Seaweed research and production in Denmark

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Seaweed history of DK

- CPKelco, started as Litex A/S ”Danish agar”
- Danisco
- Phycologist at Universities
- Recent seaweed projects

- Seaweed farm: 1 (Marifood)
- Do not eat seaweed! More aware now:
  - Sushi wave
  - Seaweed book, media….. Etc.
  - Seaweed salat in fish stores

- No Danish seaweed on the Danish market
- Demand from restaurants especially; NOMA and other restaurants
- Industrial classification code: Food safety, utilization of the raw material, cultivation, recently EU-regulation on organic seaweed cultivation
- Dialog with: Ministry of Food, Agriculture and Fisheries:
  - Danish Veterinary and Food Administration
  - The Danish Directorate of Fisheries
  - Veterinary Control Office-Aquaculture Department

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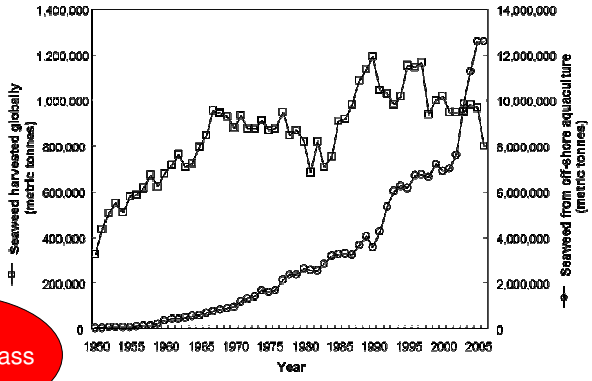
The rest of the world (Asia: 99.7 %)



Danish biomass

Figure 3. Globally harvested (□) and cultivated seaweed (○) in offshore marine and brackish water from 1950-2006 (FAO 2008).

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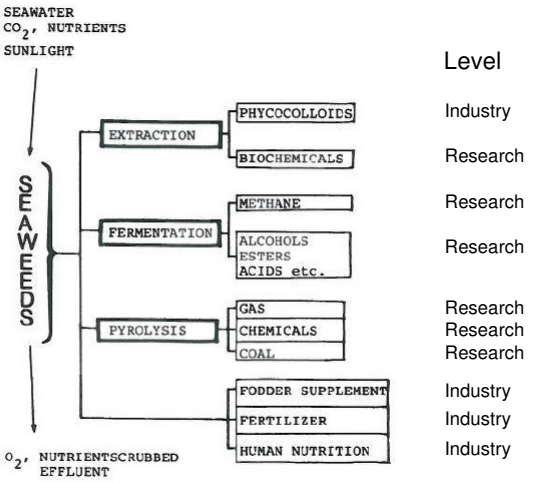
Potentials of seaweed

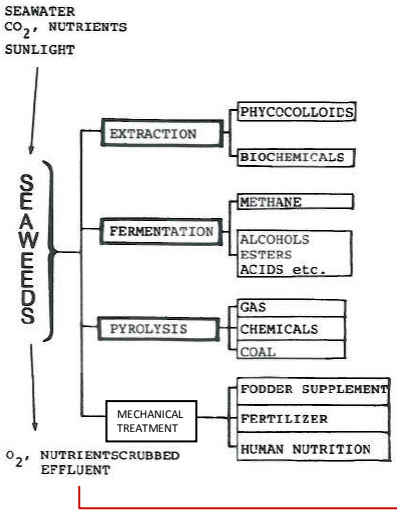


Level
Industry
Research
Research
Research
Research
Research
Research
Industry
Industry
Industry

Figure 2. Present and potential future uses of seaweeds.

