

Proposal full title:

Algae and aquatic biomass for a sustainable production of 2nd generation biofuels

Proposal acronym:

AquaFUELS

Type of funding scheme:

Cooperation

Theme 5 - Energy

Deliverable 1.2 Taxonomy

Taxonomy, Biology & Biotechnology

D 1.2 Taxonomy

-BGU (WP leader)
-UNIFI
-ISC
-UGENT

Taxonomy, Biology & Biotechnology

-BGU (WP leader)
-UNIFI
-ISC
-UGENT

-WUR
-IMIC
-UAL

Aim of the document

Given the high complexity of algal taxonomy and evolutionary relationships, this document was conceived as an instrument to place the algae that have arisen an interest for biofuel production within the correct frame.



It was beyond the scope of this document to propose any kind of new or revised taxonomy of algae.

The classification reported is based on AlgaeBase (<http://www.algaebase.org/>) and Tree of Life project (<http://tolweb.org/tree/>).

Questionnaire Species list	Task 1.4 Taxonomy- Species list
MACROALGAE	
<u>Brown algae</u>	
<i>Alaria</i> 1	<i>Alaria esculenta</i>
<i>Ascophyllum</i> 2	<i>Undaria pinnatifida</i>
<i>Ectocarpus</i> 1	<i>Ascophyllum nodosum</i>
<i>Laminaria</i> 3	<i>Fucus serratus, F. spiralis, F. vesiculosus</i>
<i>Saccharina</i> 1	<i>Himanthalia elongata</i>
<i>Sacchoriza</i> 1	<i>Cystoseira baccata, C. tamariscifolia</i>
	<i>Halidrys siliquosa</i>
	<i>Sargassum muticum</i>
	<i>Laminaria digitata, L. hyperborea, L. ochroleuca</i>
	<i>Saccharina latissima</i>
	<i>Saccorhiza polyschides</i>
<u>Red algae</u>	
<i>Asparagopsis</i> 1	<i>Chondrus crispus</i>
<i>Bangia</i> 1	<i>Mastocarpus stellatus</i>
<i>Chondrus</i> 1	<i>Grateloupia turturu</i>
<i>Gracilaria</i> 2	<i>Palmaria palmata</i>
<i>Grateloupia</i> 1	
<i>Halymenia</i> 1	
<i>Palmaria</i> 1	
<i>Porphyra</i> 1	
<u>Green algae</u>	
<i>Cladophora</i> 1	<i>Caulerpa racemosa, C. taxifolia</i>
<i>Ulva</i> 4	<i>Ulva lactuca, U. rigida</i>
MICROALGAE	
<u>Cyanobacteria</u>	
<i>Anabaena</i> 5	NONE AT PRESENT
<i>Calothrix</i> 1	PROPOSED:
<i>Cyanobacterium</i> 1	<i>Spirulina</i>
<i>Leptolyngbya</i> 1	<i>Anabaena</i>
<i>Lyngbya</i> 1	<i>Phormidium</i>
<i>Microcystis</i> 1	<i>Synechococcus (or Synechocystis)</i>
<i>Nostoc</i> 3	
<i>Phormidium</i> 8	
<i>Schyzothrix</i> 1	
<i>Synechococcus</i> 4	
<i>Synechocystis</i> 3	
<i>Spirulina</i> 10	

<i>Botryococcus</i> 5	<u>Green algae</u>
<i>Chlamydomonas</i> 14	<i>Ostreococcus lucimarinus, O. taurii</i>
<i>Chlorococcum</i> sp. 1	<i>Tetraselmis</i> sp.
<i>Chlorella</i> 32	<i>Botryococcus braunii</i>
<i>Dunaliella salina</i> 7	<i>Chlamydomonas reinhardtii</i>
<i>Dunaliella tertiolecta</i> 3	<i>Haematococcus pluvialis</i>
<i>Haematococcus pluvialis</i> 4	<i>Dunaliella</i> sp.
<i>Haematococcus</i> 4	<i>Chlorococcum</i> sp.
<i>Monoraphidium</i> 1	<i>Scenedesmus</i> sp.
<i>Muriellopsis</i> 2	<i>Desmodesmus</i> sp.
<i>Neochloris oleoabundans</i> 2	<i>Chlorella</i> sp.
<i>Oocystis</i> 2	<i>Parietochloris incisa</i>
<i>Pseudokirchneriella</i> 2	<i>Prototheca</i> sp. (heterotrophic)
<i>Scenedesmus</i> 15	
<i>Tetraselmis</i> 16	
NONE	<u>Red algae</u>
	<i>Porphyridium cruentum</i>
	<u>Diatoms</u>
<i>Asterionella formosa</i> 1	<i>Amphora</i> sp.
<i>Chaetoceros</i> 1	<i>Amphiprora hyalina</i>
<i>Cyclotella</i> 2	<i>Chaetoceros muelleri</i>
<i>Cylindrotheca</i> 1	<i>Cyclotella cryptica</i>
<i>Fragilariopsis cylindrus</i> 1	<i>Cylindrotheca</i> sp.
<i>Odontella</i> 1	<i>Navicula acceptata, N. saprophila</i>
<i>Phaeodactylum tricorutum</i> 19	<i>Nitzschia dissipata</i>
<i>Seminavis</i> 1	<i>Phaeodactylum tricorutum</i>
<i>Skeletonema</i> 2	<i>Thalassiosira pseudonana</i>
<i>Thalassiosira</i> 6	<i>Odontella aurita</i>
	<i>Skeletonema</i> sp.
	<u>Eustigmatophytes</u>
<i>Nannochloropsis</i> 28	<i>Monodus</i> sp.
	<i>Nannochloropsis</i> sp.
	<u>Prymnesiophytes</u>
<i>Emiliania huxleyi</i> 2	<i>Isochrysis</i> sp.
<i>Isochrysis</i> 12	<i>Pavlova</i> sp.
<i>Pavlova</i> 4	
	<u>Dinoflagellates</u>
<i>Alexandrium</i> 2	<i>Cryptochodinium cohnii</i> (heterotrophic)
<i>Amphidinium</i> 2	
<i>Karlodinium veneficum</i> 1	
<i>Prorocentrum</i> 1	
<i>Protoceratium</i> 2	
<i>Scripsiella</i> 1	
	<u>Raphidophytes</u>
<i>Heterosigma akashiwo</i>	NONE
	<u>Labyrinthulomycetes</u>
NONE	<i>Schyzochytrium</i> sp.
	<i>Tharustochytrium</i> sp.
	<i>Ulkenia</i> sp.

