

Microalgae Production of Biodiesel

**Ihab H. Farag, Sc.D., P.E.
Chemical Engineering Dept
University of New Hampshire
Durham, NH 03824-3591, USA
Phone: 1-603-862-2313,
fax: 1-603-862-3747
email: ihab.farag@unh.edu**

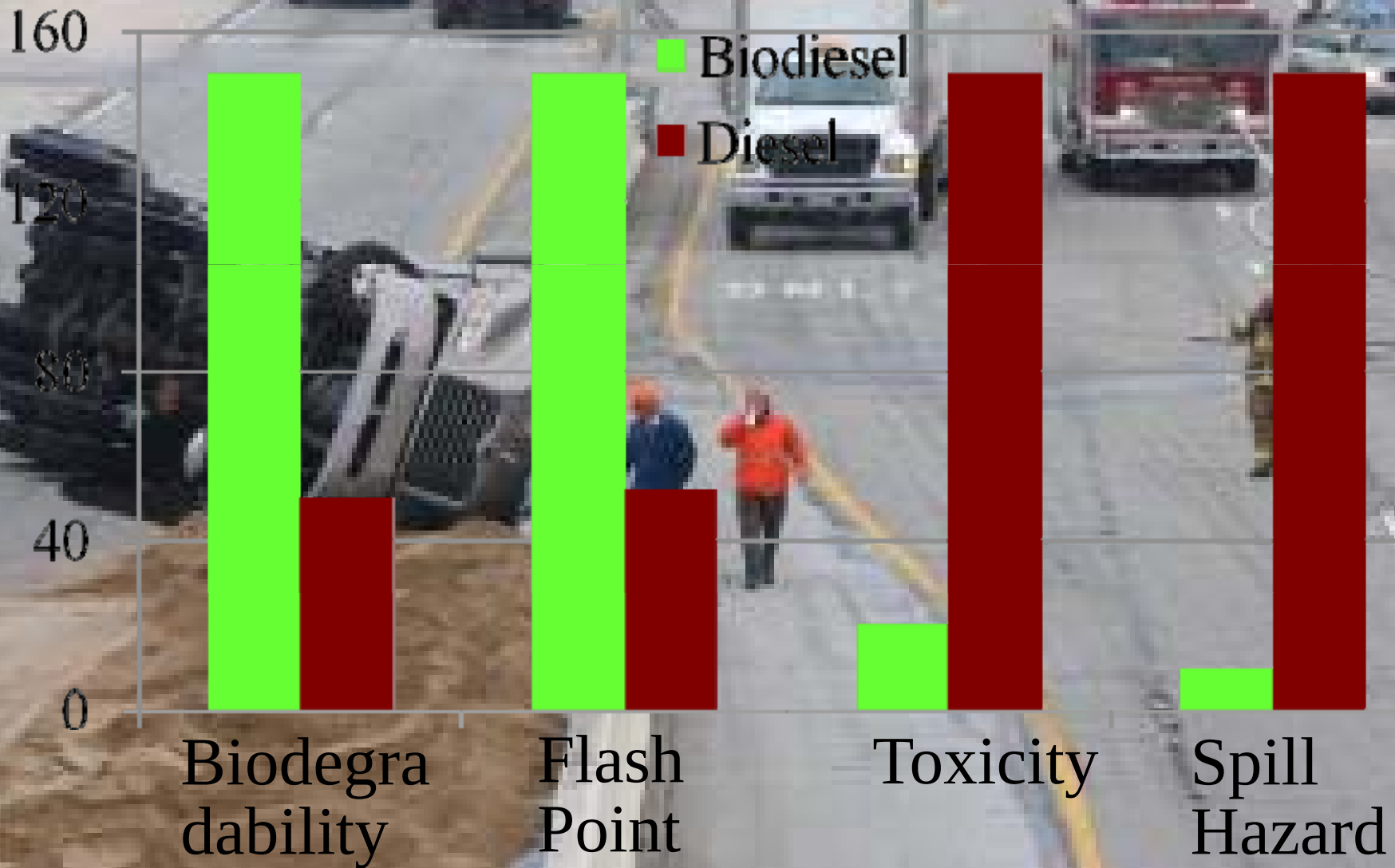
**Algae & Energy in the Northeast, Advancing knowledge,
research and innovation, University of Vermont, Davis
Center, Burlington, VT, March 17- 18, 2010**

Overview

- **Biodiesel Advantages & Challenges**
- **Algae Importance**
- **Algal Growing & Harvesting**
- **Algae Oil Extraction**
- **Large Scale production**
- **Other areas of research**