The aquatic ressource. Indergaard **1983**

Anno 2010- 27 years later



Present level	Future biorefineries
Industry	**high** added **value** products
Industry	
Research	**Low value** bulk products (2. generation)
Research: cars and air plane	
Research	
Research	
Research	
Industry	
Industry	
Industry → Western world	

Waste water management

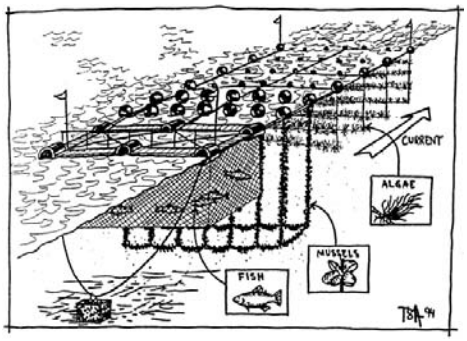
Project: ESTABLISHMENT OF A NEW SUPPORT SYSTEM FOR MONITORING, MAINTENANCE AND RESTORATION OF SEAWEED BEDS (Presentation by Dr. Fujita D. at ISS 2010, Mexico)

Japanese project: Associations of Fisheries Cooperatives (JF), Local Community, and Tokyo University of Marine Science and Technology (2007-2009)

- Seed production for seaweed beds
- Remove the sea urchins
- Control of sea urchin density-incl. transplantation
- Settlement of protected area (net cages)
- **Fertilization (nitrate and iron)**
- Cleared rocks
- Aforestation on land along rivers- to stabilize the quantity and quality of river waters
- Removal of accumulated materials (woods, garbage)

No increase in total N-discharge

Integrated aquaculture



Bring the seaweed cultivation to the nutrient source

Exploit the nutrient scrubbing
Waste water management

No increase in the total N-discharge

Increase of fish production, reduce your N-waste

Space- visual pollution:

Reduce the N-waste by 10 %:
Musholm Lax: 3.000 tonnes fish: 25 ha of seaweed
Agersø Havbrug: 260 tonnes fish: 3 ha of seaweed

2003:
Recommendations by the Committee of Marine Cultivation
Vandmiljøplaner: reducere N and P
Organisms for bioremediation (blue mussels and seaweed)
25 marine of shore fish farms
45,000 tonnes of fish production per year

Potential: Governmental plan of action: Aim at 2013:
115,000 tonnes; hereof 10,000 tonnes other species
Max release of 2,400 tonnes N/year (now 1,000)

2010:
Recommendations by the Aquaculture Committe of the Government
Regulated by the output and not input as before
Negotiable N quotas (like the CO_2 quotas)
No extra N and P waste
20 marine of shore fish farms
44,000 tonnes of fish production per year

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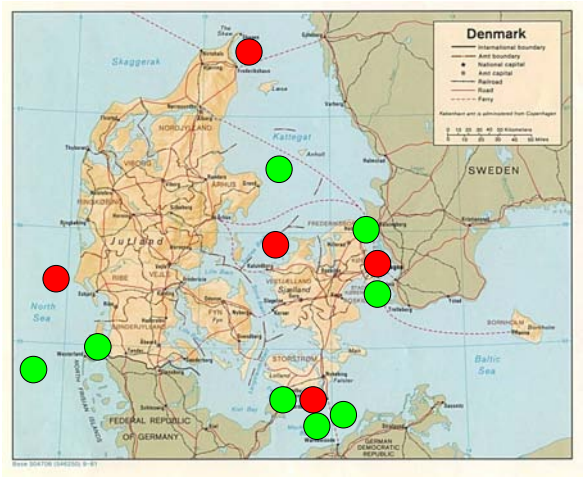
Windmill parks



existing

planned

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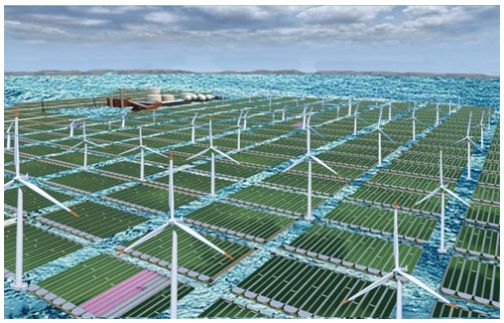
- Future …. N-quotas?



