MarBioShell

Bio-energetics and Bio-energy: Blue-mussels as source for raw materials

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UNIVERSITY OF SOUTHERN DENMARK

MarBioShell

Bio-production and Bio-energetics:
Bio-reactor production of microalgae and growth of filter-feeding bivalves

Ph.D. project periode: April, 2009 – March, 2012

18 months at AAU (Section of Biotechnology)

18 months at Marine Biological Research Centre Kerteminde (SDU)

Supervisors: Prof. Hans Ulrik Riisgård (SDU)

Assoc. Prof. Niels T. Eriksen (AAU)

Aalborg University Denmark

University of Southern Denmark

MarBioShell

Development of sustainable off shore shellfish (*Mytilus edulis*) mariculture in Denmark

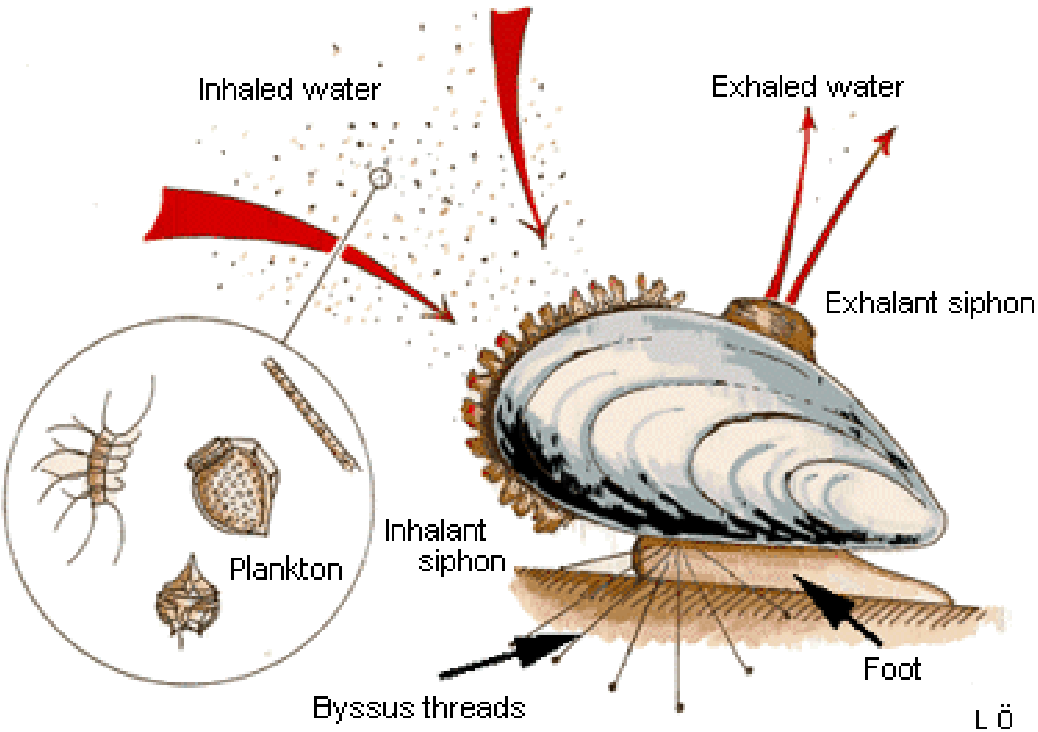
- Prospects for expansion are found in the Great Belt
  - Advantages are:
    - Constant high current speed
    - Stable food supply
    - No risk of accumulation of waste material

Outline

1. Introduction
2. Bio-energetics of blue-mussels (*Mytilus edulis*)
3. Biomass composition of blue-mussels
4. Blue-mussels as source for raw materials
5. Conclusion

1. Introduction

Mytilus edulis



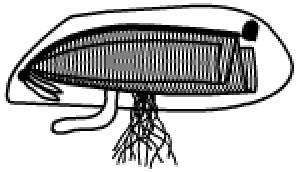
(Ref.: Aquascope)

Mytilus edulis, water flow and feeding

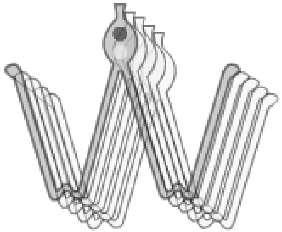
Animation from Kroening, Palmer and Bio-DiTRL.org

http://www.biology.ualberta.ca/facilities/multimedia/uploads/zoology/FilibranchBivalve.swf

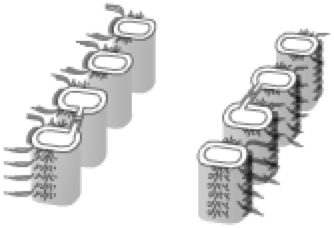
1. Whole mussel



2. Ctenidium (gills of mollusks)



3. Gills fillaments



1. Introduction

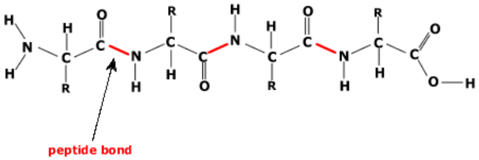
Bio-energetics:	Field of bio-chemistry concerning the energy flow through an organism Study of energy transformations in biological systems (biomass production)
Bio-energy:	Renewable energy made available from materials derived from biological sources (use of biomass)

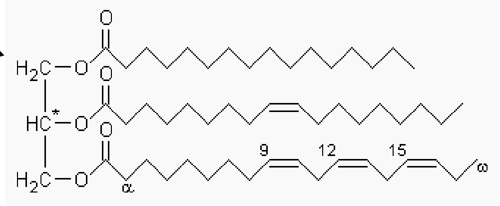
Evaluation of growth potential of blue-mussels in the Great Belt

