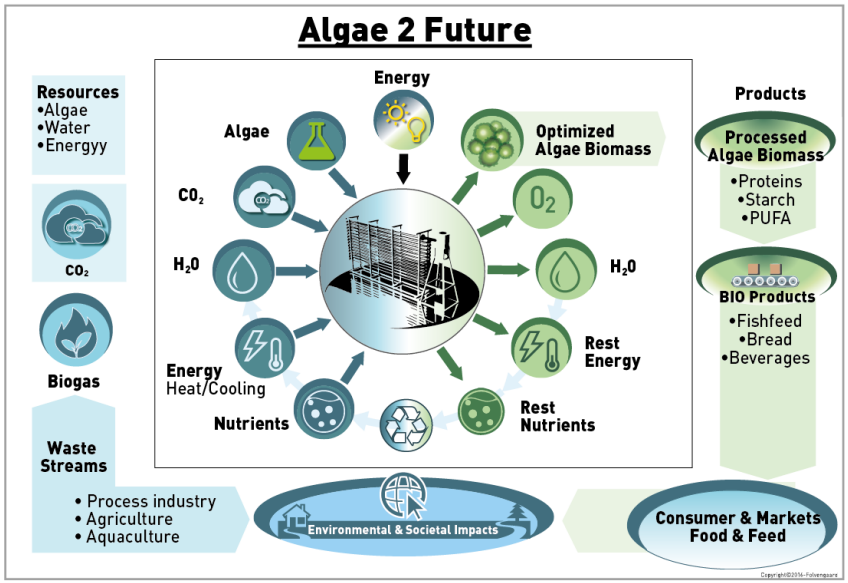
Ulisses

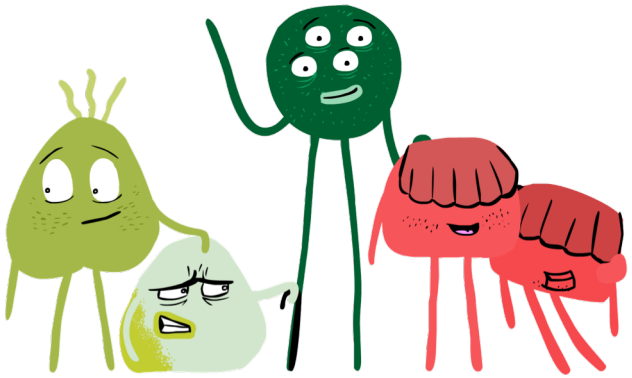
SESSION III - Microalgae as sources of bioactive compounds for food

a2F
ALGAE TO FUTURE

Financial support:
Research Council of Norway's BIONÆR Programme
(project no: 267872/E50 A2F)

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH





unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA
Hinc Patriam Sustinet
Universidade de Lisboa

LEAF
LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

Strategies do engage the consumers...

https://www.thelocal.se/20180329/ikea-develops-new-mealworm-meatballs-and-dogless-hotdogs