Potential seaweed biomass

The Sea: the unexploited ressource
(Ministry of Food, Agriculture and Fisheries)

No seaweed on the outside but mentioned inside

Concludes that seaweed are an unexploited ressource

- Examples of applications, present and future
- Create social benefits

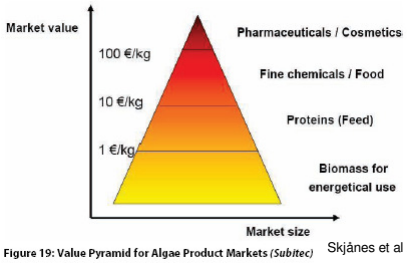


Figure 19: Value Pyramid for Algae Product Markets *(Subitec)* Skjånes et al 2007

If we get the feedstock
… what do we want with it…

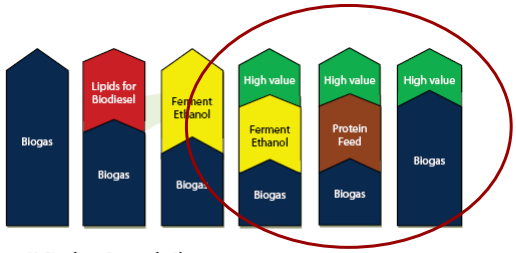


Figure 20: Biorefinery Concepts for Algae Skjånes et al 2007

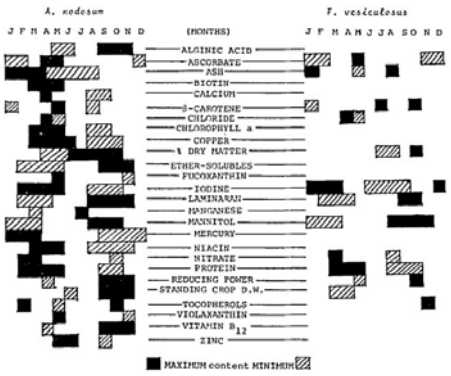
Table 5. Polysaccharides in seaweed species with characteristics, source and bioactivity

	Characteristics	Source and content	Bioactivity
Polysaccharides	Total	*Saccharina latissima* [a] *Sargassum pallidum* [b, c]	Antitumor action [a, b] Potent anti-coagulant [c] Decrease in LDL-cholesterol in rats [d] Anti-herpetic [e]
Phycolloids	Algins/alginic acid	*Undari pinnatifida* [a]: 24 % [f] *Laminaria digitata*: 32 % [g] *Laminaria* sp. [f] *Sargassum vulgare* [f] *Ascophyllum nodosum*: 28 % [g]	Anticancer [a]
	Carrageenans	*Chondrus crispus* [g-i] *Eucheuma cottonii* [g]	Antitumor and immunomodulation [i, k] Anti-HIV [k], but no efficacy on humans [l]
	Agar	*Gracilaria* sp., Gigartina sp. etc. [m]	
Fucoidan ranging from typical fucoidans (major components) to low sulphate-containing heteropolysaccharide-like fucans (minor components) [o]	Fucan composed of neutral sugars other than fucose and a high content of uronic acid(s) [o]	*Sargassum horneri* [c] *Sargassum vulgare*: uronic acid, xylose and fucose accounted for >90 % of total sugars [f] *Fucus vesiculosus* [o] *Undaria pinnatifida* [p]	Potential antiviral [c] Slightly anticoagulant activity [o] Anti-herpetic [p]
	Fucoidan=fucan sulphate, containing mainly L-fucose, sulphate, and no uronic acid [o, q]	*Laminaria digitata*: 5.5 % [g] *Laminaria* sp. [f] *Ascophyllum nodosum* [f]: 12 % [g] *Undaria pinnatifida* [p, r, f]: 1.5 % [f] *Fucus vesiculosis* [o] *Eisenia bicyclis* [f]	Potential antiviral (HIV and HSV) [r, s, t, v] Anticoagulant [o, s] Anti-arteriosclerosis [a] Anti-cancer [a, u] Potential antiviral against human cytomegalovirus and avian flue [s] Anti-tumor activity [f] Inhibits growth of *Cryptosporidium parvum* in mice [z]
Mannitol		*Laminaria digitata*: 13 % [g] *Laminaria* sp. [f] *Sargassum mangarevense*: 1-12 % [ae] *Ascophyllum nodosum*: 7.5 % [g]	Effectively protects the photosynthetic apparatus from low-salinity damage [a, d]
Laminaran	Branched (soluble) and unbranched (unsoluble) polysaccharide: beta 1-3,beta 1-6-glucan [a, p], 84-94 % sugar and 6-9 % uronic acid [o]	*Laminaria digitata*: 14 % [g] *Laminaria* sp. [f]: 99 % of total sugars [e] *Fucus vesiculosis*: 84 % of total sugars [e] *Ascophyllum nodosum*: 4.5 % [g],90 % of total sugars[e] *Undaria pinnatifida* 3 % [f]	Only found in brown seaweed [a]
Phycarine		*Laminaria digitata* [g]	Immune system, stimulation of macrophage phagocytosis [b]
Porphyran	Polysaccharide: polymer of acidic saccharide containing sulphate groups, β-1,3-xylan [a]	*Porphyra umbilicalis*: 48 % [g] *Porphyra* sp. [a]	Potential apopototic/programmed cell death activity [a]
Ulvan	Polysaccharide, highly branced polymers of soluble dietary fiber and contain rhamnose, glucuronic acid and xylose [a, n]. Structurally similar to the mammalian glycosaminoglycans [ae]	*Ulva lactuca* [ae]	Cytotoxicity and cytostaticity, HU colon cell line [ae]