Selection of species:

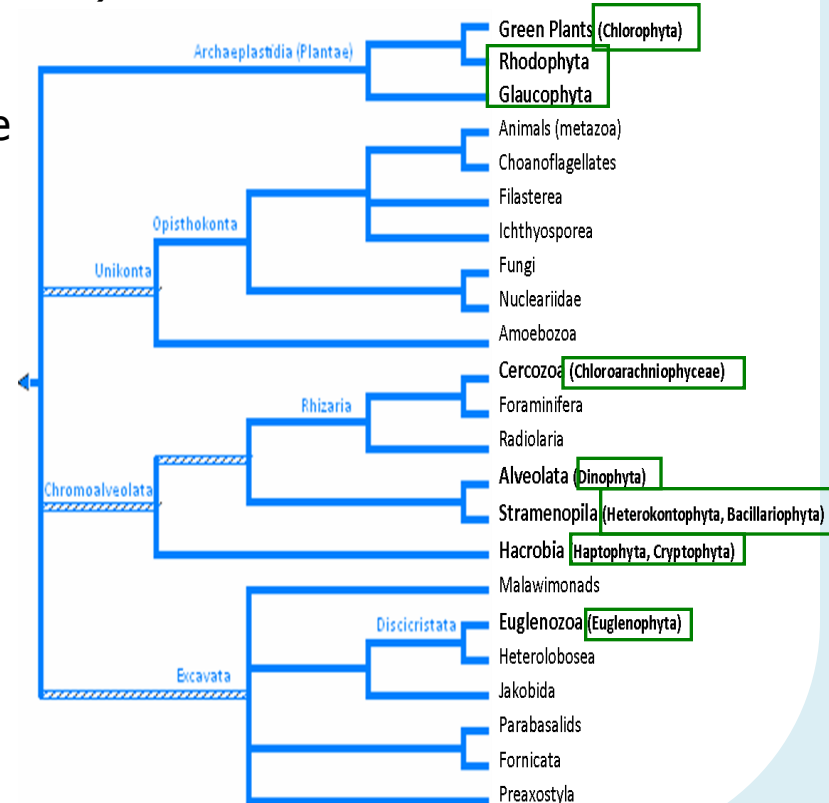
-  species list proposed by AQUAFUELS partners
-  results of the questionnaire

The list includes:

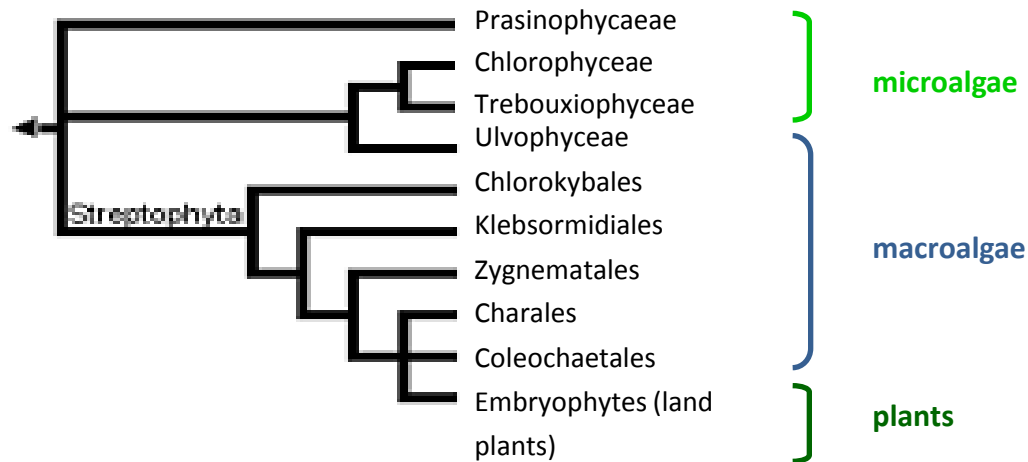
- 5 genera of prokaryotic microalgae (cyanobacteria)
- 33 genera of eukaryotic microalgae
- 20 genera of macroalgae
- 5 genera of aquatic plants