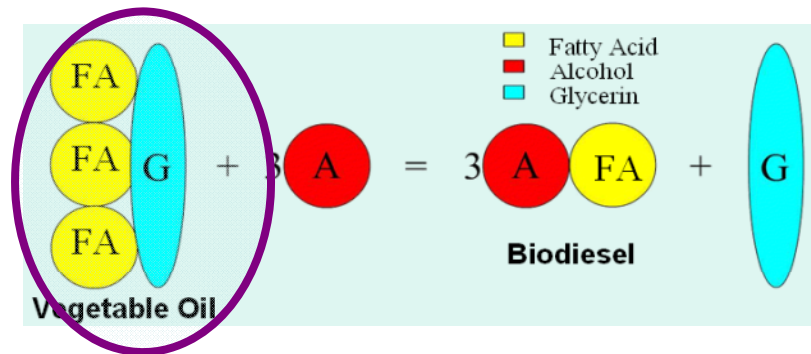
Relative Hazards: Diesel and Biodiesel



Biodiesel Challenges

- **Cold Weather Operation**
- **Stability/Storage**
- **Producing enough feedstock oil to replace a large portion of petroleum**

Oil & Biodiesel yield of Soybeans & Canola



Soybeans



Canola

Gallons
biodiesel/acre

50

92

Acres/million
gallons BD

~24,000

~14,000

Tortilla Protests

Last Updated: Thursday, 1 February 2007, 01:56 GMT

 E-mail this to a friend

 Printable version

Mexicans stage tortilla protest

Tens of thousands of people have marched through Mexico City in a protest against the rising price of tortillas.

The price of the flat corn bread, the main source of calories for many poor Mexicans, recently rose by over 400%.

President Felipe Calderon has said the government will clamp down on hoarding and speculation to ease the problem.

But some blame the rise on demand for corn to make environmentally-friendly biofuels in the United States.



A peasant protests in Mexico City at the rising price of corn. Photograph: Luis Acosta/AFP



Mexicans are angry at the rise in price of their staple food

Pasta Demonstrations Italy



July 11, 2007

[Print](#) | [E-Mail](#) | [Feedback](#) | [Share](#)

SPAGHETTI SHOCK IN ITALY

Font:

Biofuels Boom Results in Pricey Pasta

Italian pasta makers say bad harvests and competition from biofuel manufacturers have led to a durum disaster. Consumers will be paying for it by summer's end.



REUTERS 

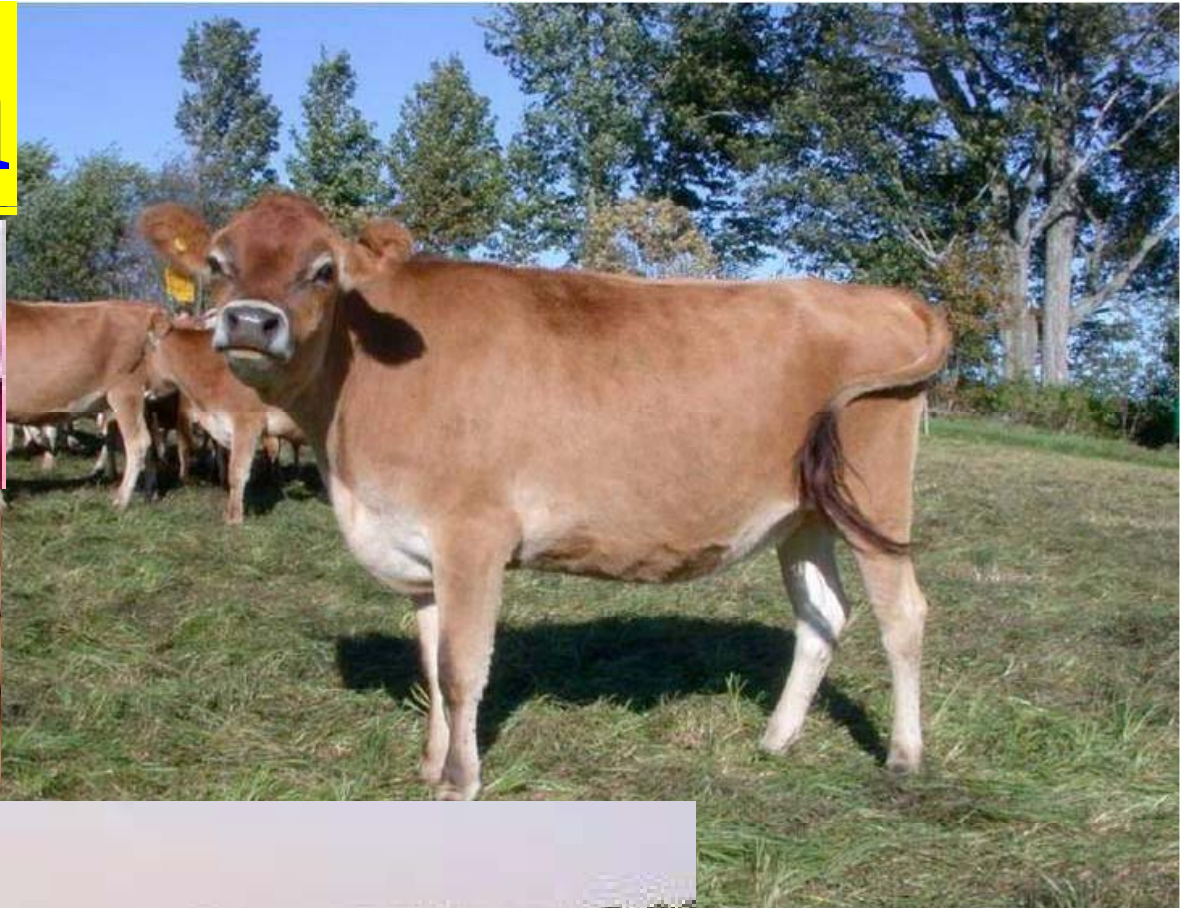
Pasta prices are going up. And it's not just the truffles.