a= (Murata and Nakazoe, 2001), b= (Ye et al., 2008), c= (Athukorala et al., 2007), d=(Amano et al., 2005), e= (Ghosh et al., 2009), f= (Je et al., 2009), g= (MacArtain et al., 2007), h= (Bartsch et al., 2008a), i= (Dietrich et al., 1995), j= (Yan et al., 2004), k= (Zhou et al., 2006a), l= (Skoler-Karpoff et al., 2008), m= (FAO, 2008), n= (Vlieghe et al., 2002), o= (Nishino et al., 1994), p= (Hemmingson et al., 2006), q= (Matsubara et al., 2005), r= (Marais and Joseleau, 2001), s= (Lee et al., 2004), t= (Maruyama et al., 2007), u= (Yamamoto et al., 1984), v= (Schaeffer and Krylov, 2000), x= (Mayer and Hamann, 2004), y= (Han et al., 2008), z= (Snit, 2004), aa= (Zubia et al., 2008), ab= (Geissner, 1971), ac= (Loiloban and Harrison, 1994), ad= (Rioux et al., 2007), ae= (Mayer et al., 2007), af= (Plaza et al., 2008), ag=(Kaeffer et al., 1999), ah= (Bobin-Dubigeon et al., 1997), ai= (Michel and Macfarlane, 1996)

Basic research needed

- What do we know about our seaweed species
- Like the Norwegians: natural variations (seasonal, regional)
- Like the Canadians: breeding, improving the stock (biorefineries, like Danish conditions)



Seasonal maxima (solid bars) and minima (shaded bars) of constituents (dry weight basis) of Norwegian *A. nodosum* and *F. resiculosus:* (references in (Ragan and Jensen, 1978)).

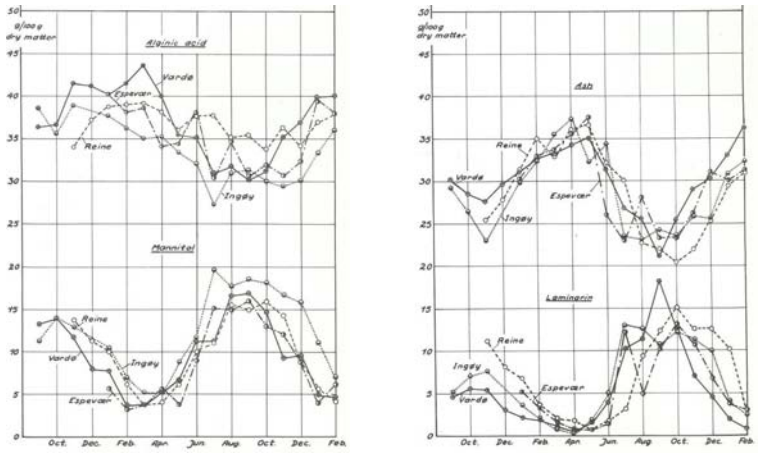
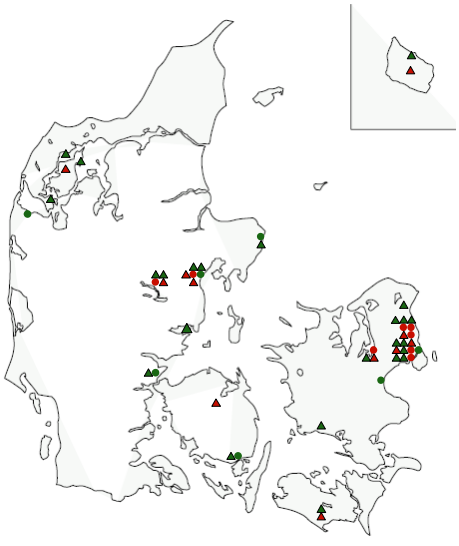