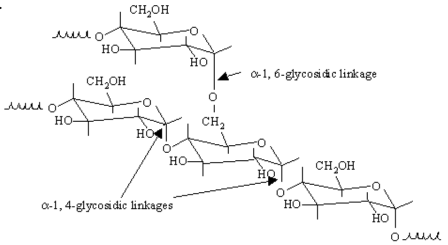
- Growth rate at different algal concentrations

Mytilus edulis as ”bio-refinery”: Collecting and accumulation of phytoplankton components

- High value compounds (e.g. PUFA)
- Amounts of lipids, proteins and glycogen





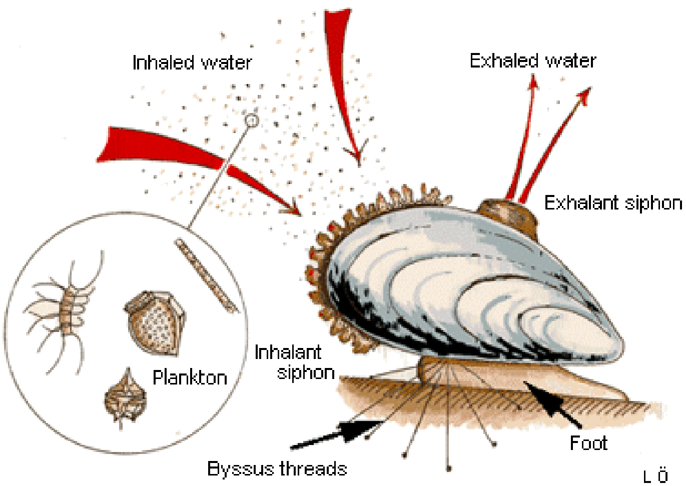


2. Bio-energetics

- **1. Step: Filtration**

$RE = IE - EE$

IE = Energy content inhaled water
EE = Energy content exhaled water
RE = Retained energy



(Ref.: Aquascope)

Filtration efficiency 100 % for cells bigger than 4 µm (Riisgård et al. 1980)

$F\ (\mathrm{l\ h^{-1}}) = 0.0024L^{2.01} = 2.2\ \mathrm{l\ h^{-1}}$
$L = 30$ mm
Pleissner et al., in prep.

2. Bio-energetics

- **2. Step: Digestion**

  Activity of hydrolytic enzymes:

  Amylases (starch)
  Cellulases (cellulose)
  Proteases (proteins)
  Lipases (lipids)

  Note, not all of the retained energy (cells) is assimilated

  For *Mytilus edulis* fed *Rhodomonas salina* assimilation efficiency ~80 % (Clausen & Riisgård 1996)

2. Bio-energetics

- Growth rate determination using the energy balance equation:

$$G = I - E - R$$

Where:

G = energy used for growth
I = energy obtained from the particles ingested
E = energy lost by particles excreted
R = energy used for respiration