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa

LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

Ulisses

SESSION III - Microalgae as sources of bioactive compounds for food

The role of Gastronomic science to engage the consumers

Food of the world

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa

LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

Ulisses

SESSION III - Microalgae as sources of bioactive compounds for food

Tasting Menu with *Chlorella vulgaris*…

a2F ALGAE TO FUTURE






unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa

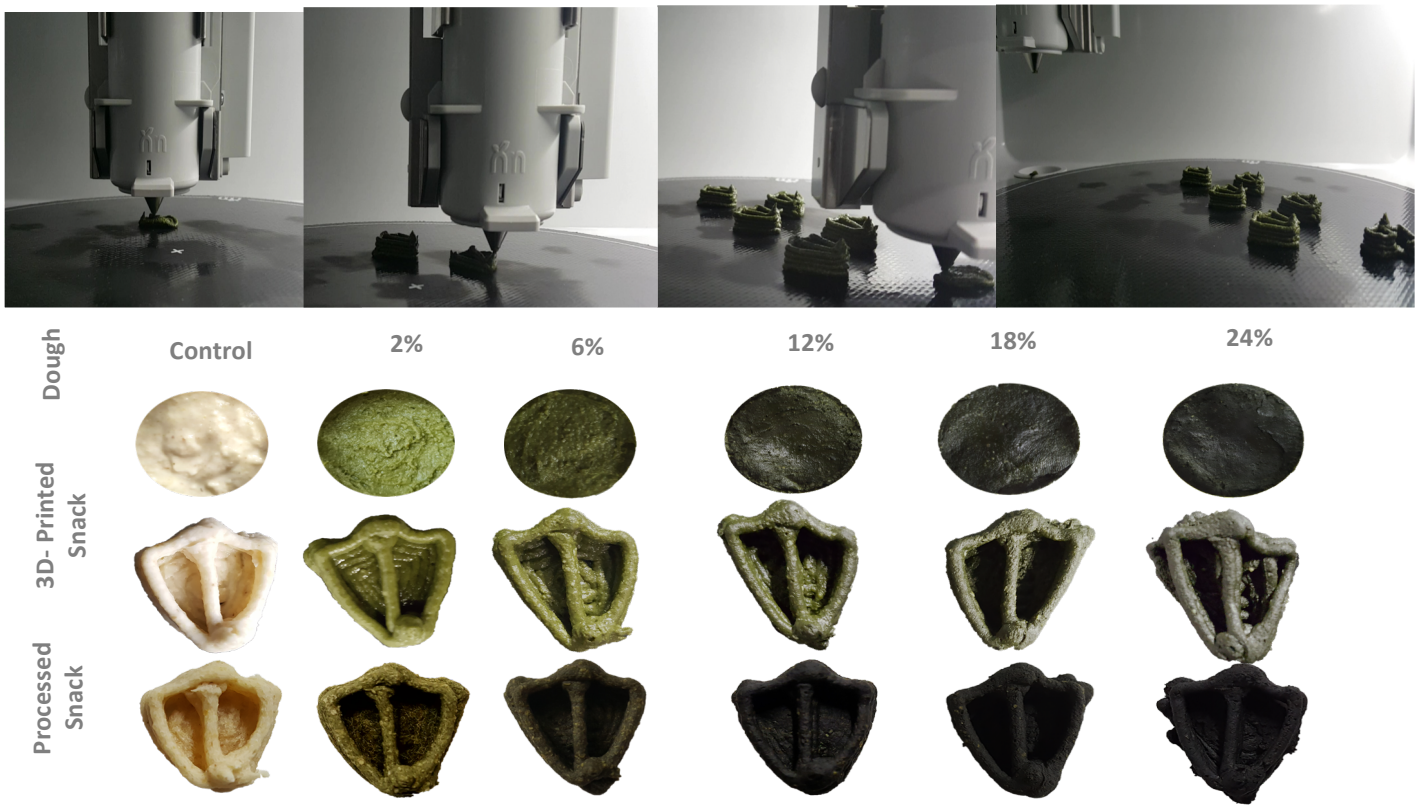
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

Ulisses

SESSION III - Microalgae as sources of bioactive compounds for food

3D-Printing



unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

INSTITUTO SUPERIOR DE AGRONOMIA
Hinc Patriam Sustinet
Universidade de Lisboa

LEAF
LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD

Co-funded by the Erasmus+ Programme of the European Union

Massages to take home

Microalgae are rich in bioactive compounds, which make them extremely important for food and pharmaceutical industries.

The use of microalgae as a food ingredient requires consumer engagement.

The use of gastronomic science techniques allows the creation of structures and flavors that are decisive for increasing the acceptance of microalgae in food.

unite! University Network for Innovation, Technology and Engineering
U LISBOA | UNIVERSIDADE DE LISBOA
INSTITUTO SUPERIOR DE AGRONOMIA Universidade de Lisboa
LEAF LINKING LANDSCAPE, ENVIRONMENT, AGRICULTURE AND FOOD
Co-funded by the Erasmus+ Programme of the European Union


Ulisses
UNITE!
University Network for Innovation, Technology and Engineering
U LISBOA
UNIVERSIDADE DE LISBOA