Figure 8. Seasonal variations of alginic acid, mannitol, laminarin and ash content (g/100 g dw)of *Laminaria digitata* in four locations (Reine, Vardø, Espevær and Ingøy) in Norway during 1951-1953 (Jensen and Haug, 1956).

- Research has changed from basic to applied
- Less money from government
  - Less researchers that are fully finansed
  - Proposal writing, less research
  - Reduction in Ph.D. scholarships (200 in Copenhagen University)

However, Denmark should be in the top 10 in research in 2010. Knowledge is our raw material!



University (projects at present)

Industry or other business

University (interest)

Industry (interest)

Holdt 2009

Van Deur 2009

Present and future projects

- Entrepreneurs
- Funded
  - Food application (whole)
  - Functional food (extractions)
  - Biorefineries
  - Bioenergy
  - Cultivation

Food application

Havets spisekammer/"Pantry of the sea"

"Frisk fangst" and a chef : 300,000 Dkr (LAG)
Add whole seaweed to bread, spice, pasta etc.
Buy via the internet

(Tonny Kristensen and Jesper Pedersen)

LAG: Local Action Groups

Food application

"OPUS: Bladderwrack and savoy cabbage will be tested in the worlds largest food experiment".

New Nordic food will be tested at schools and in private families. Claus Meyer (chef), Arne Astrup (KU-LIFE), includes NOMA: 100 mil Dkr (Nordeafonden)


GOURMET

Nomas nabo

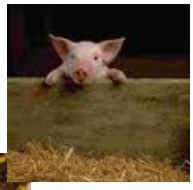
Magien på verdens bedste restaurant, Noma, starter ofte på husbåden overfor, hvor Nordic Food Lab holder til. Her eksperimenterer Torsten Vildgaard med tang og spiselige blomster.

NOMA and Nordic Food Lab are already working with seaweed in their scientific kitchen
- Creating attention

Food application

Seaweed fed to piglets (Faculty of Agricultural Sciences and AlphaSign A/S)

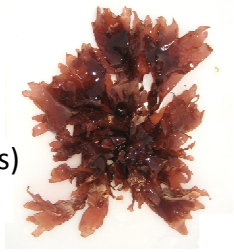
- -milk to solid fed
- -diarrhea and infections- penicillin
- -seaweed showed really good results on *E. coli*
- -organic meat production



Upcoming: Functional food

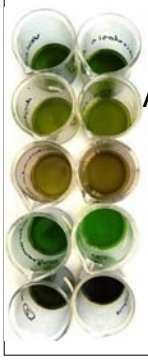
Jan Stagsted and Trine Huusfeldt

Functional food (extract)



Exploring algae for new food ingredients

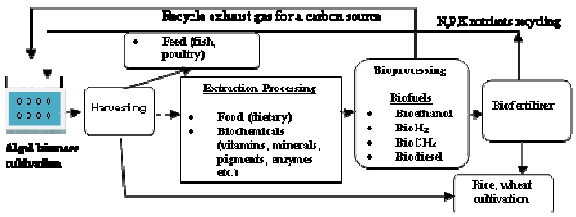
- Micro and macroalgae
- Højteknologifonden (4 mill. Dkr.)(3 years)
- KU-LIFE (William Willats) and Danisco