$$G_{est} = [(F \times AE \times C \times E) - R_m]/1.12$$

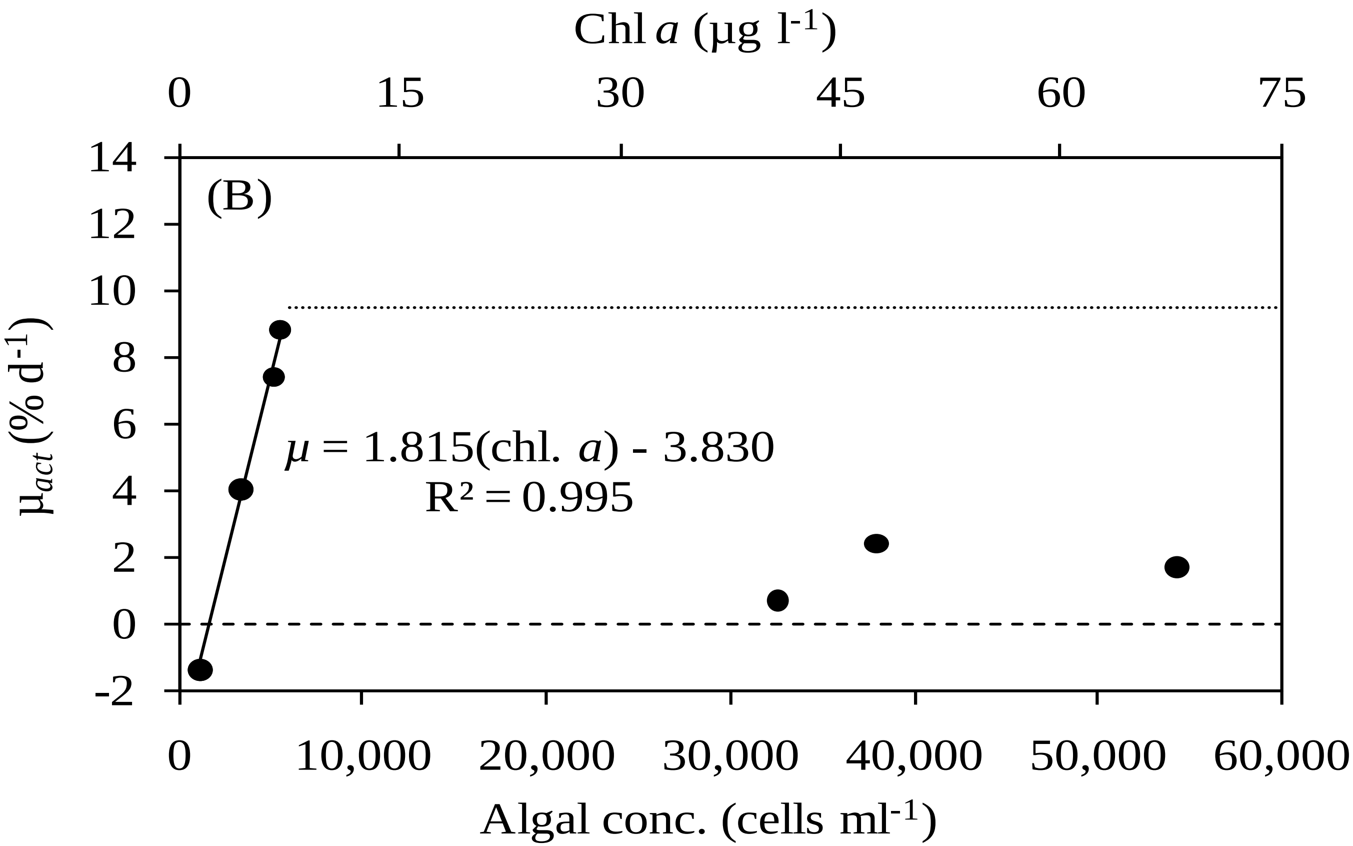
Where

G_{est} = estimated growth rate (mg day^{-1})
F = filtration rate (ml s^{-1})
AE = 80 % for *Rhodomonas salina*
C = algal cell concentration (cells ml^{-1})
E = energy content per cell (µJ $cell^{-1}$)
R_m= maintenance respiratory rate (1 ml O_2 h^{-1} = 5522 µW)
$R_m = 0.475 DW^{0.663}$ (DW = g, ml O_2 h^{-1}, Hamburger et al. 1983)
1.12 = respiratory costs of growth (12% of the growth rate)
1 mg dry weight of soft parts = 20.51 J (Clausen & Riisgård 1996)

What is the lowest algal cell concentration for optimum growth?

$$\mu = [(\ln(W_t/W_0)/t] \times 100$$

μ = weight specific growth rate (% day^{-1})
W_t and W_0 = dry weight at time t and tim
t = duration of the experiment



Riisgård et al., in prep.

3. *Mytilus edulis* biomass composition

Composition of naturally grown mussel

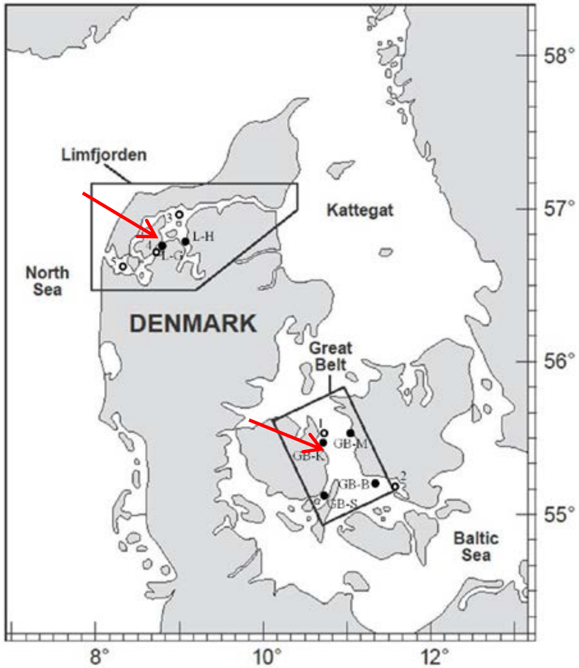
-Growth studies at 2 locations

Accumulation of phytoplankton components

-Mussels fed *Crypthecodinium cohnii*

Specific biomass concentration as a function of *CI*

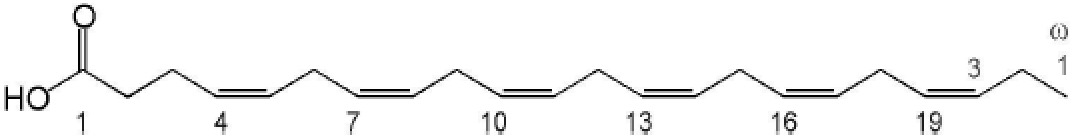
-Mussels with different condition index (*CI*)



