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EUROPEAN UNION
European Regional Development Fund

Algae for biochemicals and biofuels

Seminar in Biogas and Chemicals from Marine and Agricultural Biomasses November 29 Nov. 2010, Malmö

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DTU

Fuel and Food Debate

Why algae?

Need:

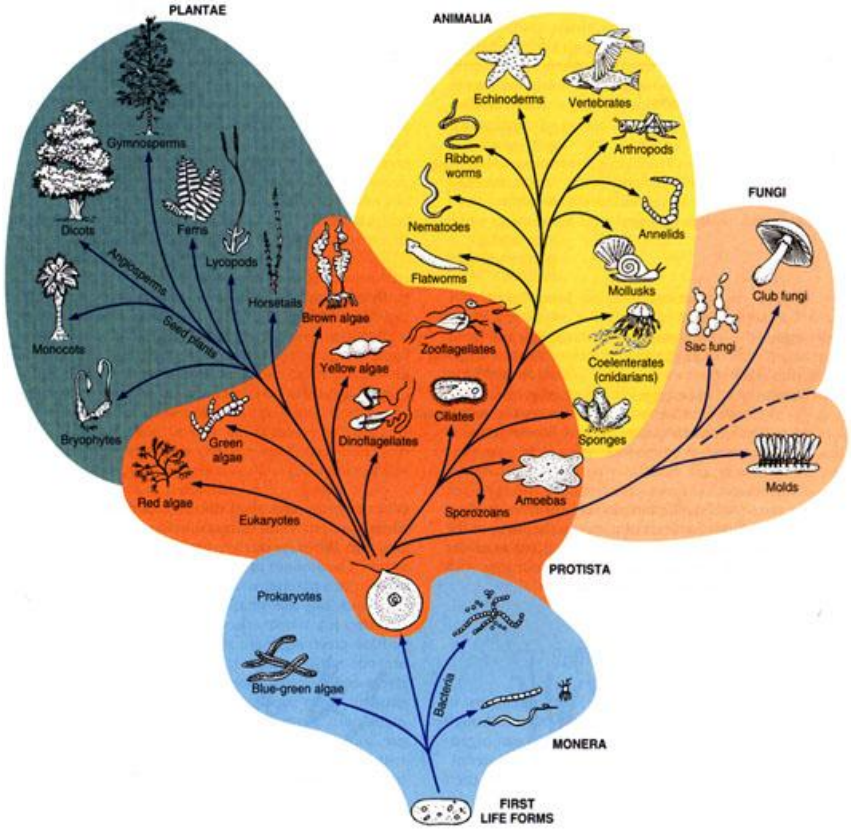
- Need for alternative energy sources
- Need for food and biochemicals
- Limitation of agricultural land

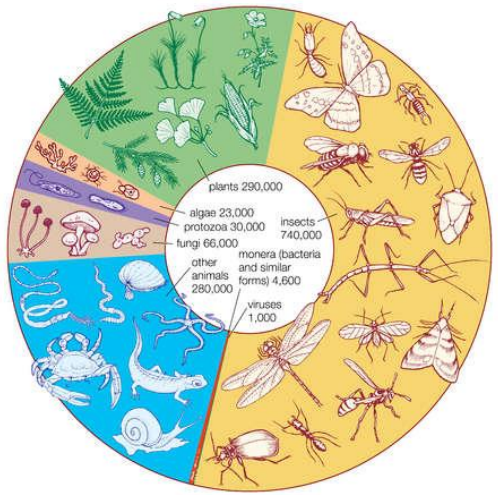
Solution:

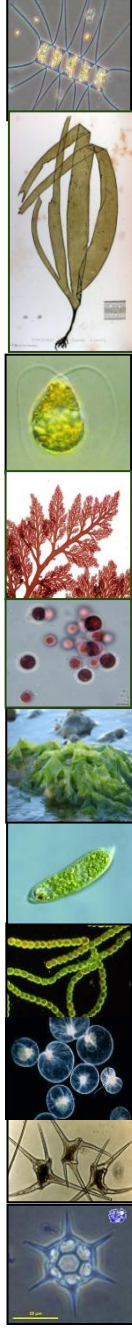
ALGAE

- no need for agricultural land;
- require 99% less fresh water than conventional agriculture;
- high biomass yields per unit area - (8-10 times of terrestrial crops yield per hectare);
- no CO_2 emissions (CO_2 neutral) compared to fossil fuels

What are algae?







What do algae contain?

