

Commercial Production of Spirulina

Cyanotech

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Cyanotech

- **Specializing in Microalgae Technology**
- **Operating since 1984**
- **100 Employees**
- **GMP Certified by NPA**
- **Non-GMO, environmentally friendly products**
- **Public Company:
NASDAQ:CYAN**



Keahole Point, Hawaii

Cyanotech's Production Facility



- 90 acre facility in Kona, Hawaii.
- Consistent sun and temperature year-round
- Separate production facilities for *Spirulina* and *Haematococcus*
- Major Spirulina production capacity
- Astaxanthin production is consistent and growing to meet market demand

Spirulina-High Nutritional Value

- **60% Protein**
- **Rich in carotenoids**
 - **Beta Carotene**
 - **Zeaxanthin**
- **Phycocyanin**
 - **Liver and Kidney protection**
- **Immune stimulating compounds**
- **Antiviral compounds**

Microalgae Production In Kona, Hawaii

- **Ideal Climate**
 - Warm year round
 - High solar insolation
 - Low rain fall
 - Unique resource
 - Cold deep seawater
- **High Costs**
 - Land Clearing (hard lava)
 - \$85,000/Acre
 - CO₂
 - \$440/ton
 - Power
 - \$0.37/Kwh

Spirulina Production



- **40 Culture ponds**
- **Average size
30,000 sq. ft.**
- **Culture media
150,000 gal**
- **Total area
29 acres**



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Spirulina Culture Ponds

- Lined with Reinforced Plastic
- Paddle Wheel Agitation
- Cost per 30,000 ft² Pond
 - Land Leveling \$56,800
 - Lining \$22,000
 - Agitation \$24,900
 - Piping \$15,100
 - Total \$118,800