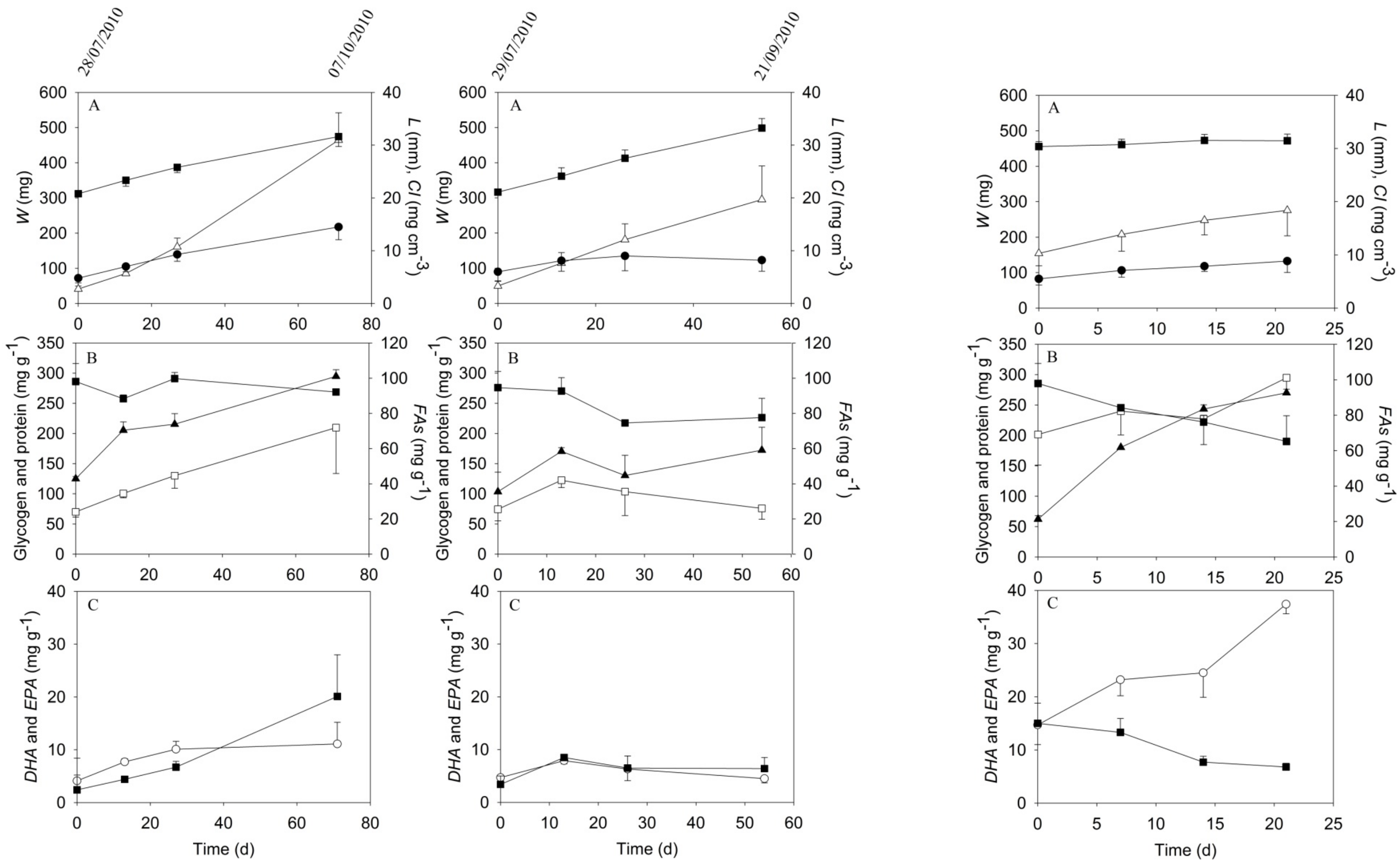
$CI = W / L^3$

W = dry weight of soft parts
L = Shell length

Docosahexaenoic acid (DHA, C22:6, ω-3)



Kerteminde Bay (Great Belt) Salling Sund (Limfjorden) mussels fed *Crypthecodinium cohnii*