	Micro	Macro
Polysaccharides	Low (4-60 %)	**High** (15 to 75 %)
Lipids	**High** (up to 40 %)	Low (max 4 %)
Proteins	Similar (6-60 %)	Similar (5-50 %)
Pigments	Similar/but different types	Similar/but different types
Phenolics (flavonoids)	Similar (up to 16 %)	Similar (up to 14 % in brown sp.)

What biofuel can we produce from algae?

- Biodiesel from microalgae
- Bioethanol from macroalgae
- Biohydrogen from cyanobacteria
- Biogas from all types

Is biofuel production from algae feasible?

- Cultivation installations
- Algae bioprocessing installations
- Light
- Nutrients
- Land costs
- Harvesting

Solution – Biorefinery ?

Multi-product process: Biorefineries

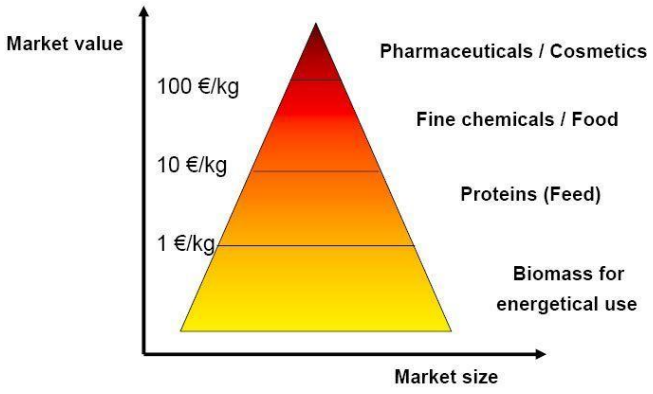
Food

Feed

Chemicals

Energy

Fertilisers



High rate algal biomass production for food, feed, biochemicals and biofuels

An Indo-Danish Collaboration project 2010-2015

Aim: Develop a new algae-based biorefinery for sustainable production of:

- Food/food-supplements(alginates, β-carotene)
- Biochemicals (pigments, phenolic compounds)
- Feed (omega-3, proteins)
- Biofuels (bioethanol, biogas, biodiesel)
- Biofertilizer

Project partners

1. Technical University of Denmark ,DTU Environment, Bioenergy Group (**DTU**), DK

2. Copenhagen University, Aquatic biodiversity and Systems ecology, Department of Biology (**KU**), DK

3. Lemvig Biogas plant, (**LBP**) DK

4. Department of Biotechnology, IIT Kharagpur (**IITKgp-1**), India

5. Department Agricultural and Food Engineering, IIT Kharagpur (**IITKgp-2**), India

6. Indian Agricultural Research Institute (**IARI**), New Delhi, India

7. Partner 7. Spirulina Production Research and Training Centre (**STTC**)

Work Packages

WP1: Project coordination
WP2: Selection of suitable Algal species

Criteria for species in DK

- High in added value products
- High growth rates
- Low cultivation costs/manpower

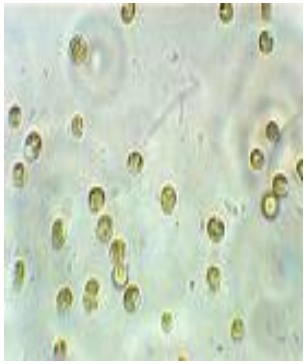
Ex: Macroalgae

Sargassum

Laminaria

Ecklonia

Ex: Microalgae



Isochrysis

Botryococcus

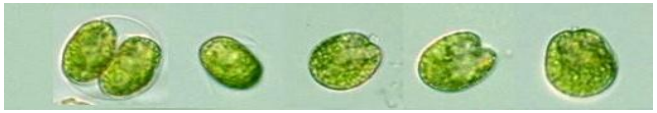
Microalgae chosen

Omega 3/ PUFA (EPA, DHA) or pigments
Aquaculture feed

Tetraselmis striata
Tetraselmis chui
Settles quick within 10 min
Total lipids of 9-22 % of dw

http://protist.i.hosei.ac.jp/pdb/images/Chlorophyta/Tetraselmis/index.html
www.algaedepot.com