Mamma mia! The price of a plate of pasta is expected to rise 20 percent this summer as a bad wheat harvest and increasing competition from biofuel manufacturers send the price of delicate, delicious durum wheat skyrocketing.

Italian consumers, accustomed to paying 70 euro cents (\$1) for a pack of the good stuff -- half the cost of a cup of coffee -- will be the first to feel the pinch, but the Italian Pasta Manufacturer's Association will be passing the costs on to export customers as well.

"Pasta producers have tried, with growing difficulty that has now become no longer sustainable, to absorb the high cost differentials," the Association announced last week. "But this situation cannot go on any longer in the face of the dynamics of the durum wheat market."

Dilemma

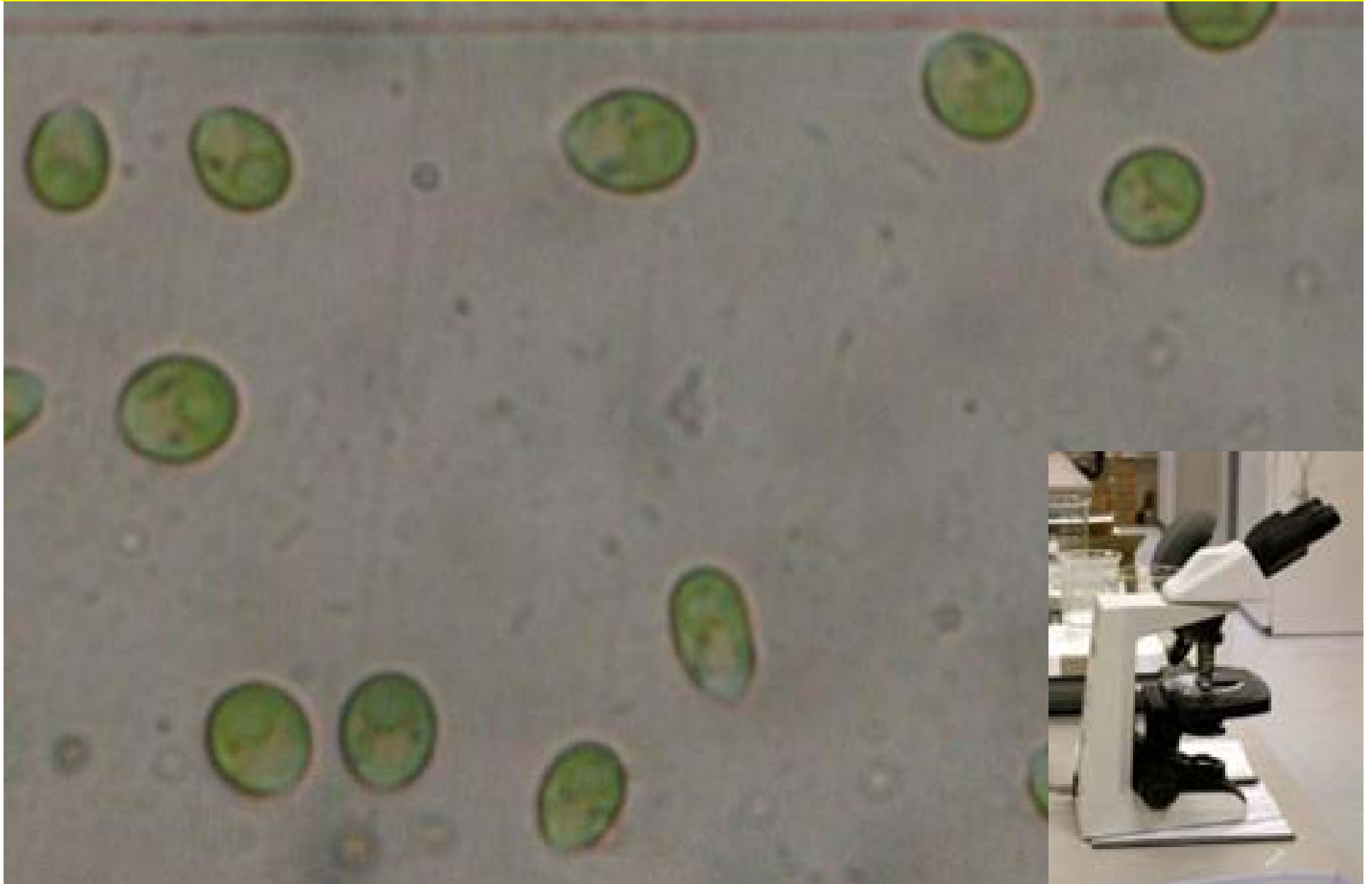


United Nations Environmental Program

- The global rush for energy crops threatens to bring food shortages and increase poverty.



The New Frontier

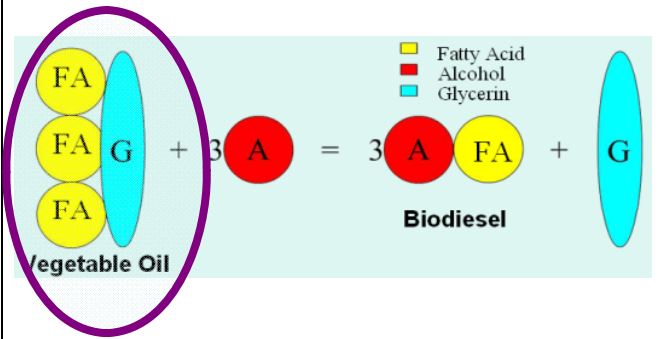


What is Algae?

- Simple plant-like organism
 - Simple: no leaves, no roots, etc
 - Plant-like: photosynthesis
- Fast Growth, e.g., Chlorella quadruples approximately every 24 hours