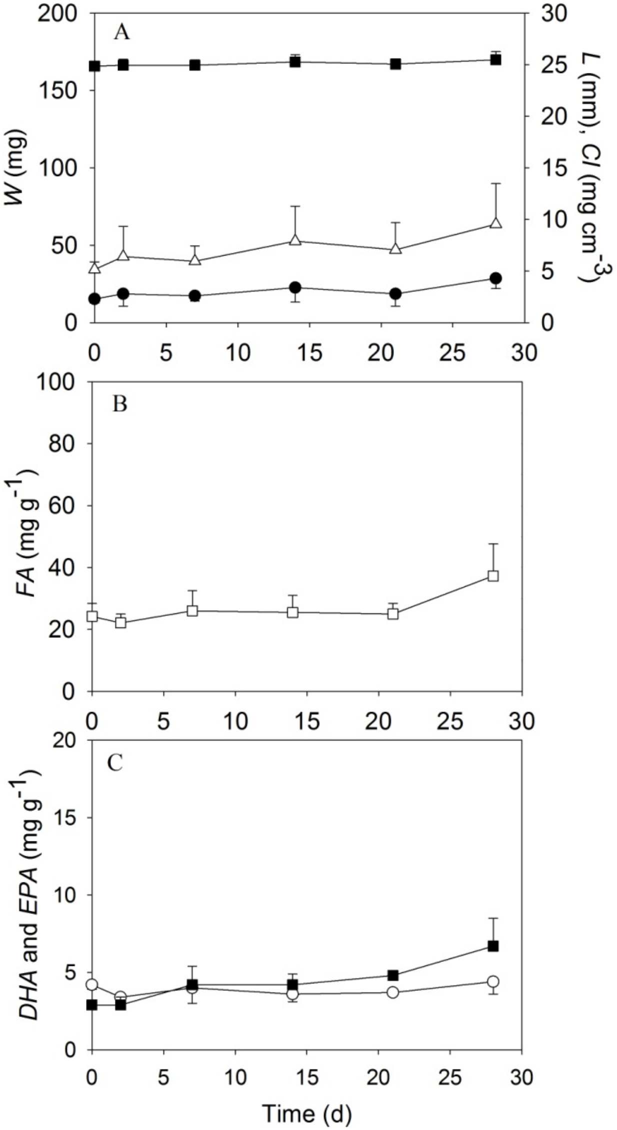


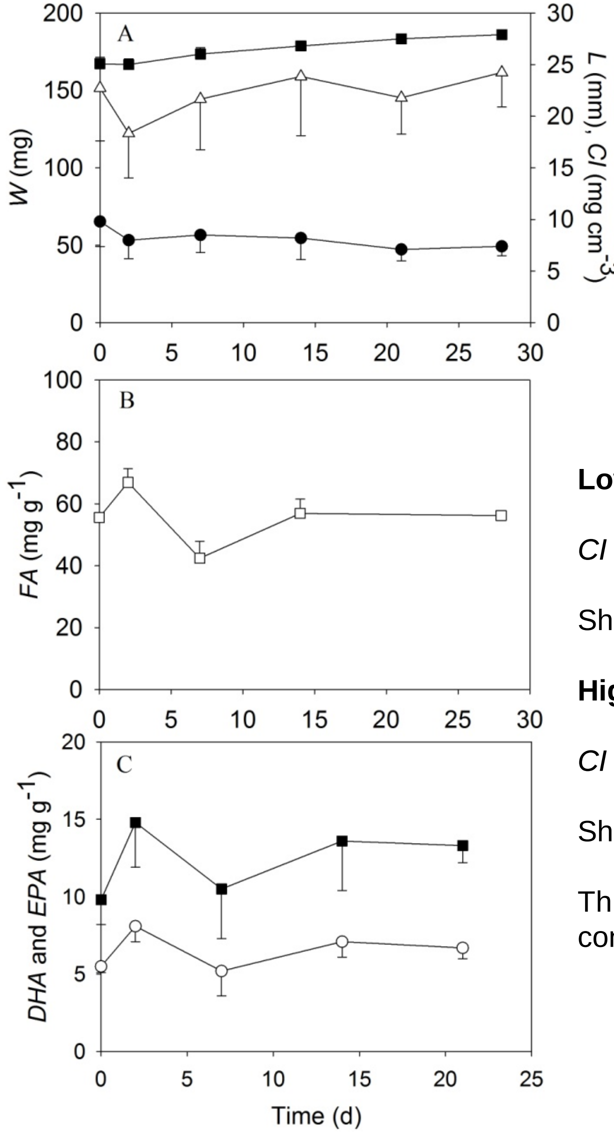
Growth of mussels in net-bags at two localities (Kerteminde Bay and Salling Sund) and in laboratory fed *Crypthecodinium cohnii*. **A:** Dry weight of soft parts (*W*, open triangle), condition index (*CI*, closed circle*)* shell length (*L*, closed quadrate) *,* **B:** Glycogen (filled circle), sum of fatty acids (*FA*, open quadrate) and proteind (filled quadrate), **C:** Docosahexaenoic acid (*DHA,* open circle) and eicosapentaenoic acid (*EPA*, filled quadrate) .

Pleissner et. al, in prep.

Low condition

High condition





Low condition index:

CI of 2 mg cm^{-3}, increased to 5

Shell length remained at 25 mm

High condition index:

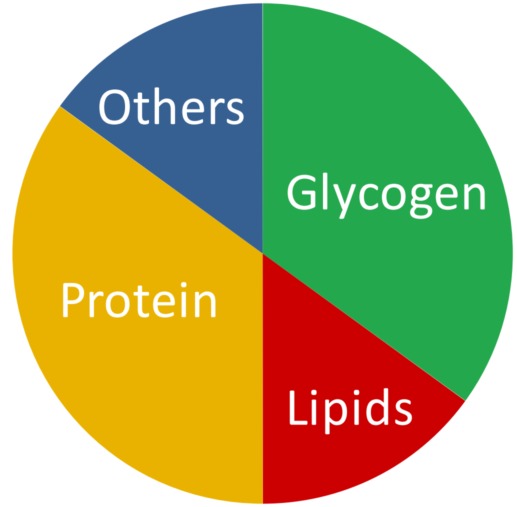
CI of 9 mg cm^{-3}, no sig. change observed

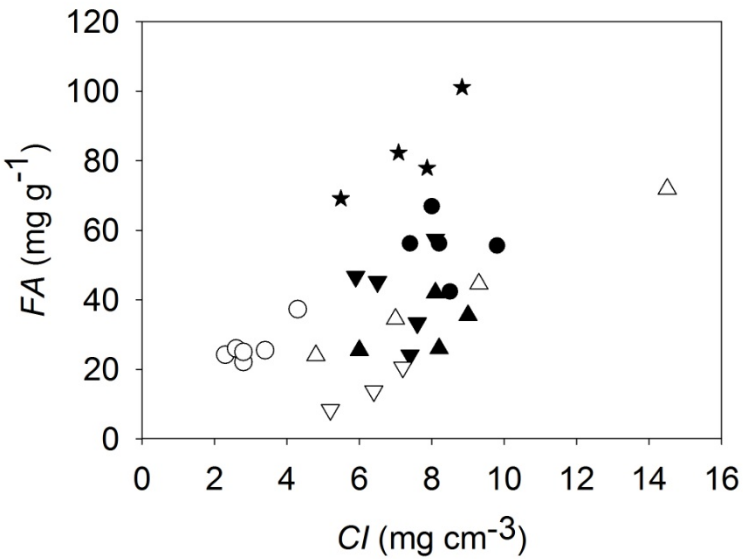
Shell length increased from 25 to 28 mm

Three fold higher spec. fatty acids conc. in high condition than in low condition mussels

Growth of mussels with low and high condition index (*CI*) fed algal cells in laboratory . **A:** Dry weight of soft parts (*W*, open triangle), condition index (*CI, closed circle)* shell length (*L*, closed quadrate) , **B:** Sum of fatty acids (*FA*, open quadrate), **C:** Docosahexaenoic acid (*DHA,* open circle) and eicosapentaenoic acid (*EPA*, filled quadrate) .