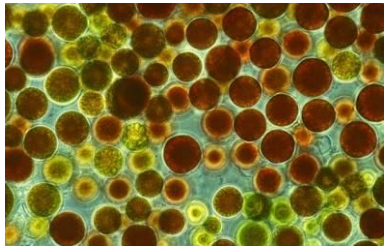
Nanochloropsis oculata
Total lipids of 18-32 % of dw



http://cid-12da36d60f963106.spaces.live.com/blog/

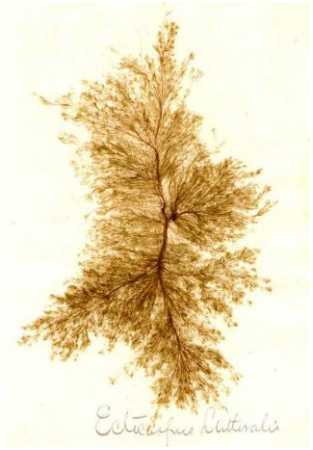
Dunaliella sp.

Haematococcus sp.
Astaxanthin



Filamentous algae chosen

Ectocarpus siliculosus
Ectocarpus fasciculatus



Pylaiella littoralis

Macro algae chosen

Saccharina latissima

polyphenols (antioxidants)
Laminaran
Mannitol
Pigments

Laminaria digitata

polyphenols (antioxidants)
Laminaran
Mannitol
Pigments

Ulva sp.

High growth rate (>0.15/d)
ulvan

Work Packages

WP3: Algal cultivation optimisation

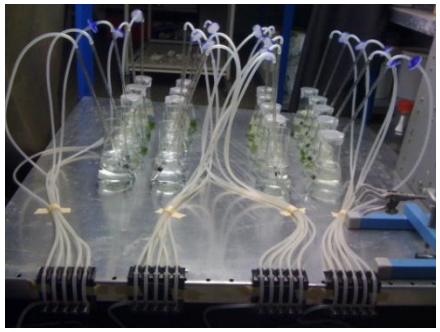
-High rate and yield of biomass (temp, pH, nutrients etc)

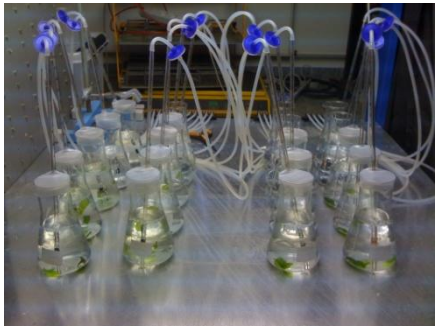
-Process configuration: CO_2 mass transfer

-Algae-rotation concept

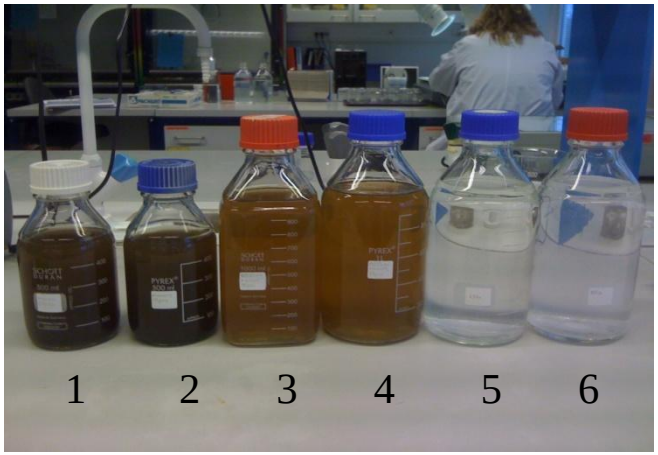
Cultivation of Ulva lactuca and Ulvaria fusca

- Effect of temperature
- Effect of N supply, NO_3^-, NH_4^+, digested manure
- Effect of light intensity
- Effect of aeration
- Effect of CO_2
- Determination of the methane potential

