

#### Nordic Algae Symposium 2018 (NAS18)

# Innovations with disruptive impact ! in the microalgae sector

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# the world is changing

disruptive changes

shape the future

and

why this presentation ? what is the background ?

create opportunities

#### the framework



world largest taxi company owns no cars



world largest accommodation provider owns no Real Estate



largest phone company owns no telco infra



Alibaba.com Global trade starts here. world most valuable retailer has no inventory



facebook \_ largest and most popular media provider creates no content



world largest movie house owns no cinema



\_ the most valuable photo company sells no cameras



largest encyclopedia is updated by users

none of this existed 20 years ago !



#### LEDs Enzymes GMO

Membranes Hydrolysis

Microfarming

# the world is changing

• the **LED** revolution brought low-cost efficient and selective *light technologies* 

+ the availability of *low-cost renewable energy* sources available 24 hours per day

= a reduction in production costs for microalgae biomass in some specific unexpected locations such as Iceland.

#### **LIGHT 4 BIOMASS**

• the new low-cost lignocellulosic **enzymes** can be used to provide a new source of organic molecules for chemicals as *sugars* 

- + yeast *fermentation technologies* used
- + *heterotrophic microalgae* knowledge

= a new low-cost production platform for lipids, proteins and other specific chemicals FERMENTATION 4 VALUABLE BIOMASS

- the **GMO** stunning developments as CRISPR
- + availability of *microalgae genetic pool* information
- = tailor made microalgae cell factories for production and biorefinery

**CELL FACTORIES 4 BIOMASS** 

# the world is changing

advanced hydrolysis technologies with water, acids and enzymes
 microalgae / cyanobacteria biomass with high amino acid and mineral profile
 hydrolyzed biomass for agriculture as a valued option for organic farming
 BIOMASS 4 PRODUCT

cost effective membrane technologies for wastewater treatment
 + microalgae harvesting replacement of centrifugation and other technologies
 = clean and efficient microalgae harvesting with recycling potential
 MEMBRANES 4 SEPARATION

• micro-business as micro-breweries generated

a trend that it is possible to think locally and act locally in a cost-effective way

+ e-business with the possibility to sell locally and directly to the end user

= microalgae microfarming mostly *Spirulina* related business MICROFARMING 4 BUSINESS

### What? LEDs revolution and low-cost energy locations

low cost LED solutions (efficient and selective light sources)
+
location with water and low cost electrical energy

Actual photochemical efficiency
 Absorption spectrum









#### South Davis Sewer District, USA (2018) Largest indoor PBR in the world, volume 1.600 m<sup>3</sup>



with 400.000 LEDs supplied by Reliance Instruments



#### www.clearaswater.com

Waste water cleaning with tubular glass PBR\* reduced 10x more phosphate and 3x more nitrate than conventional systems.

\*) Demonstration PBR in Spokane, Washington in 2014 with 531 glass tubes, 381 glass bends, and 675 couplings from SCHOTT

Testimonial: SCHOTT glass tubing is preferred over UV-PVC tubing due to high, sustainable light transmission and easy, mechanical cleaning without scratches.

SCHOTT glass made of ideas



#### **GREATER YIELDS WITH VALOYA**

Successful plant production demands high quality light. Accelerate the growth and efficiency of your plant production with Valoya LED grow lights which have been optimised through more than 400 large scale research projects done in collaboration with Wageningen University, Max Planck Institute, Julius Kühn-Institut etc.

FOCUS ON QUALITY. EXPERTISE IN PHOTOBIOLOGY.

# Impact ?

#### • It is possible to grow microalgae cost-effectively in north Europe



### What ? Enzymes for ligno-cellulosic materials

Cellulose is *the most abundant organic molecule on the earth*, and a renewable and seemingly inexhaustible feedstock for the production of fuels and chemicals. Bacteria and fungi have evolved complex enzymatic systems enabling their growth on plant material rich in cellulose, but these organisms typically require weeks, months, or even years to decompose a fallen log or a tilled corn stalk.



For chemical or fuel production from these same materials, industry requires affordable chemical or enzymatic systems that can do the job in hours or in days. **Novozymes** has conducted research focused on improving the performance and reducing the cost of **fungal cellulases** for the conversion of dilute acid pre-treated **cellulosic materials to fermentable sugars.** 

A number of genes were transferred from different organisms creating a **super-cellulase** producing family of fungus capable of meeting industrial needs.

# **Impact ?** • countries with forest residues as in North of Europe can become large producers of sugars...

#### Accellerase® Biomass Enzymes to Unlock C5 & C6 Sugars

Accellerase® offers varoius enzyme mixtures for your specific configuration.