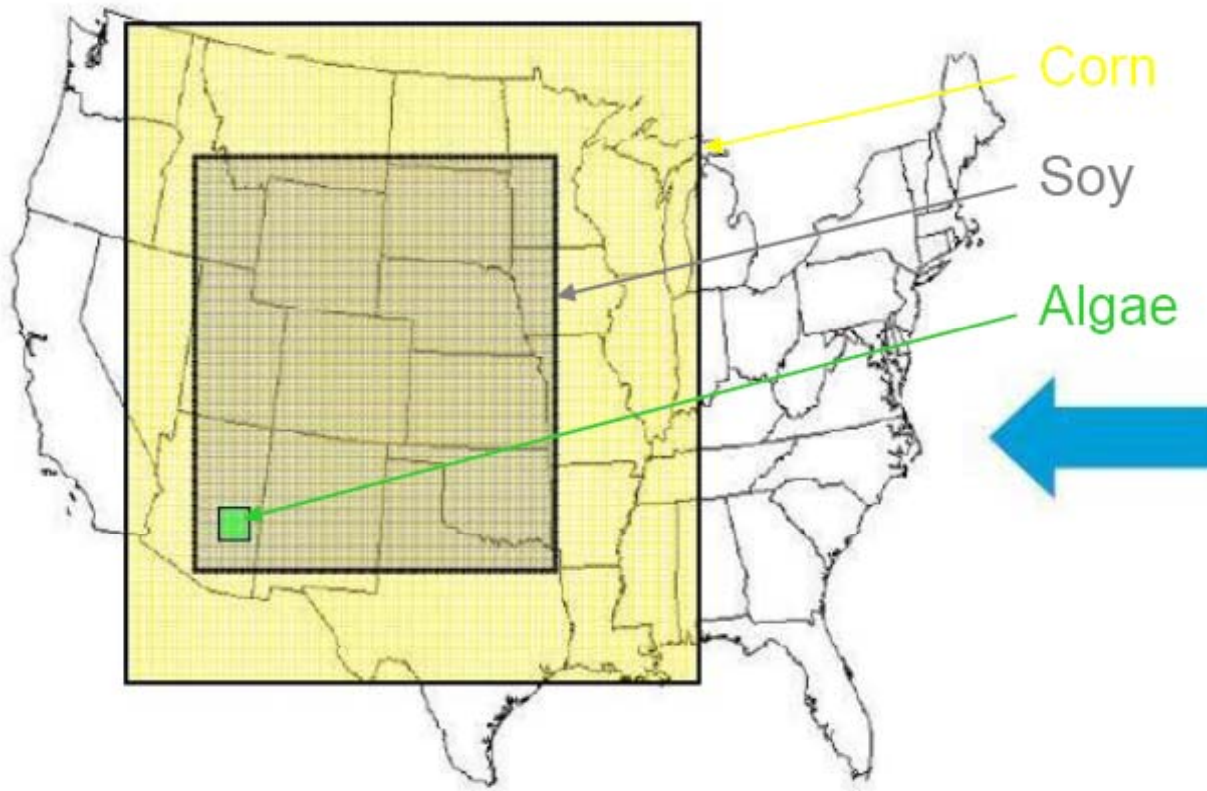


Oil & Biodiesel yield of Soybeans, Canola & Algae

	 Soybean	 Canola	 Algae
Gallons biodiesel/acre	50	90	2000- 15000
Acres/million gallons BD	~24,000	~14,000	~130