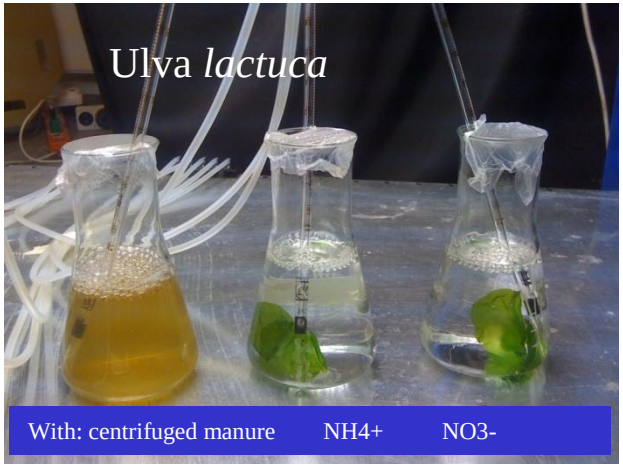


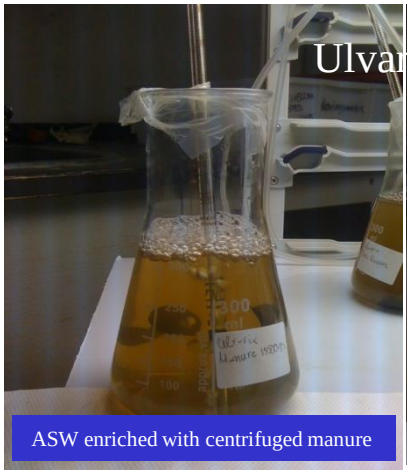


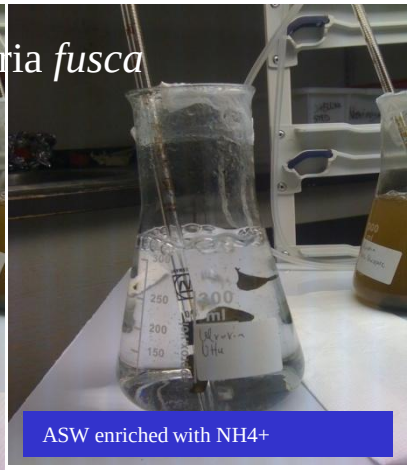
Effect of N tilsætning på vækstraten



1&2: Artificial seawater (35ppt salinity) enriched with pig manure
3&4: ASW enriched with centrifuged pig manure (13500rpm)
5: ASW enriched with NH4
6: ASW enriched with NO3 (F/2)







Salinity: 35ppt or 35 psu
Temperature: 10°C
Light intensity: 45µmol photons/ m^2/sec (24h)

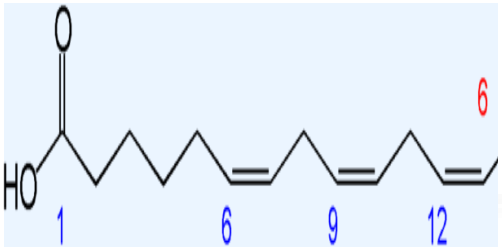
Conclusions from cultivations

- High growth rates (Maximum specific growth 0.3d^{-1} and the average biomass yield per disc was 23 mg*d^{-1}
- Temperature range 5-15^{o}C
- Ulvaria Fusca more robust than Ulva lactuca
- Digested manure has negative effects on growth

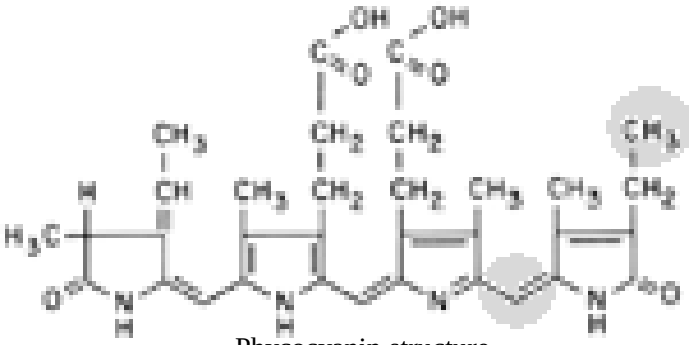
WP4 Production of food supplements from algal biomass

-Alginates, vitamins, polyunsaturated fatty acids, carotens, etc.

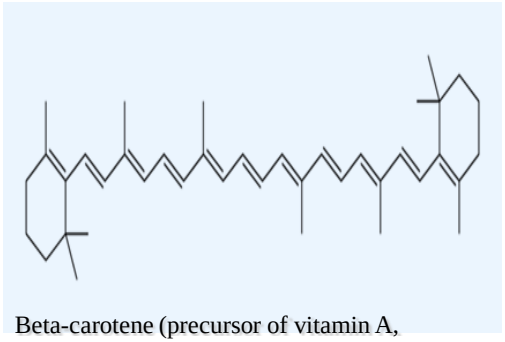
WP5 Production of Biochemicals/Bioactive compounds



Gamma linolenic acid (dietary supplement, anticancer activity



Phycocyanin structure (important fluoresent marker)



Beta-carotene (precursor of vitamin A, antioxidant)