List composition per phylum

- Cyanobacteria ➤ 5 genera
 - Chlorophyta ➤ 17 genera (13 micro + 4 macro)
 - Rhodophyta ➤ 6 genera (1 micro + 5 macro)
 - Heterokontophyta ➤ 13 genera of which:
 - 2 Eustigamtophyceae
 - 11 Phaeophyceae
 - Bacillariophyta ➤ 11 genera
 - Haptophyta ➤ 2 genera
 - Dinophyta ➤ 1 genus
 - Labyrinthulomycetes ➤ 3 genera
- Other Aquatic Biomass (OAB):
- Class Liliopsida ➤ 5 genera



Example: evolution within the green plants lineage

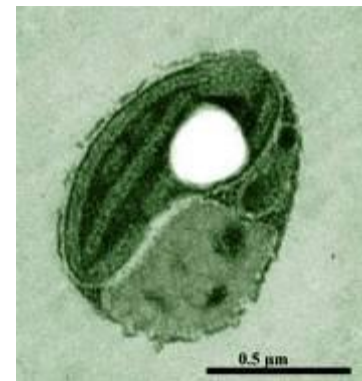


Giant sequoia section
trunk diameter 5-8 m
branch diameter 2 m
height 50-80 m
weight up to 2000 t
volume 1200 m³






average size of 0.8 μm

Phylum	Chlorophyta
Class	Prasinophyceae
Order	Mamiellales
Family	Mamiellaceae
Genus	<i>Ostreococcus</i>
Species	<i>O. tauri</i>



Derelle, E. *et al.* (2006). *Genome analysis of the smallest free-living eukaryote Ostreococcus tauri unveils many unique features.* Proceedings of the National Academy of Sciences of the United States of America 103: 11647-52

Symbology used in D 1.2 Taxonomy

<i>SYMBOLGY of the level of use of the alga</i>	
	This symbol indicates that the alga has a potential application and is currently used at pilot experimental level for biofuels
	This symbol indicates that the alga has a potential application for biofuels, though there is no pilot production
	This symbol indicates that the alga is commercially produced and available in large quantities

Examples of species forms in D 1.2

3.1.2 *Tetraselmis* sp

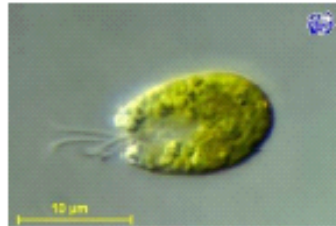


Figure 9 - *Tetraselmis chuii*
CNRS, Station Biologique de Roscoff
<http://planktonnet.uwi.de>

SYMBOL:



TAXONOMY

Phylum	Chlorophyta
Class	Prasinophyceae
Order	Chloodendratales
Family	Chloodendraceae
Genus	<i>Tetraselmis</i>
Species	

Related Species

T. flavis, *T. apiculata*, *T. ascus*, *T. astigmatica*, *T. chuii*, *T. consociata*, *T. confiformis*, *T. desikacharyi*, *T. gracilis*, *T. hansenii*, *T. impellucida*, *T. inconspicua*, *T. levis*, *T. maculata*, *T. marina*, *T. microcapitata*, *T. rubres*, *T. striata*, *T. suecica*, *T. tetraabrachia*, *T. tetraethale*, *T. verrucosa*, *T. westjohanni*.

References

1. Theodorou, J. (1986). The planktonic marine flagellates. In: *Identifying marine phytoplankton*. (Tomas, C.H. Eds), pp. 591-730. San Diego: Academic Press.

4.3.3 *Ascophyllum nodosum*



Figure 66 - *Ascophyllum nodosum* (Linnaeus) Le Jolis
Côte de l'Île de Sein, au Cap de l'Île, Co. de Gwynedd; 10.5-mm lens
© M.D. Guiry.

SYMBOL:



TAXONOMY

Phylum	Heterokontophyta
Class	Phaeophyceae
Order	Fucales
Family	Fucaceae
Genus	<i>Ascophyllum</i>
Species	<i>Ascophyllum nodosum</i>

Related species

The genus *Ascophyllum* only includes *Ascophyllum nodosum*. A free floating variety is known as *Ascophyllum nodosum* var. *machayi* (Turner) Cotton.