Our biomass enzyme solutions convert pretreated biomass into sugars for the production of renewable fuels and chemicals. When paired with a pretreatment, theses enzymes break down the chemical bonds in lignocellulosic material to produce C5 and C6 sugars that can be fermented to produce ethanol or processed to produce bioplastics or other high-value chemicals.

DuPont develops cellulase mixtures and accessory enzymes that fit the needs of your unique process



#### Cellulases

Endo- $\beta$ -1.4-glucanases, cellobiohydrolases,  $\beta$ -glucosidases Fungal cellulases *e.g. Trichoderma, Humicola, Acremonium* Bacterial cellulases *e.g. Clostridium thermocellum* 

#### Hemicellulases

Backbone degrading enzymes Enzymes removing the side groups β-xylosidases

#### Lignin modifying enzymes?

Laccases, peroxidases Enzymes hydrolyzing lignin-carbohydrate complexes?

#### Other helper enzymes/proteins?

Swollenin

#### Sugar from cellulose will be a reality with large scale production in North Europe

> Forest residues and wastes will become a major source for chemicals

### What ? GMO microalgae as cell factories for biorefinery



Yao et al, 2016 ACS Synthetic Biology, 5:207–212

#### Genetically engineered microbial strains including prototheca lipid pathway genes

WO 2013082186 A2

#### ABSTRACT

Genetically engineered microbial, e.g., Prototheca, cells provide microbial oil useful as a food additive and a source of renewable fuels and industrial chemicals.

DESCRIPTION (OCR text may contain errors)

GENETICALLY ENGINEERED MICROBIAL STRAINS INCLUDING PROTOTHECA Genetic engineering + Cell factory potential in microalgae + Maturity of microalgae fermentation + Biorefinery development

Publication number Publication type Application number Publication date Filing date Priority date ①	WO2013082186 A2 Application PCT/US2012/066893 Jun 6, 2013 Nov 28, 2012 Nov 28, 2011
Also published as	CA2857017A1, 6 More +
Inventors	Scott Franklin, 9 More =
Applicant	Solazyme, Inc., BHAT, Riyaz
Export Citation	BiBTeX, EndNote, RefMan
Patent Citations (13), No Classifications (17), Leg	in-Patent Citations (119), Referenced by (14), al Events (6)
External Links: Patents	cope, Espacenet

# Impact ?

• Microalgae are a platform for the expression of genes that enable the industrial production of a large range of food and feed ingredients or chemicals for a wide range of applications

## **TAKING FOOD FURTHER**

AlgaWise<sup>®</sup> Algae Oils are today's answer to a more sustainable, healthy tomorrow. Our innovative line of algae oils are designed to help tear down barriers to achieving meaningful, healthy food innovations.

#### WORKING BY YOUR SIDE TO CHANGE THE WAY THE WORLD EATS

The future belongs to those who step forward with profoundly simple ideas, back them with sound research and demonstrate the means and mettle to see them through to fruition. AlgaWise<sup>®</sup> Algae Oils is committed to creating innovations that will shape the future of food.

#### MICROALGAE. MACRO SOLUTIONS.

At the heart of our innovations lies microalgae, one of nature's first foods. AlgaWise<sup>®</sup> Algae Oils were created by TerraVia, the leading company in microalgae-derived solutions to the world's biggest problems.

#### www.corbion.com/algae-nortfolio

#### 50:50 Joint Venture Veramaris<sup>™</sup>



- DSM and Evonik to found a 50:50 joint venture to be named Veramaris<sup>™</sup>, headquartered in The Netherlands
- Joint venture for high value omega-3 fatty acid products rich in EPA and DHA for animal nutrition produced from natural marine algae
- Facility is scheduled to open in 2019
- · New facility will be built in the United States, at an existing site of Evonik
- Joint venture's capital expenditure in the facility will amount to around US\$ 200 million over the next 2 – 3 years
- Initial annual production capacity will meet roughly 15% of the total current annual demand for EPA and DHA by the salmon aquaculture industry
- Finalization of the joint venture is subject to regulatory approvals and other customary closing conditions

March 2017



1 kg of our EPA and DHA algal oil can replace 60 kg wild catch fish



What ? Hydrolyzed microalgae biomass for agriculture application

AGRIALGAE

pre-treated acid plus enzyme processing

+

biomass with diversified amino acid profile and mineral content

market demand for organic growth promoters for precision agriculture

this is a specific type of hydrolysis NOT for fuel



AlgaEnergy has developed a potent agricultural biostimulant based on extracts from different own cultured microalgae, named AgriAlgae®. It is a 100% natural product, which combining the benefits of a selection of microalgae strains, reaches high levels of all essential free L-amino acids, polysaccharides,

phytohormones, trace elements and antioxidants among others, forming the perfect complement to any application and crop variety.