Antioxidants from marine organism

- Including seaweed, polyphenolics
- Screened 16 Danish species for antiox. activity
- Post doc Sabeena Farvin, DTU National Food Institute

Biorefinery



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

Danish Indian project (15 mill. Dkr, 4 year)

Indian Universities and Industry, DTU Environment, KU, Lemvig Biogas

Biorefinery

Upcoming…

MAVP: Macroalgal value added products:

Collected seaweed (cult. potential), extraction of bioactive compounds, protein and lipids for fish feed trials, carbohydrates tested for bioactivity

Involve: DTU Food, DTU Environment, KU-LIFE, DTU Aqua, Risø DTU, Grønt Center, etc…

MAB: Macroalgal Biorefinery:

Cultivation of seaweed in effluent/waste water, extraction of biochemicals for building blocks, proteins for fish feed, carbohydrates for bioenergy

Involve: Risø DTU, DTI, DMU, Biomar

Cultivation of seaweed

AlgeCenter Danmark

Tanks (flow through, aerated) for cultivation of seaweed biomass: Grenaa
DMU, Ocean Centre Denmark, Kattegatcentret, DTI etc.
Funded: Brd. Hartmanns Fond (600,000 Dkr) and DMU, DTI and EU

Blue Revolution

Unravelling the potential for a large Ocean Technological Platform in DK including fish, mussel and seaweed cultivation
Danish Organisation of Aquaculture, DHI, DTU Aqua, DTU

Seaweed cultivation on the small Danish Islands

Unravelling the potential (report finalised) and funded by LAG and others (1.2 mill. Dkr.)
Partners: Småøernes Aktionsgruppe, Bornholm / Ertholmene, Det sydfynske øhav, Bornholms LAG

AlgaeInnovation and The Local Virtues

Grønt Center Lolland and Dansih Shellfish Centre, respectively, Fornyelsesfonden

Bioenergy

BioWalk4Biofuel

Cultivation of algae in the Mediterranean: EU-FP7 project
Partners: DMU, DTI, Italy, India, Sweden, Spane, Estonia, Jordan

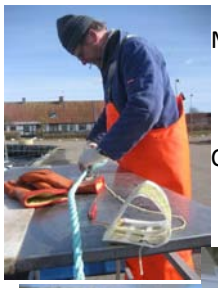
Algae for Biogas in the Jutland Region

Region Midtjyllands Vækstforum, DMU, DTI,
Ocean Centre Denmark, DJF, DONG Renescience, Kattegatcentret

Energy production from marin bomass (*Ulva lactuca*)

Energinet.dk
DMU, DTI, Ocean Centre Denmark, DONG Energy

Cultivation of seaweed

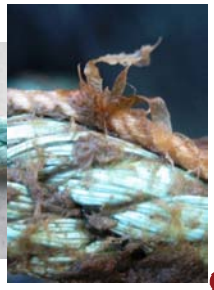


Marin Centre of the Great Belt (MKS)

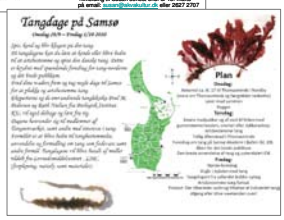
Funded by: Slagelse local authority and LAG Ministry of Food
Partners: Slagelse, GEMBA Seafood Consulting, Bisserup Fisk, DTU Food, Fishermen at Omø

Commercial utilization of organic seaweed for consumption

DFFE: Bælternes Fiskeriforening, GEMBA, DTU



Danish Seaweed Network



157 members from industry, universities, restaurants, organizations, or persons that work with or have interest in seaweed

The network group started in winter 2008

4 meetings and 4 newsletters

Fundings from LMC: Centre for Advanced Food Studies

Danish Seaweed Network

- Aim is to promote production, application, communication and knowledge of seaweed and strengthen the national collaboration

- Sure that this network has already created new contacts, awareness of other projects, and future partners… and not least the industry, restaurants … etc.
- … and there will be more

Conclusion

- We are just at the beginning in DK
  - Production and Research wise
- Basic research needed
- Development of technology to reduce manpower
- The Dansih Seaweed Network will help