References

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2. Brauns, W. (2005). Meeresalgen. Ein Farnebildatlas zu den verbreiteten benthischen Grün-, Braun- und Rotalgen der Weltmeere. pp. [1]-596, 266 pls. Ruggell: A.B.G. Gantner Verlag.
3. Cho, G.Y., Rousseau, F., Reviers, B. de & Bon, S.M. (2006). Phylogenetic relationships within the Fucales (Phaeophyceae) assessed by the photosystem I coding psalA sequences. *Phycologia* 45: 512-519.

TAXONOMY, BIOLOGY & BIOTECHNOLOGY STRUCTURE OF THE DOCUMENT

- ① general part merging the D1.2 Taxonomy and the D 1.4 Biology & biotechnology general parts

- ② species forms

pivotal species




other species

extensive description of biology & biotech
(from D1.4 Biology and Biotechnology)

synthetic description of biology
& potential biotech interest

- ③ Annex: availability of algae (from D 1.2 taxonomy)

Symbology used in the merged document TAXONOMY, BIOLOGY & BIOTECHNOLOGY

<i>SYMBOLGY of the level of use of the alga</i>	
	This symbol indicates that the alga has a potential application and is currently used at pilot experimental level for biofuels
	This symbol indicates that the alga has a potential application for biofuels, though there is no pilot production
	This symbol indicates that the alga is commercially produced and available in large quantities
D	Potentially interesting for biodiesel production
E	Potentially interesting for bioethanol production
H	Potentially interesting for biohydrogen production
B	Interesting for biomass production
PIV	Pivotal taxon for biotechnology description

Criteria for strain selection

- ☒ Productivity
- ☒ Robustness

Condition	Relevant for	Range
pH	Reduce risk of infection CO ₂ transfer	i.e. <4 and >10
Oxygen concentration	Closed photobioreactors	>20%
Temperature	Outdoor cultivation Open water cultivation	Large range to accommodate day/night and seasonal fluctuation (e.g. 10 – 40 °C)
Salinity	Cultivation in fresh / sea / brackish water Reduce risk of infection	e.g 0-10% salinity
Organic contaminants	Ability to grow on wastewater / flue gas	Concentration of organic contaminants that still allows good growth

- ☒ Harvestability
- ☒ Biomass composition
- ☒ Processability / extractability
- ☒ Added value of co-products
- ☒ Local origin of strains

Pivotal species for Biotechnology

microalgae

Cyanobacteria

Arthrospira sp. (common name spirulina)



Chlorophyta

Tetraselmis sp.

Chlamydomonas reinhardtii

Haematococcus pluvialis

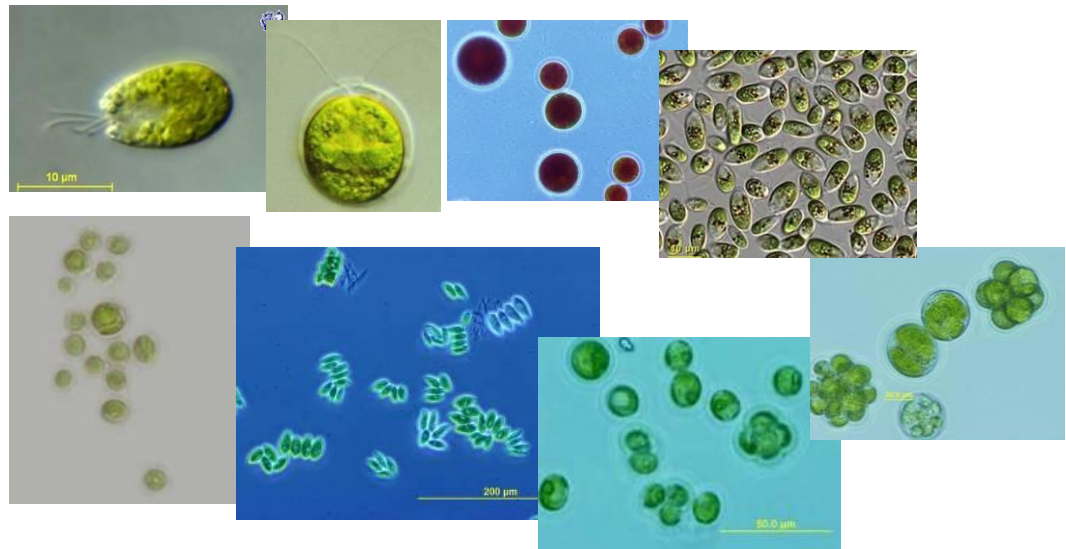
Dunaliella sp.

Neochloris oleoabundans

Scenedesmus sp.

Chlorella sp.