<http://www.pioneer.com/usa/agronomy/soybeans/biodiesel.htm>, 60 billion gal biodiesel = 8 million acres

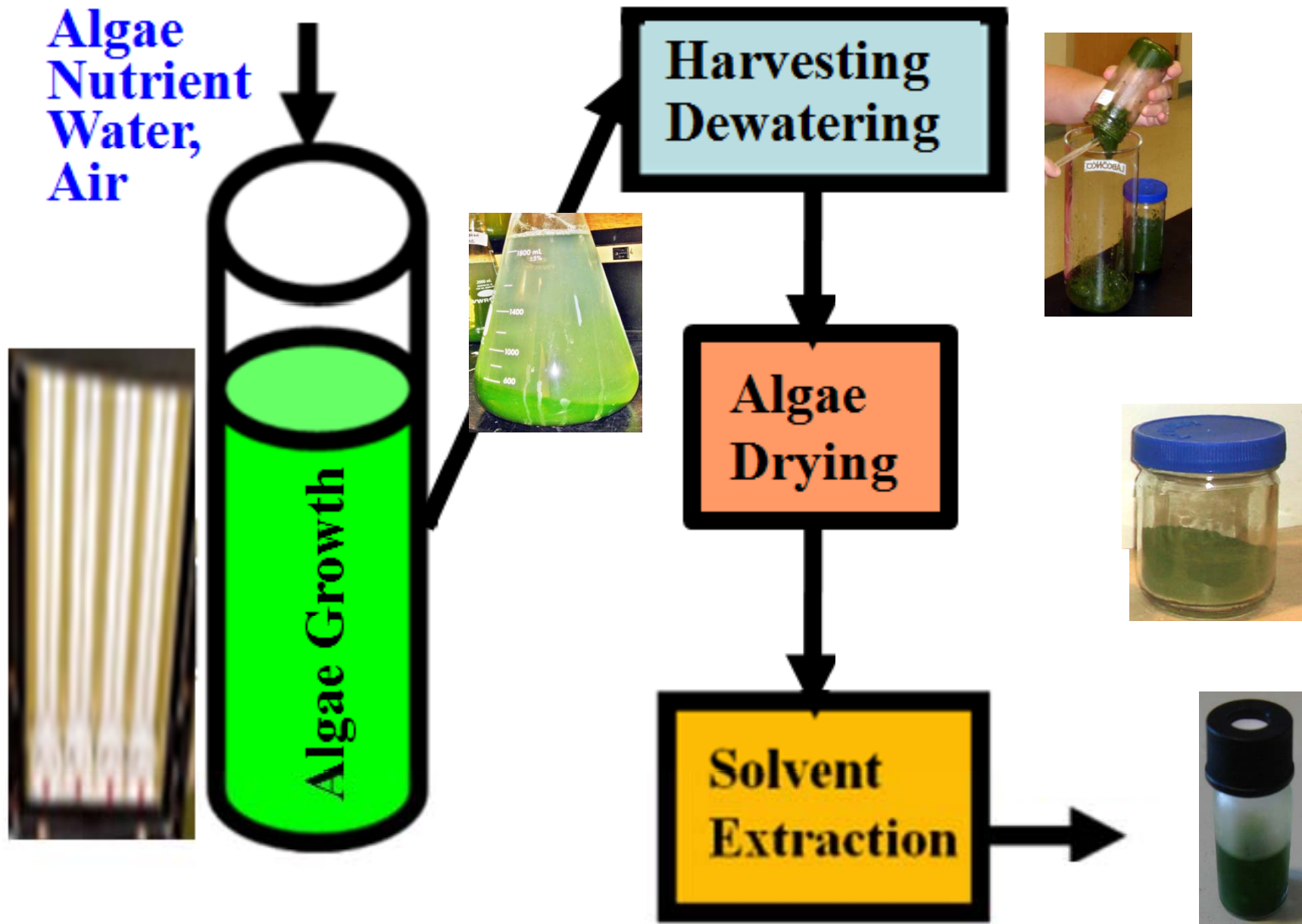
The Algae Promise?