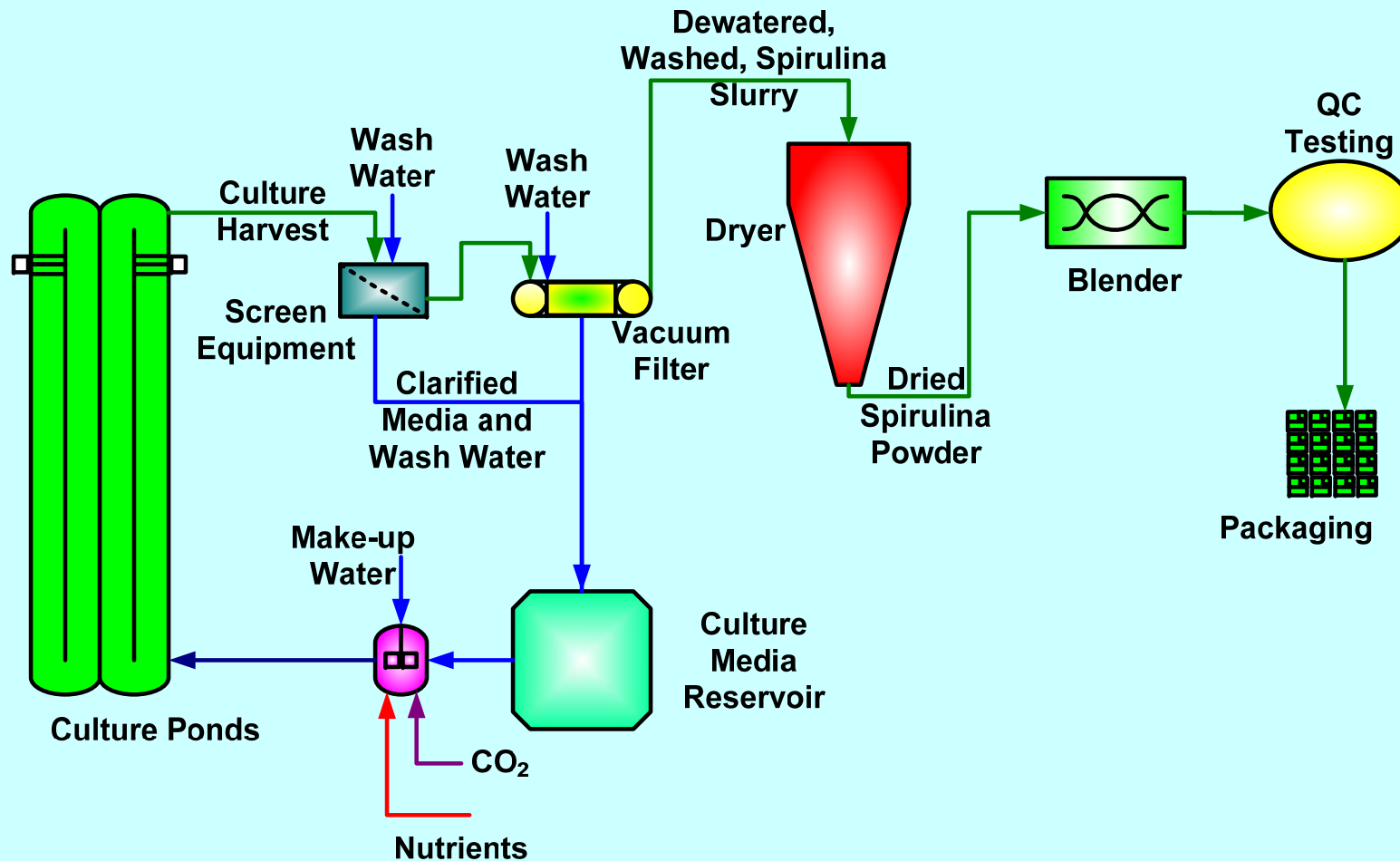
Spirulina Typical Growth Media

<u>Item</u>	<u>Grams/Liter .</u>
NaHCO₃	16.0
NaNO₃	2.5
NaCl	1.0
K₂SO₄	1.0
K₂HPO₄	0.5
MgSO₄·7H₂O	0.2
FeSO₄·7H₂O	0.01
Na-EDTA	2.5
Trace minerals	

Highly Alkaline Growth Media