Parietochloris incisa

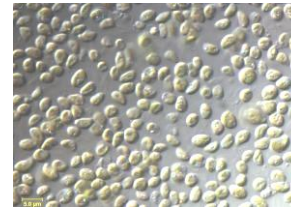


Pivotal species for Biotechnology

microalgae

Heterokontophyta **Class Eustigmatophyceae**

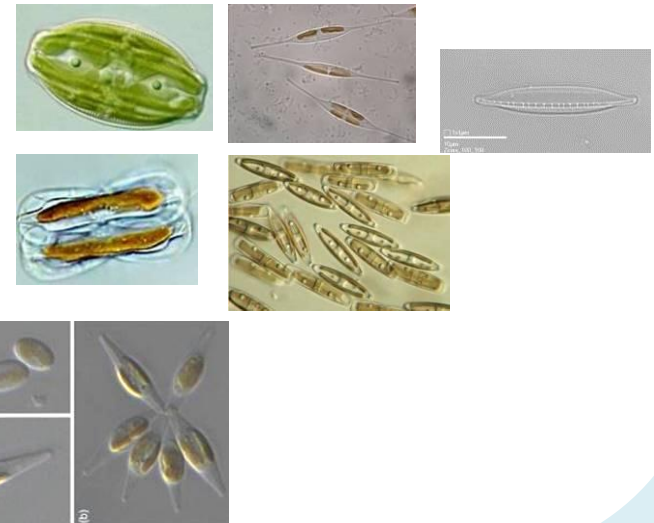
Nannochloropsis sp.



Bacillariophyta

Benthic diatoms (*Amphora*, *Amphiprora*, *Cylindrotheca*,
Navicula, *Nitzschia*)

Phaeodactylum tricornutum



Pivotal species for Biotechnology

macroalgae

Chlorophyta

Ulva sp. (*U. rigida*, *U. lactuca*)



Heterokontophyta

Class Phaeophyceae

Laminaria sp. (*L. digitata*, *L. hyperborea*, *L. ochroleuca*)

Saccharina latissima

Saccorhiza polyschides



other aquatic biomass (OAB)

Family Lemnaceae

Lemna minor



Example of a pivotal species form



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8.1.2 *Tetraselmis* sp

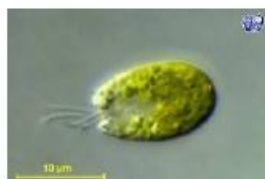


Figure 17 - *Tetraselmis chaili*
CNRS, Station Biologique de Roscoff
<http://planctonnet.awi.de>

SYMBOLS:   D, E, PIV

TAXONOMY

Phylum	Chlorophyta
Class	Prasinophyceae
Order	Chlorodendriales
Family	Chlorodendraceae
Genus	<i>Tetraselmis</i>
Species	

Related Species

T. alacris, *T. apiculata*, *T. ascus*, *T. astigmatica*, *T. chuii*, *T. convolutae*, *T. cordiformis*, *T. desikacharyi*, *T. gracilis*, *T. hazeni*, *T. impellucida*, *T. inconspicua*, *T. levis*, *T. maculata*, *T. marina*, *T. micropapillata*, *T. rubens*, *T. striata*, *T. suecica*, *T. tetrabrachia*, *T. tetrahele*, *T. verrucosa*, *T. wettsteinii*.

BIOLOGY

Structural and morphological features

Tetraselmis is a marine green flagellate. The four flagella of this alga, inserted in an anterior depression of the cell, are covered by scales of different types: pentagonal, rod-shaped and hair scales and, only in some strains, knotted scales (Barsanti and Gualtieri, 2006). Most species of the genus usually are encountered as solitary, free-swimming, thecate cells. Cell wall or theca is formed by the fusion of scales similar to those found covering the flagella (Nozaki, 2003). Cells are ovoid or ellipsoidal, somewhat compressed equatorially. In the case of *Tetraselmis suecica* cells have an average size of 10 x 8 μm and a weight of about 200 pg. The chloroplast is single, cup shaped with one pyrenoid (in the species were it is present) and a stigma. The asexual reproduction is by bipartition within the theca, while sexual reproduction is unknown

(Nozaki, 2003). It is a very common component in inshore marine environments, tide pools in particular, but there are also seven freshwater species (Nozaki, 2003). *Tetraselmis* is a very robust microorganism able to resist to extreme pH, salinity and temperature and to adapt to rapid changes in environmental conditions. This feature makes it particularly suitable for outdoor mass cultivation. Among the 50 species known, the most widely used are the marine *T. suecica*, *T. chui* and *T. tetrahele*.

Gross composition under optimal and stressed conditions

Tetraselmis suecica has a high protein content (up to 40-50%). Carbohydrate is about 20% and lipid about 20% of the cell dry weight. Under nutrient stress (nitrogen or phosphorus deprivation) *Tetraselmis suecica* accumulates carbohydrates.

Renaud et al. (1999) report for *Tetraselmis* sp. a content of 26-30% protein, 13-14% lipid, 8-9% carbohydrate and 14-17% ash as well as about 60% of polyunsaturated fatty acids over the total fatty acid content.