Pleissner et. al, in prep.





Specific biomass composition increases with increasing *CI*

LC-mussels (open circle)
HC-mussels (closed circle)
Kerteminde Bay (open triangle)
Salling Sund (closed triangle)
Mussels fed *C. cohnii* (star)

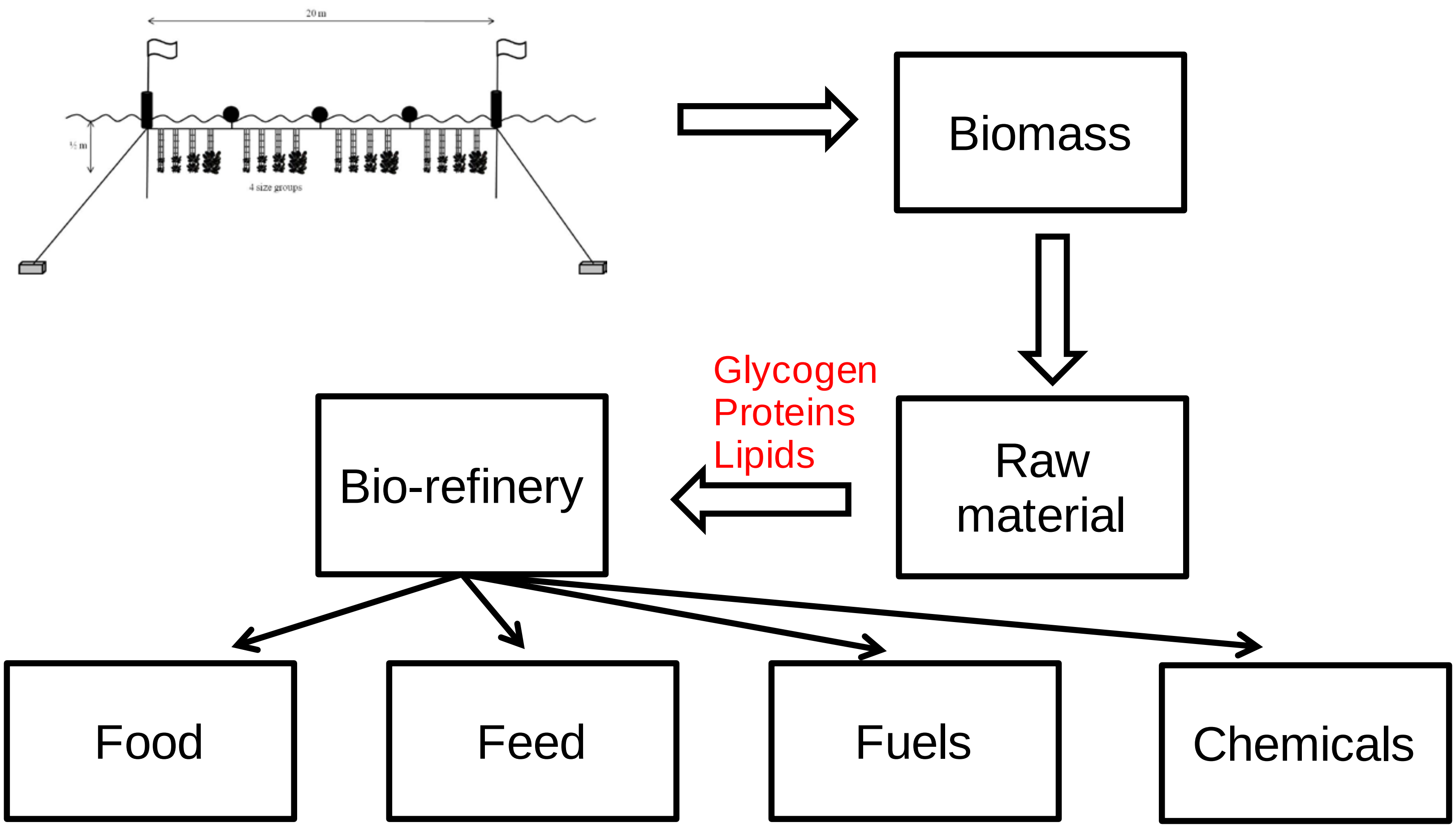
$$CI = W \times L^{-3}$$

W = dry weight of soft parts
L = Shell length

Specific fatty acids content (*FA*) of mussels as a function of condition index (*CI*)

Pleissner et al., in prep.

4. Source of raw materials



Bio-refinery: Biomass conversion process

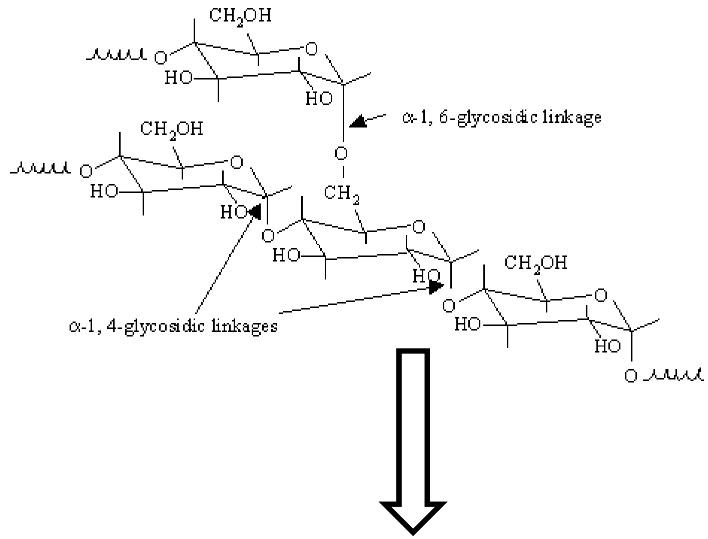
MarBioShell research mussel farm (1 season May-Nov):