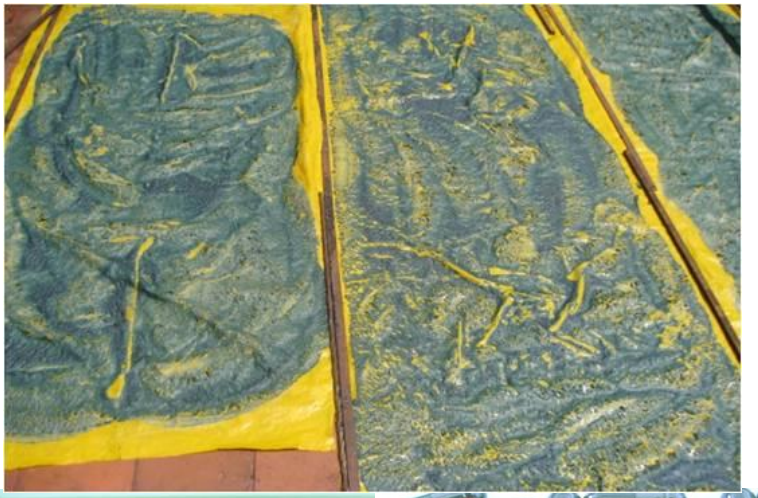
Pre-concentration

Extracted Phycocyanin

Freeze drying at -55 ^{o}C

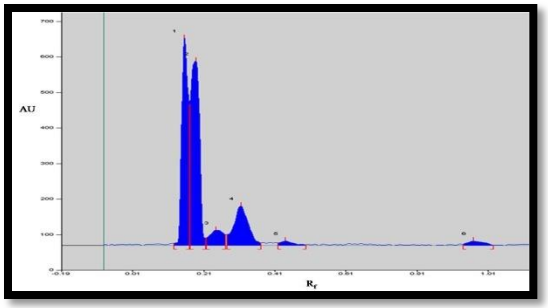
Outcome: successful algae conversion to food supplements

Development of products from algae
Example: Products from Spirulina



Spirulina Powder

Spirulina Capsules



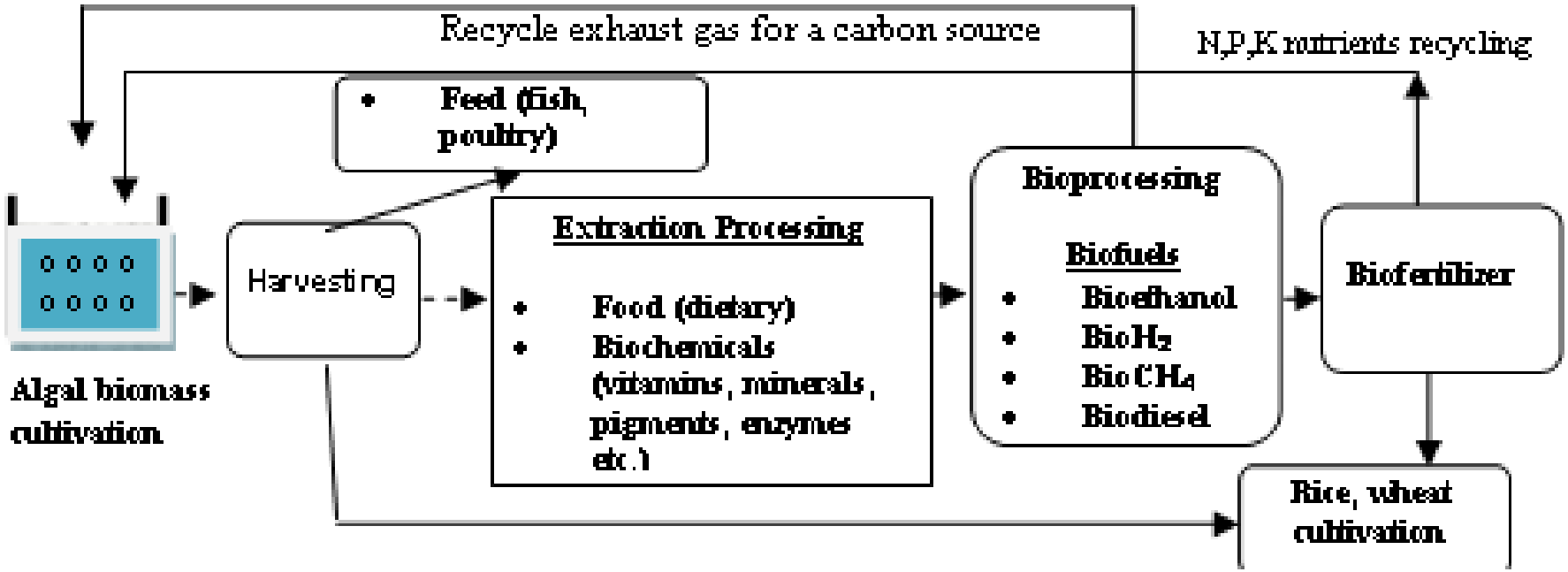
Zeaxanthin
Violaxanthin
Chlorophyll a and b
β-carotene