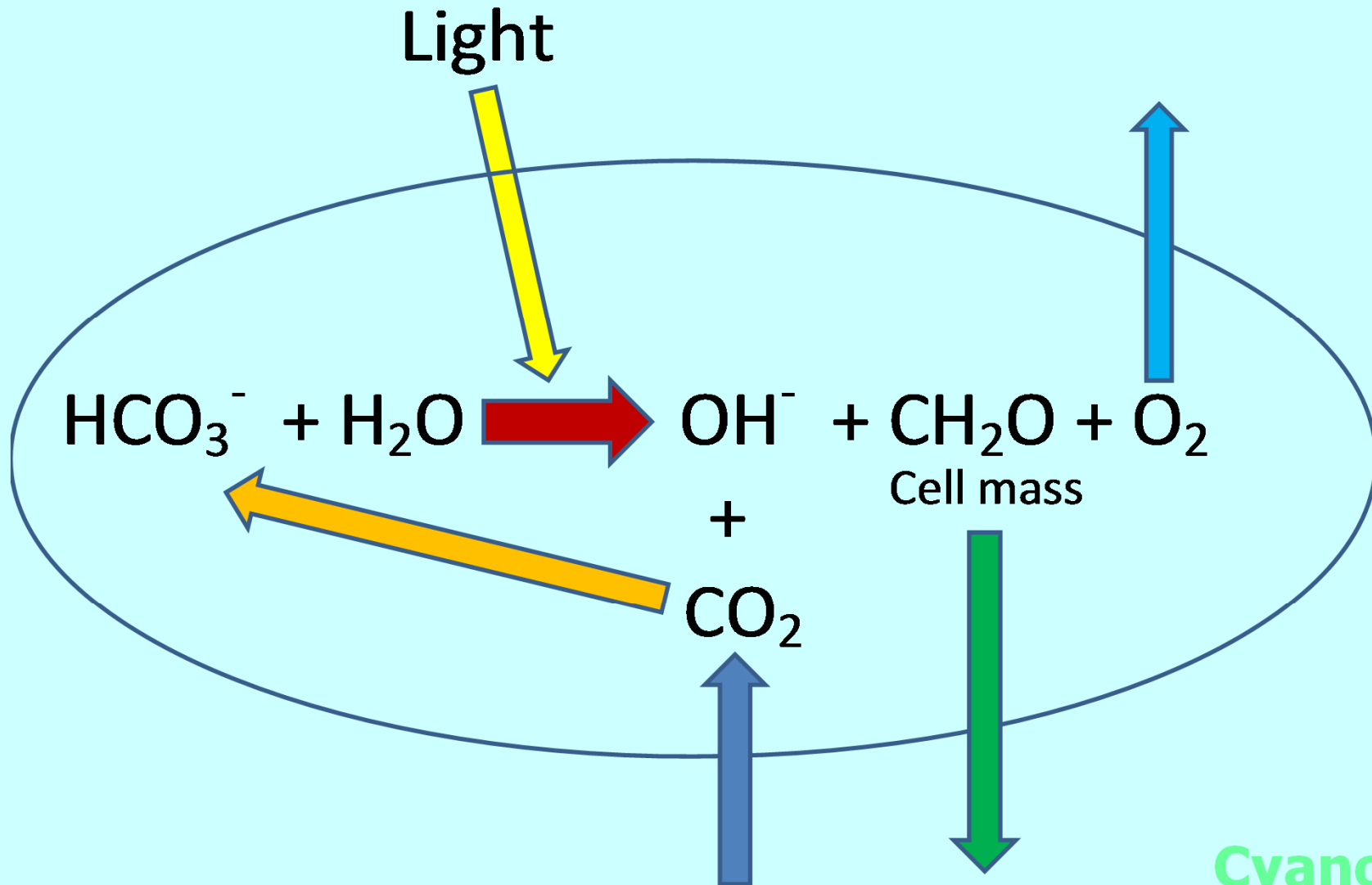
- **Operation Necessities**
 - **Recycle growth media**
 - **Each 30,000 ft² ponds contains \$7,500 sodium bicarbonate (\$330,000 on farm)**
- **Operation Opportunities**
 - **Reduced or no culture contamination**
 - **Carbon dioxide recovery**