Land
Required to
replace 50%
of current US
Diesel use
using corn,
soybean and
algae



The Algae Growth Process

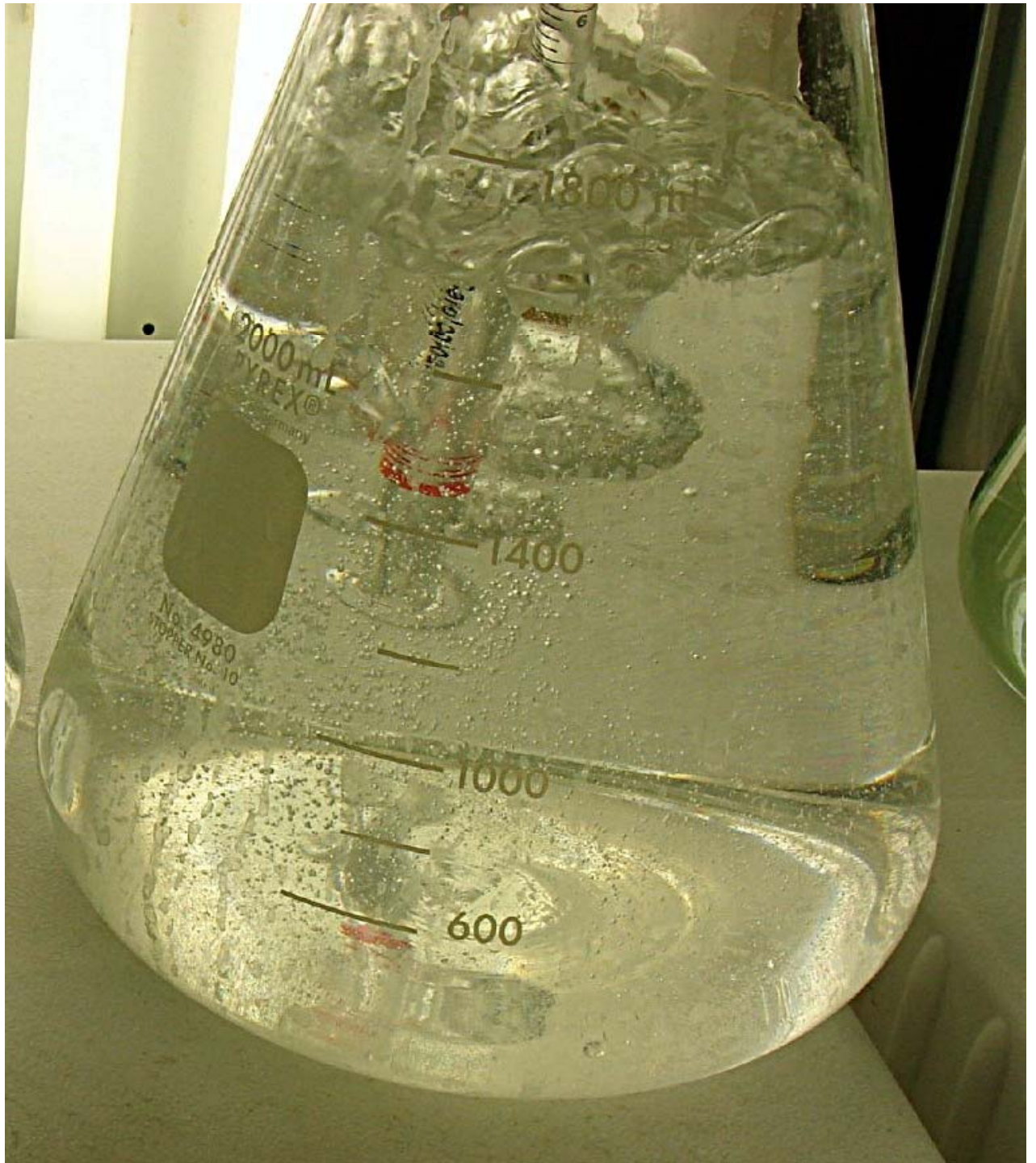


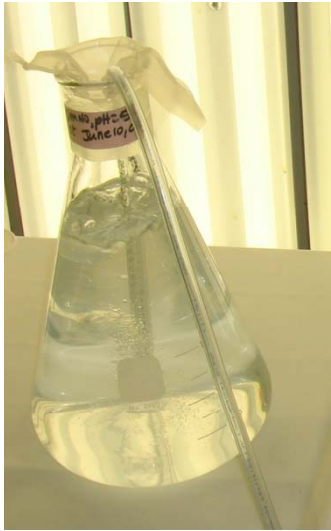
Growing Algae

- **Light Energy**
- **Water**
- **Nutrient: N, P, K**
- **Aeration: CO₂**
- **pH 6-9**
- **Mixing**
- **Temperature**