BIOTECHNOLOGY

Tetraselmis offers a valuable source of protein, bioactive compounds, antioxidants, vitamins, sterols and polyunsaturated fatty acids for human and animal consumption. One the most important applications of *Tetraselmis* is in aquaculture for rearing zooplankton and larval stages of marine fish, bivalve molluscs and crustaceans (Muller-Feuga et al., 2003; Tredici et al., 2009). The genus has been found to have antibacterial activity towards important aquaculture pathogens (Austin et al., 1992) and it was also proposed as probiotic (Tredici et al., 2009; Irianto and Austin, 2002). Due to its high content of good quality protein (40-50% d.wt), *Tetraselmis suecica* biomass could represent an alternative ingredient for animal feed. Because of its high content of vitamin E (0.13-0.25 g kg⁻¹), *Tetraselmis* has also been proposed as a source of this vitamin as preservative in foods, additive in animal feed and sunscreen in cosmetics (Carballo-Cárdenas et al., 2003). Active ingredients extracted from this microalga are currently used in the development of novel cosmetic formulations influencing growth of human hair and/or pigmentation of human skin (Pertile et al., 2010). An emerging use of *Tetraselmis* is for carbon biofixation in combination with biofuels production (biodiesel, bioethanol) (Tredici, 2010).

Culture Media

F medium (Guillard and Ryther, 1962) is widely used for cultivation of *Tetraselmis*. The microalga can be grown also in natural seawater integrated with nutrients.

Cultivation methods

In general *Tetraselmis* is cultivated under autotrophic conditions. Some species have also heterotrophic or mixotrophic capacity. Intensive cultivation of *Tetraselmis* has been carried out in open "raceway" ponds and in different kinds of closed photobioreactors (PBR). In Hawaii in 24-m² flumes Laws and Bering (1991) obtained a productivity of 15-20 g C m⁻² day⁻¹ with photosynthetic efficiencies of 9-10% with *Tetraselmis suecica*. In pilot-scale open ponds in Southern Italy, *Tetraselmis tetrahele* has reached productivities of about 30 g m⁻² day⁻¹ during the summer, with photosynthetic efficiencies in the PAR region around 5% (Materassi et al., 1983). A parallel cultivation of *Tetraselmis suecica* in pilot-scale open ponds and near-horizontal tubular reactors has shown similar productivities for the two systems, about 26 g m⁻² day⁻¹ (Pedroni et al., 2004). Current methods for its culture rely on batch, semi-continuous or continuous cultivation. At present, culture methods used in hatcheries for *Tetraselmis* production use mainly polyethylene bags and transparent glass-fibre cylinders (up to 500 L) usually kept indoors with artificial light (Fulks and Main, 1991). Advances have recently been made in the field of photobioreactor technology

(Tredici et al., 2010) that improved microalgae productivity in comparison to the traditional culture systems. Among these systems annular columns (Chini Zittelli et al., 2006) and disposable flat panels (Tredici et al., 2010) have been and are currently used in laboratory and at pilot-scale outdoors. During the summer in Central Italy in an experiment reproducing a full scale plant arrangement, in 120-L annular columns at a daily dilution rate of 40%, *Tetraselmis suecica* attained an average volumetric productivity of 0.46 g l⁻¹ day⁻¹, and an overall area productivity of 36.3 g m⁻² day⁻¹ with a photosynthetic efficiency in the PAR region of 9.4% (Chini Zittelli et al., 2006). *Tetraselmis* has been also grown at industrial scale under heterotrophic conditions in fermenters with yields in excess of 100 g L⁻¹ day⁻¹ (Day et al., 1991).

Harvesting methods

Tetraselmis settles spontaneously and can be harvested in funnels, though centrifugation is a faster and a more efficient harvesting method.

Upscaling limitations

Although *Tetraselmis* is a very robust microorganism able to resist to extreme pH, salinity and temperature and to adapt to the rapid changes in environmental conditions, to obtain high productivities high amounts of energy are generally required for culture mixing due to the high sedimentation rate of the microalga.

HIGHLIGHTS IN BIOTECHNOLOGY

Major characteristics of this genus are robustness and high productivity in outdoor mass cultures

References

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Example of a non-pivotal species form



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BIOTECHNOLOGY

9.3.3 *Ascophyllum nodosum*



Figure 77 - *Ascophyllum nodosum* (Linnaeus) Le Jolis
Céibh an tSruatháin, an Cheathrú Rua, Co. na Gaillimhe; 10.5-mm lens
© M.D. Guiry

SYMBOLS:   B

TAXONOMY

Phylum	Heterokontophyta
Class	Phaeophyceae
Order	Fucales
Family	Fucaceae
Genus	<i>Ascophyllum</i>
Species	<i>Ascophyllum nodosum</i>

Related species

The genus *Ascophyllum* only includes *Ascophyllum nodosum*. A free floating variety is known as *Ascophyllum nodosum* var. *mackayi* (Turner) Cotton.