Spirulina Production Flow Chart

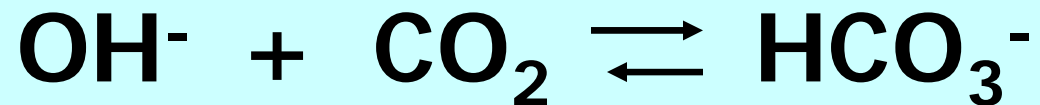


Simplified Bicarbonate Cycle in Spirulina Cultivation

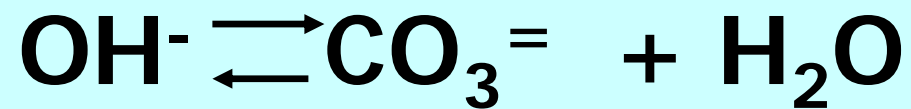
Light and carbon dioxide go in. Photosynthesis produces cell mass, oxygen, and hydroxide. Oxygen and cell mass come out. Bicarbonate is regenerated from carbon dioxide and hydroxide.



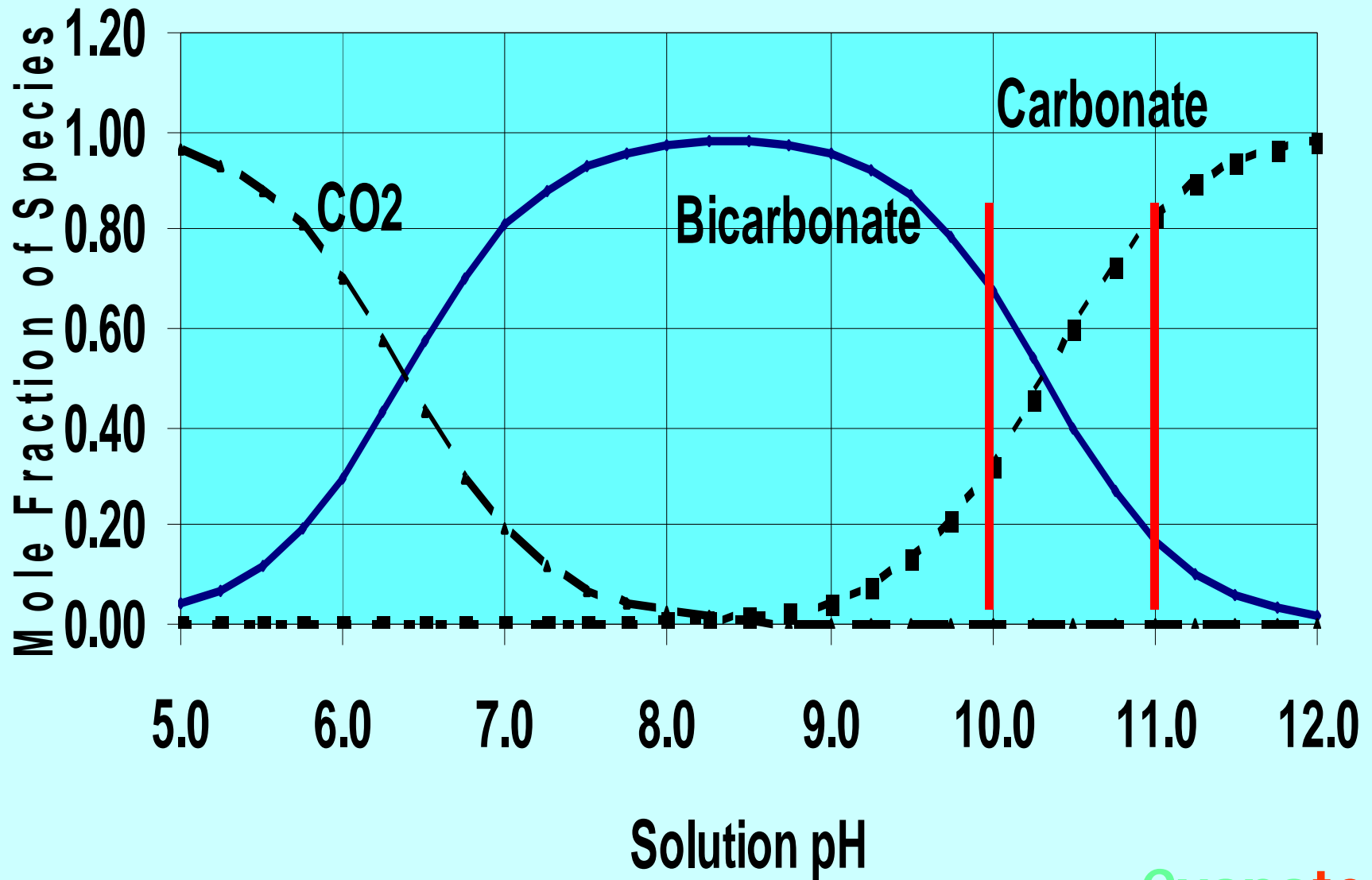
$\text{CO}_2 / \text{HCO}_3^- / \text{CO}_3^{=} \text{ Equilibrium}$