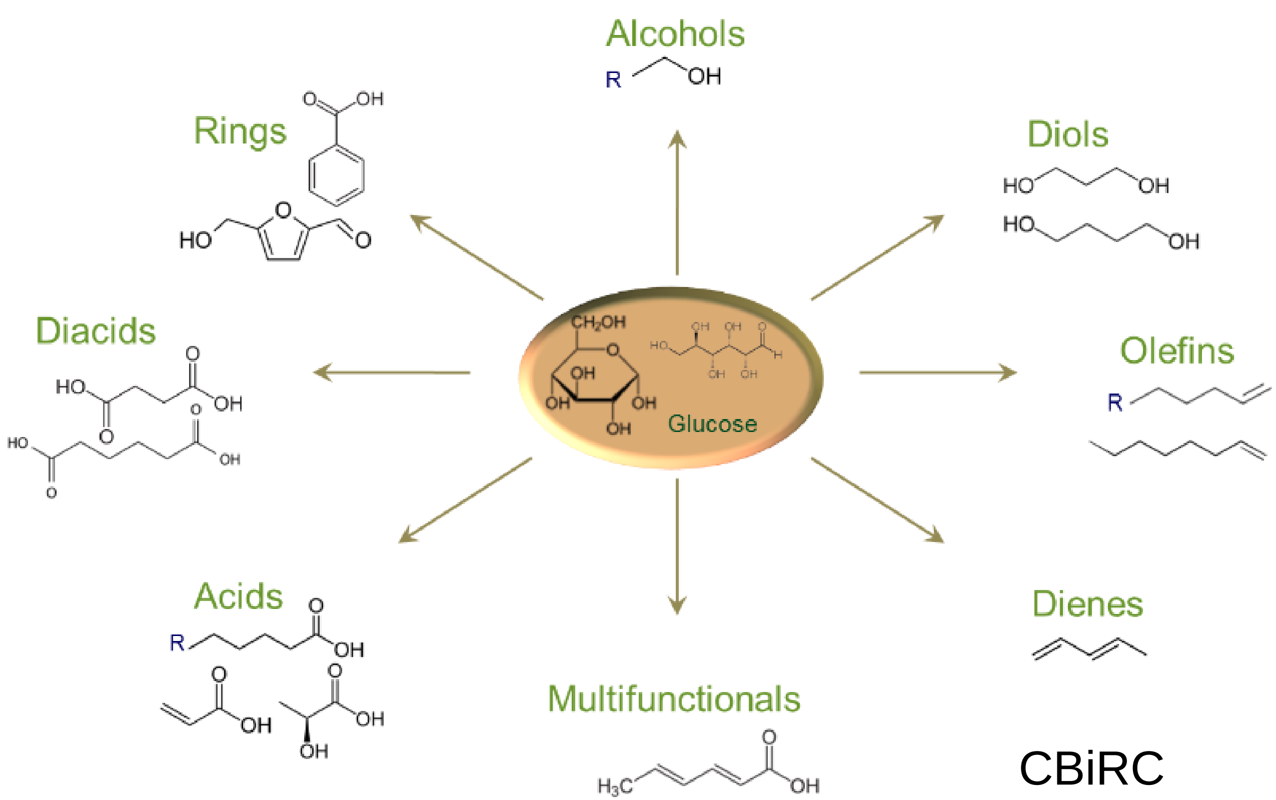
Total productivity:	40,000 kg mussels (wet)
Shells (50 %):	-20,000 kg
Water (80 %):	-16,000 kg
Dry mussel meat:	**4,000 kg**

1,400 kg glycogen   1,400 kg proteins   400 kg fatty acids

MuMiHus – project in Skive Fjord 1,000,000 kg mussels (wet)

Glycogen





CBiRC

Lipids

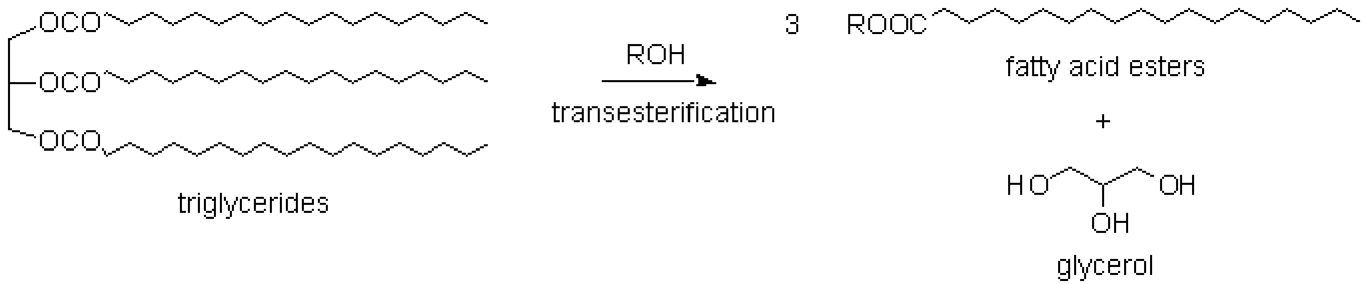
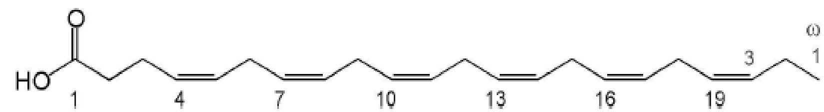