BIOLOGY

This is a brown seaweed that is closely related to *Fucus*. It forms a single bladders centrally in long, flattened strap-like fronds. The fronds hang downwards, draping sheltered intertidal rocks. Many fronds grow from the base and the plant generally regenerates new fronds from the base when one of the larger fronds are damaged. There is evidence that clumps can be over 400 years old and may be even older. *Ascophyllum* is currently confined to the North Atlantic basin, but plants have been found growing in San Francisco Bay, but the species does not persist there. The plants are used as packing for shellfish from the North Atlantic and when discarded may take hold.

Ascophyllum nodosum is used in agriculture as a fertilizer and plant growth promoter (France, Canada, China, Iceland, US) and for alginate production (Ireland, Norway, UK) (Zemke-White and Ohno, 1999). All the annual production is harvested from the wild. Annual production is: Ireland 8,999 t dry weight, Norway 6,632, Iceland 4,400, UK 3,500, China 3,000, Canada 2,500, France 1,700 and US 280 (Zemke-White and Ohno, 1999).

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Availability of microalgae: list of culture collections

ANNEX I

AVAILABILITY of ALGAE

The main Culture Collections of algae and cyanobacteria are listed in the table below:

Collection + website
CCAP (Culture Collection of Algae and Protozoa) http://www.ccap.ac.uk/cultures/cultures.htm
SAG (Sammlung von Algenkulturen der Universität Göttingen) http://sagdb.uni-goettingen.de/
CCMP (Provasoli-Guillard National Center for Culture of Marine Phytoplankton) https://ccmp.bigelow.org/node/56
UTEX (The Culture Collection of Algae at the University of Texas Austin) http://web.biosci.utexas.edu/utex/Search.aspx
CCALA (Culture Collection of Autotrophic Organisms) http://www.butbn.cas.cz/ccala/index.php
PCC (The Plymouth Culture Collection of Marine Algae) http://www.mba.ac.uk/culturelist.php
PCC (Pasteur Culture Collection of Cyanobacteria) http://www.pasteur.fr/ip/easysite/go/03b-000012-00g/collection-of-cyanobacteria-pcc/
ALGOBANK (la collection de cultures de microalgues de l'Université de Caen Basse-Normandie) http://www.unicaen.fr/ufr/ibfa/algobank
CCBA (Culture Collection of Baltic Algae at the University of Gdansk) http://ocean.ug.edu.pl/~ccba/ien.php?id=ccba
SCCAP (Scandinavian Culture Collection of Algae & Protozoa) http://www.sccap.dk/search/
RCC (Roscoff Culture Collection) http://www.sb-roscoff.fr/Phyto/RCC
BCCM (Belgian Co-ordinated Collections of Micro-organisms) Diatom Collection at the Ghent University

F&M Culture Collection, Italy

<http://www.femonline.it/>

CSIRO (Collection of Living Micro-algae)

<http://www.marine.csiro.au/algaedb/default.htm>

CCCM (Canadian Center for the Culture of Microorganisms) including:

NEPCC (North East Pacific Culture Collection)

FWAC (Freshwater Algal Culture Collection)

<http://botany.ubc.ca/cccm>

CPCC (Canadian Phycological Culture Centre) (formerly known as UTCC)

<http://www.phycol.ca/cultures>

ATCC (American Type Culture Collection)

<http://www.lgcstandards-atcc.org/>

SERI microalgae culture collection

<http://www.tpub.com/content/altfuels05/3814/38140091.htm>

FACHB (Freshwater Algal Culture Collection)

<http://www.ctccas.ac.cn/typecc/danshui/database.html>

Japan - NITE (holding former MBIC strains)

<http://www.nbrc.nite.go.jp/NBRC2/NBRCDispSearchServlet?lang=en>

Japan - NIES (National Institute for Environmental Studies)

<http://mcc.nies.go.jp>

Availability of microalgae: an example

Tetraselmis sp.