+



CO₂/Bicarb/Carbonate Equilibrium

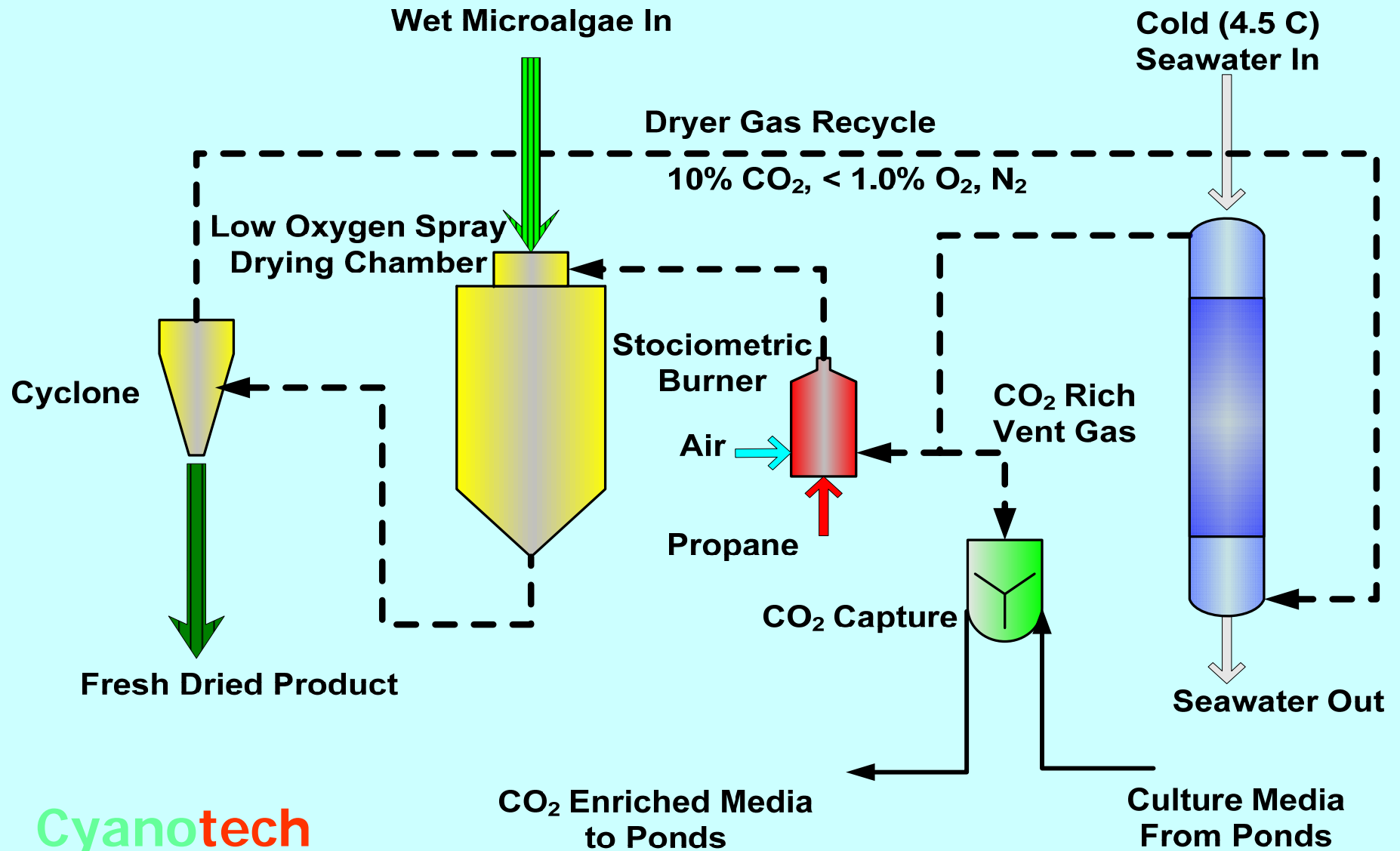


Highly Alkaline Growth Media

- At pH 10.5 40% of C is HCO_3^-
- At pH 10.0 68% of C is HCO_3^-
- At 16 g/l of NaHCO_3 :
 - A pH decrease from 10.5 to 10 absorbs sufficient CO_2 (carbon) to produce 1.3 g dry wt/l cells ($\text{CO}_2 + \text{OH}^- \rightarrow \text{HCO}_3^-$)
- All carbon can be absorbed in media for a complete growth cycle. (at pond injection is not required)

Ocean-Chill Spray Drying

Low Oxygen with CO₂ Recovery



Ocean-Chill Spray Drying

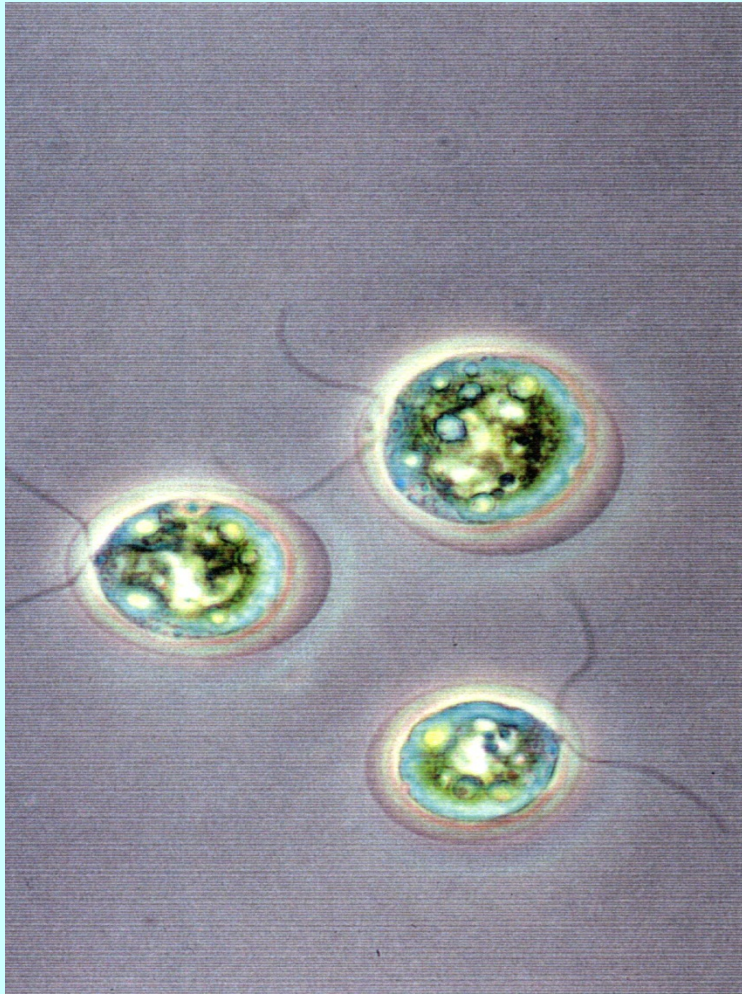
- **Low Oxygen environment**
 - protects sensitive nutrients
 - Beta carotene, Zeaxanthin, Phycocyanin
- **Cold Deep Seawater Cost Effective**
 - 4.5 °C seawater--US\$0.21 per 1000 gallons
 - Electric power for identical cooling—US\$ 5.60
- **Carbon dioxide recovery reduces costs**