Role of Air: CO₂, Mixing, Temp





Day 0



Day 1



Day 3



Day 6



Day 7



Day 12



Day 11



Day 10

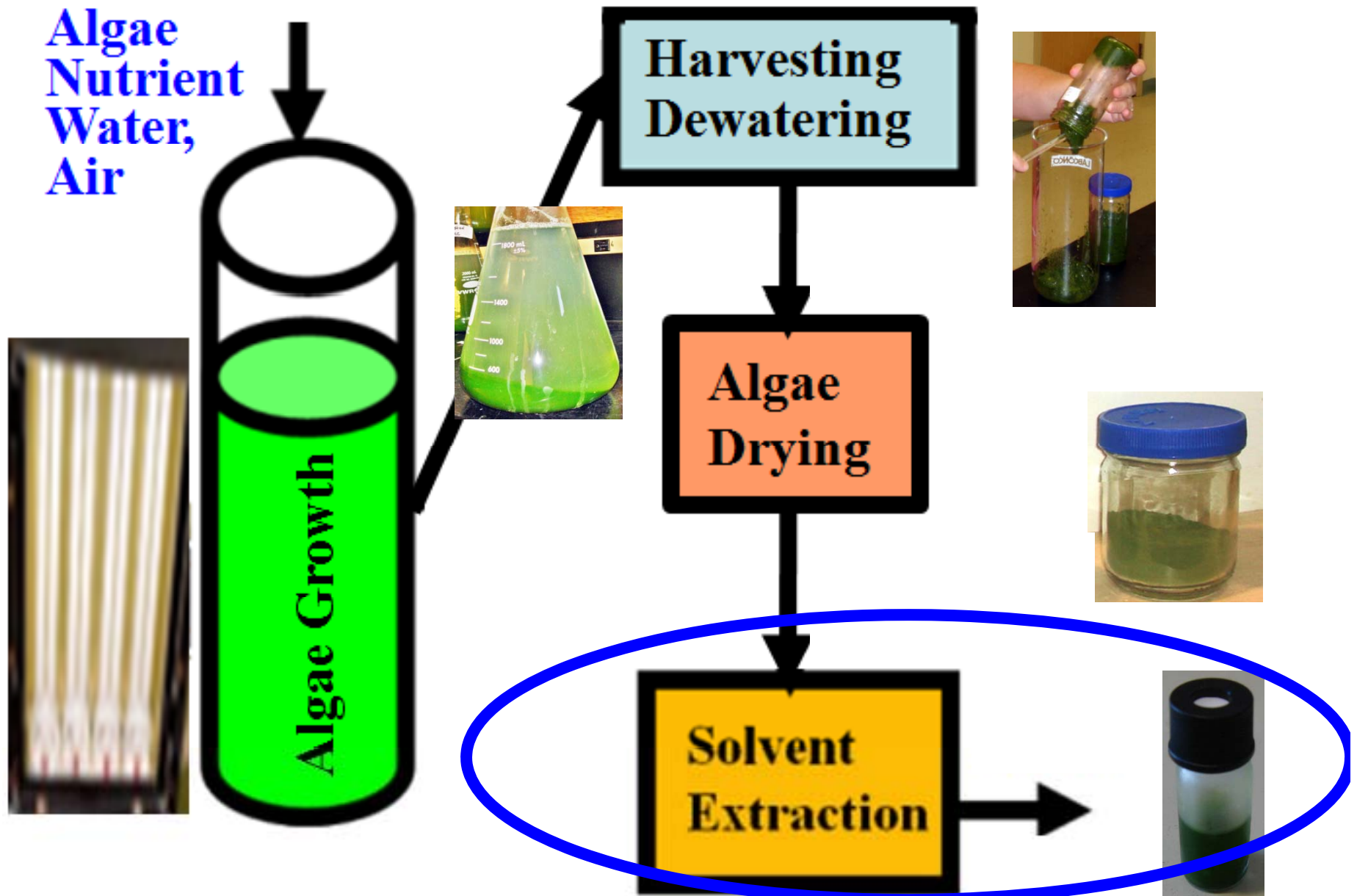


Day 8

**Growing
Algae**

Foaming, evaporation

The Algae Growth Process



Algae Oil Extraction Challenges

Lysing: to break down algae cells to release oil.

Challenges:

- Algae cell walls are difficult to break down.
- Mechanical methods are energy-intensive.