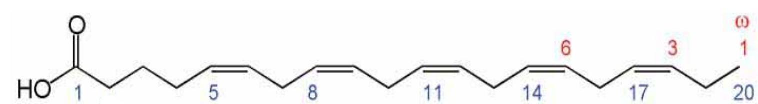
Table: Major fatty acids in mussels grown in the Kerteminde in Dec. 2010

Fatty acid	mg g^{-1}
C14:0	8.9±0.6
C16:0	19.5±0.9
C16:1	16.2±0.8
C18:0	1.5±0.1
C18:1n9t	3.2±0.2
C18:2n6c	1.6±0.1
C18:3n3	1.7±0.1
C20:3n3	1.4±0.1
C20:5n3	32.6±1.2
C22:6n3	14.4±0.5

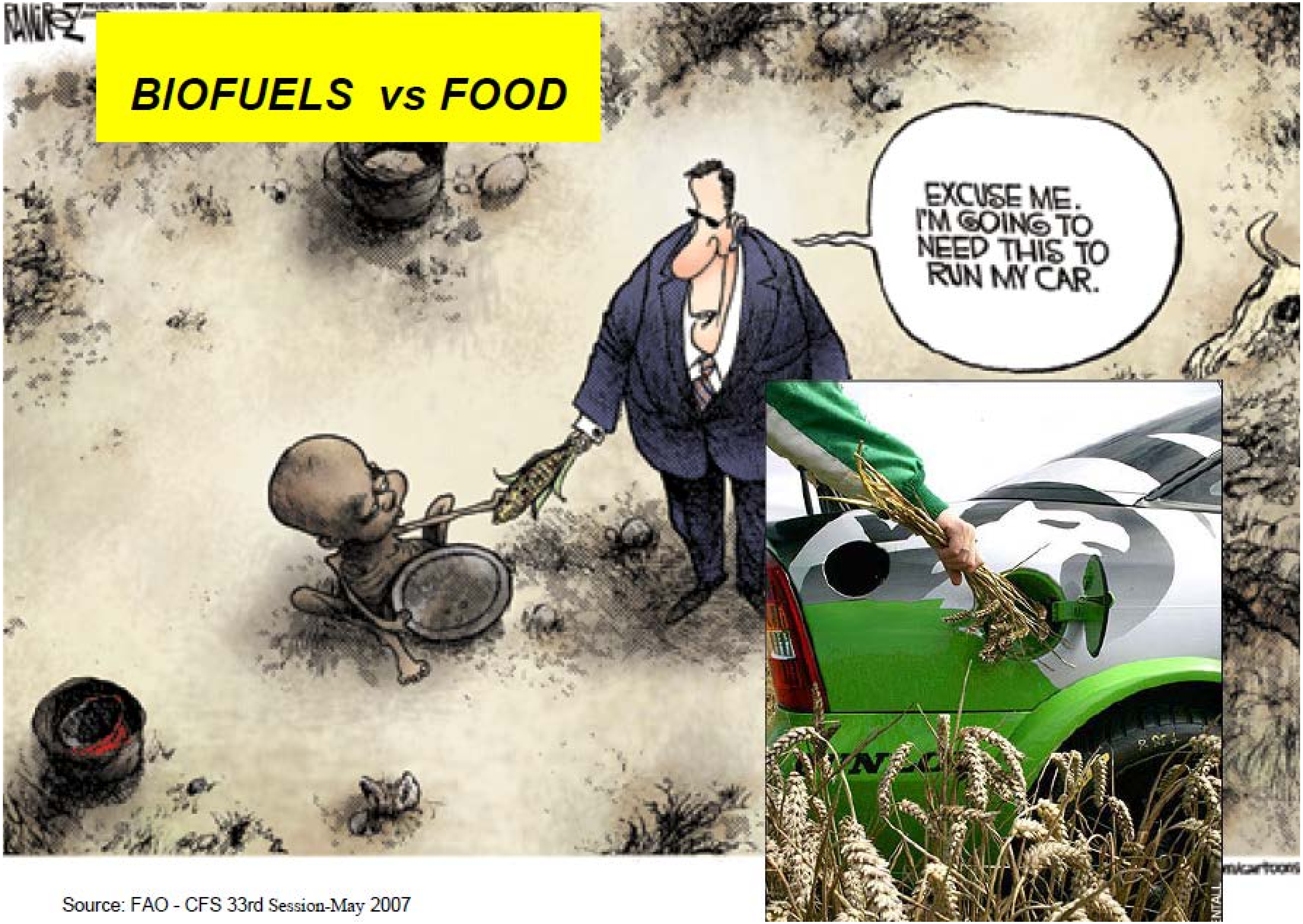
Docosahexaenoic acid (DHA, C22:6, ω-3)



Eicosapentaenoic acid (EPA, C20:5, ω-3)



BIOFUELS vs FOOD



Source: FAO - CFS 33rd Session-May 2007

5. Conclusion

a) Blue-mussels filter efficiently large amounts of water

b) Harvesting of phytoplankton components, accumulation of high value fatty acids

c) Mussel grow equally in Salling Sund and Kerteminde Bay

d) Possibility of harvesting of mussels after only one season (mini-mussels, grown between May-Nov.)

e) Food and raw material for bio-refinery

f) No use of land for biomass production

g) Recovery of nutrients (N and P)

h) Production of high value products (e.g. PUFA)

Thank you for your attention

http://www.marbio.sdu.dk/

References

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