# What ?

#### Membrane technologies for harvesting and recycling

20 years ago membrane technologies were innovative and very expensive > Wastewater treatment

> Desalination plants

#### + scale and the technological maturity > changed all !



#### Overview

Capacity: 624,000 m³/day (26,000 m³/hour) Technology: <u>Reverse Osmosis (RO)</u> Project Type: Build-Operate-Transfer (BOT) Location: Sorek, Israel Footprint: 100,000 m² (10 ha) Commission Date: 2013 The Sorek desalination plant sets significant new industry benchmarks in <u>desalination</u> technology, capacity and water cost. It provides clean, <u>potable water</u> for over 1.5 million people, comprising 20% of the <u>municipal water</u> demand in Israel, thus alleviating the country's potable water shortage while minimizing the impact on terrestrial and marine environments.







Jurong Membrane Bioreactor Plant Capacity: 68,000 m<sup>3</sup>/day



# Impact ?

Cost-effective membrane technologies are available for microalgae harvesting

> Recycling can be made in a effective way with a relevant contribution for sustainability and cost reduction



#### Important to have low-cost harvesting and recycling of culture media

Microalgae harvesting market is growing but still small...

http://liqoflux.com



#### LIQ FLUX The solution provider for the algae downstream processing

#### Algae Pre-Concentration Solution

We deliver the Algae Pre-Concentration Solution to harvest high volumes of algae cultures. The Capillary Algae Pre-Concentration System.

The first step in your algae harvesting process to pre-concentrate the algae culture.

#### Water Recycling Solution

We deliver the Water Recycling Solution to recycle clean water back to your algae production system. The Capillary Water Recycling System.

The necessary final step in your algae downstream process to make water recycling possible.







What ? Microalgae microfarming related business

#### Several phenomena created the environment such as microbreweries

#### FINANCIAL TIMES

Microbreweries shake up Europe's beer market



Microbusiness fashion

volunteer work < knowledge and experience growing Spirulina in Africa

- < independence < unemployment
- < internet sales < local market development > Veggie trend



# Impact ?

The microfarming started with *Spirulin*a but is **expanding to niche applications** as specialty feeds for aquaculture, for pets foods and for racing animals

#### Sustainable small business generate differentiated products

#### Growing microalgae as aquaculture feeds on twin-layers: A novel solid-state photobioreactor





Four strains of marine microalgae commonly used as live feeds in hatcheries (Isochrysis sp. T.ISO, Tetraselmis suecica, Phaeodactylum tricornutum, Nannochloropsis sp.) were grown in a novel solid-state photobioreactor, the twin-layer system. Microalgae were immobilized by self adhesion to vertically oriented twin-layer modules which consisted of two different types of ultrathin layers, a macroporous source layer (glass fiber...



#### Spirulina producers >



#### average:

400-4.000 m2 1 Kg / m2 / year

**120-150 €/kg** From producer to consumer















Brand based for local market / B2C Sun dried (=> less tast, less smell) Quality (and safety) Distribution (local market & B2C)

#### Spirulina "La Spirale Verte", the health food

Spirulina "The Green Spiral" is produced in Corsica in Linguizzetta, rural town of the eastern plain, on a protected site pollution sources. Grown in freshwater ponds which inorganic salts are added, Spirulina is harvested by filtration, pressed and dried at low temperature to keep all its nutritional qualities. Our artisanal production uses no pesticides or preservatives and is environmentally friendly. Production processes and packaging Spirulina Green Spiral adhere to the food safety management standards (ISO 22000), of ENVIROMENTAL management (ISO 14001) and quality management (ISO 9001).

Spirulina "La Spirale Verte." Glitter 100gr pack. 100% dry spirulina flake. Packaged in aluminized pouch sealed and resealable after opening.

#### **15 € the 100 g pack.**

Green Spiral. Pierre Etienne LD Peragnolo, Bravone - 20230 LINGUIZZETTA -06 18 58 46 91 - pep@laspiraleverte.com La Spirale Verte. Pierre Etienne LD Peragnolo, Bravone - 20230 LINGUIZZETTA – 06 18 58 46 91 - pep@laspiraleverte.com



### Impact:

specific innovations with disruptive impact ! in the microalgae biotech sector

- product related
- process related

# LEDs Enzymes GMO Membranes Hydrolysis Microfarming

#### The microalgae composition





#### what else ?

#### **THE APPLICATIONS FRAMEWORK**



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and

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Thank you !

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