COLLECTION + WEBSITE	STRAIN NUMBERS
CCAP (Culture Collection of Algae and Protozoa) http://www.ccap.ac.uk/cultures/cultures.htm	73 strains of which 27 <i>Tetraselmis</i> sp.; other species: <i>T. apiculata</i> ; <i>T. chuii</i> ; <i>T. convolutae</i> ; <i>T. gracilis</i> ; <i>T. inconspicua</i> ; <i>T. levis</i> ; <i>T. maculata</i> ; <i>T. marina</i> ; <i>T. striata</i> ; <i>T. subcordiformis</i> ; <i>T. suecica</i> ; <i>T. tetrabrachia</i> ; <i>T. tetrathele</i> ; <i>T. verrucosa</i>
SAG (Sammlung von Algenkulturen der Universität Göttingen) http://sagdb.uni-goettingen.de/	SAG 1.96; 8-6 (<i>T. chuii</i>); SAG 50.87 (<i>T. contracta</i>); SAG 26.82 (<i>T. cordiformis</i>); SAG 202.80 (<i>T. marina</i>); SAG 41.85 (<i>T. striata</i>); SAG 161-1a (<i>T. subcordiformis</i>); SAG 161-2b to 161-2c (<i>T. tetrathele</i>); SAG 161-3; 3.98; 35.93 (<i>Tetraselmis</i> sp.)
CCMP (Provasoli-Guillard National Center for Culture of Marine Phytoplankton) https://ccmp.bigelow.org/node/55	119 strains of which 110 <i>Tetraselmis</i> sp.; other species: <i>T. astigmatica</i> ; <i>T. convolutae</i> ; <i>T. marina</i> ; <i>T. rubens</i> ; <i>T. suecica</i> ; <i>T. wertsteinitii</i> ; <i>T. striata</i>
UTEX (The Culture Collection of Algae at the University of Texas Austin) http://web.biosci.utexas.edu/utex/Search.aspx	UTEX B 2562 (<i>T. apiculata</i>); UTEX LB 232 (<i>T. chuii</i>); UTEX B 2563 (<i>T. gracilis</i>); UTEX B 2565; B SP22 (<i>T. striata</i>); UTEX LB 2286 (<i>T. suecica</i>); UTEX LB 557 (<i>T. tetrathele</i>); UTEX 2767; LB 2767 (<i>Tetraselmis</i> sp.)
PCC (The Plymouth Culture Collection of Marine Algae) http://www.mba.ac.uk/culturelist.php	PCC 372; 372A; 581 (<i>T. convolutae</i>); PCC 429 (<i>T. impellucida</i>); PCC 308; 308A; 570 (<i>T. marina</i>); PCC 443 (<i>T. striata</i>); PCC 305 (<i>T. suecica</i>); PCC 272 (<i>T. tetrathele</i>); PCC 456 (<i>T. verrucosa</i>); PCC 315; 511A to 511B; 512 to 513; 514B (<i>Tetraselmis</i> sp.)
ALGOBANK (la collection de cultures de microalgues de l'Université de Caen Basse-Normandie) http://www.unicaen.fr/ufr/lbfa/algobank	AC 726 (<i>T. chuii</i>); AC 258 (<i>T. marina</i>); AC 725 (<i>T. striata</i>); AC 254 (<i>T. suecica</i>); AC 261 (<i>T. tetrathele</i>); AC 255; 257; 264 (<i>Tetraselmis</i> sp.)
SCCAP (Scandinavian Culture Collection of Algae & Protozoa) http://www.sccap.dk/search/	K-0011 (<i>T. contracta</i>); K -0937 (<i>T. levis</i>); K-0298 (<i>T. aff. maculata</i>); K-0377 (<i>T. marina</i>); K-0297 (<i>T. suecica</i>); K-0243; K-0950 (<i>T. verrucosa</i>); K-0296; K-0380; K-0524; K-0930; K-0935 (<i>Tetraselmis</i> sp.)
RCC (Roscoff Culture Collection) http://www.sb-roscoff.fr/Phyto/RCC	RCC 128 to 129 (<i>T. chuii</i>); RCC 1563 to 1564 (<i>T. convolutae</i>); RCC 132 to 133 (<i>T. rubens</i>); RCC 130 to 131 (<i>T. striata</i>); RCC 119 to 127; 233; 235; 348; 500; 1947; 1975 to 1976 (<i>Tetraselmis</i> sp.)
CSIRO (Collection of Living Micro-algae)	CS-691/01 (<i>T. antarctica</i>); CS-26 (<i>T. chuii</i>); CS-

http://www.marine.csiro.au/algaedb/default.htm	56; CS-187 (<i>T. suecica</i>); CS-87; CS-91; CS-317; CS-352 (<i>Tetraselmis</i> sp.)
NEPCC (North East Pacific Culture Collection) http://botany.ubc.ca/cccm	NEPCC 485; 502 (<i>T. apiculata</i>); NEPCC 484; 501 (<i>T. chuii</i>); NEPCC 486 (<i>T. convolutae</i>); NEPCC 489; 551 (<i>T. gracilis</i>); NEPCC 503 (<i>T. inconspicua</i>); NEPCC 488 (<i>T. levis</i>); NEPCC 487; 497 (<i>T. striata</i>); NEPCC 494 (<i>T. suecica</i>); NEPCC 483; 500 (<i>T. tetrathele</i>); NEPCC 496 (<i>T. verrucosa</i>); NEPCC 46; 86; 365; 498 (<i>Tetraselmis</i> sp.)
CPCC (Canadian Phycollogical Culture Centre) (formerly known as UTCC) http://www.phycol.ca/cultures	CPCC 196 (<i>Tetraselmis</i> sp.)
Japan - NITE (holding former MBIC strains) http://www.nbrc.nite.go.jp/NBRCC2/NBRCCDispSearchServlet?lang=en	NBRCC 102994; 102997 to 102998; 103003 (<i>Tetraselmis</i> sp.)
Japan – NIES (National Institute for Environmental Studies) http://mcc.nies.go.jp	NIES 18; 533 (<i>T. cordiformis</i>); NIES 1430 (<i>T. levis</i>); NIES 1019 (<i>T. striata</i>); NIES 1836 (<i>T. verrucosa</i>); NIES 1421; 1431 to 1434 (<i>Tetraselmis</i> sp.)