Spirulina Tablets

Spirulina drinks

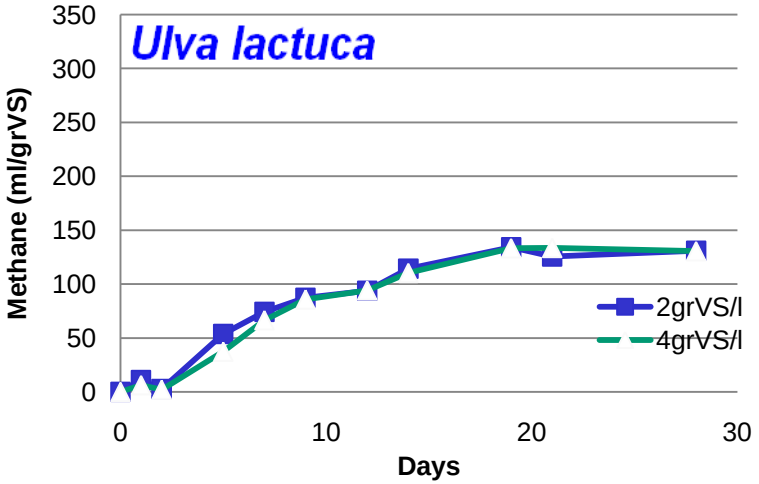
Utilisation of algae as biofertilisers

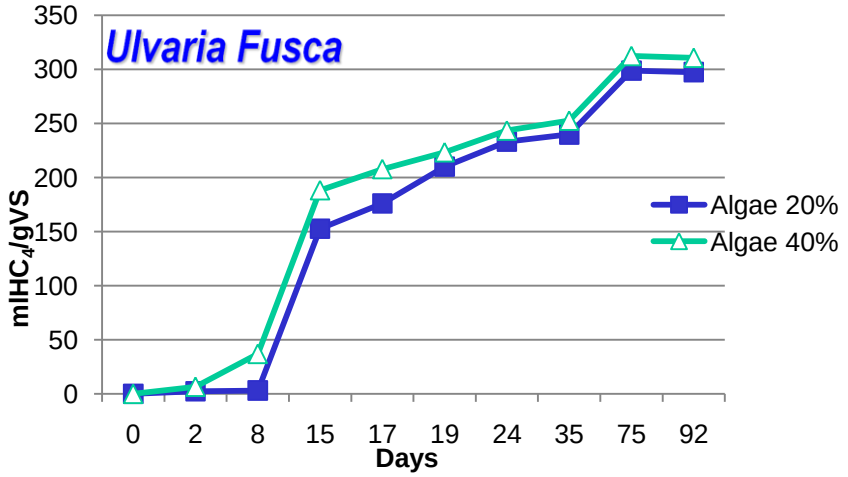
Integrated algae concept



Results

- **Methane potential: *Ulvaria fusca*: 300 mlCH_4/gVS (or 55 m^3-CH_4/tons algae)**
- **Methane potential *Ulva lactuca*: 150 mlCH_4/gVS (or ca. 25-30 m^3-CH_4/tons algae)**
- **Salt was not inhibiting the biogas process in co-digestion with manure**





Work Packages

WP7: Technological, societal, environmental and economical assessment of sustainability

- ***Economical***
- ***Energy***
- ***Environmental***

WP8: Demonstration

- ***Algae rotation***
- ***Biofertilisers***
- ***Biogas from off-shore algae***

Partners in India – Visit October 2010

1. IARI Delhi- Dr. Dolly W. Dhar

2. SPRT- Madurai- D.Selvendran

3. ITT-1 Kharagpur (Calcutta)- Prof. Debabrata Das

4. ITT-2 Kharagpur (Calcutta)- Dr. Hari Niwas Mishra

Information

- *Two large international conferences – India (2012), Denmark (2014)*

- *Homepage: www.algaebiorefinery.org*