Haematococcus (Astaxanthin) Production

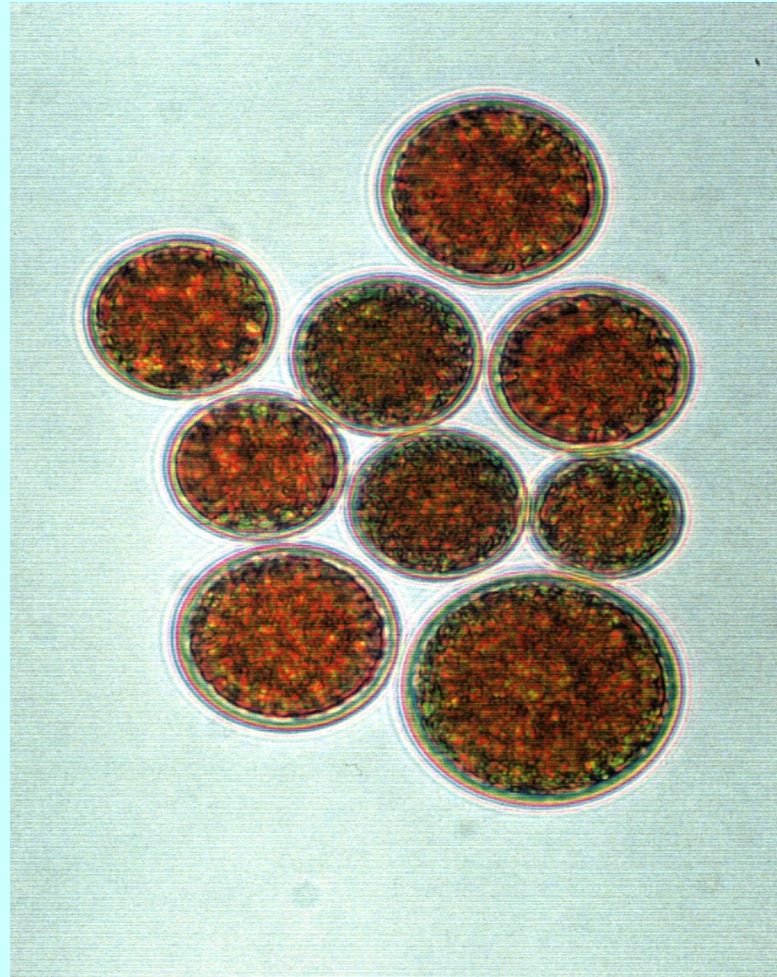


- 28 Culture ponds
- Average size
28,000 sq ft
- Total area
18 acres

Haematococcus Cells



Motile, green
Haematococcus
cells



Encysted cells produce massive
amounts of astaxanthin (400x
magnification)

Productions of Haematococcus

- Two Stage System
 - Closed Culture
 - Outdoor Open Culture
- All cultures scaled up from 200 ml lab shake flasks
 - 20 liter
 - 400 liter
 - 30,000 liter
 - 500,000 liter reddening ponds
- Haematococcus spores cracked and dried
- Production 10 times more difficult than Spirulina!

Productions of Haematococcus

- Dried, cracked biomass currently sent offsite for extraction
 - Supercritical CO₂ extraction
 - New Jersey
 - New Zealand
 - Bringing Supercritical CO₂ extraction on site
 - 1,000 bar (15,000 psi) system
 - Operational April 2016
 - Will generate 60,000 kg/yr of extracted biomass

Productions of Haematococcus

- Extracted Haematococcus Biomass (60,000 kg/yr)
 - 35 % Protein
 - 52 % Carbohydrates
 - 2.6 % Fat
 - 7% Ash
 - 370 calories/100 grams
- Successfully tested in shrimp and fish feeds
 - Detailed analysis available
 - Samples available
 - Biomass available April 2015

Extracted Haematococcus Biomass



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