- Commonly used chemical solvents are toxic and require special handling



Algae Oil Extraction Methods

Conventional methods:

Oil expeller/press

Solvent extraction

Supercritical fluid extraction

Recent Methods:

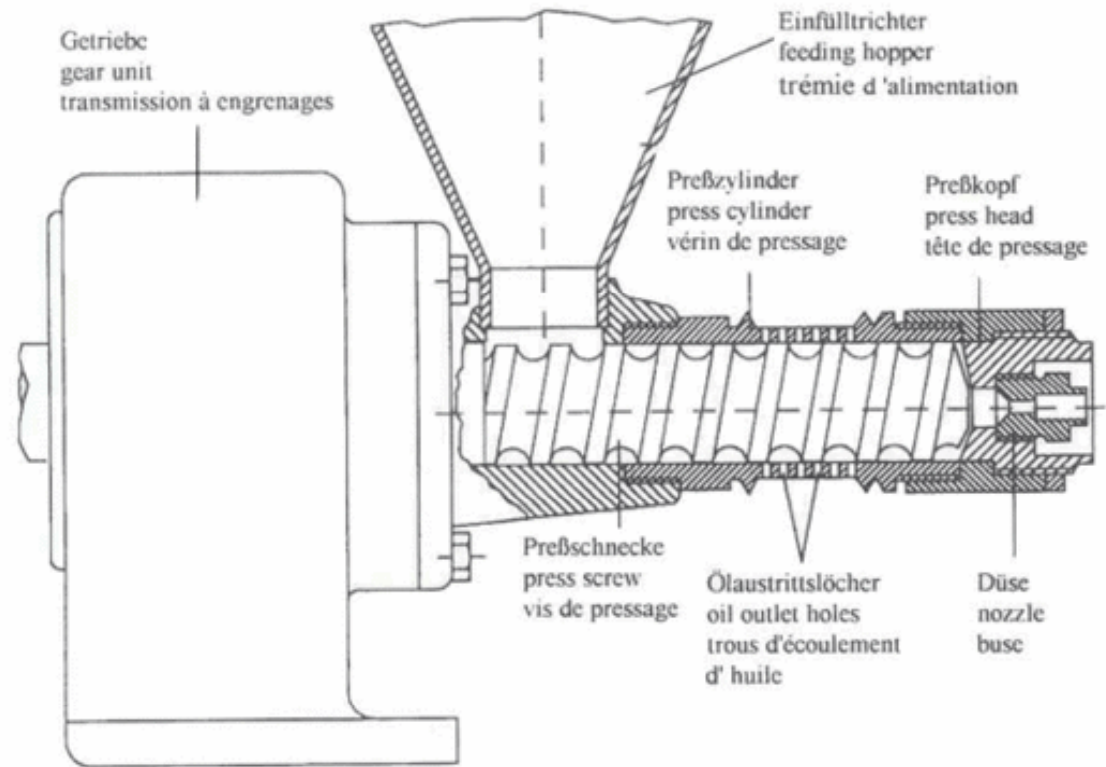
Enzymatic extraction

Osmotic shock

Ultrasound assisted extraction

Algae Oil Extraction Methods: Oil Expeller/Press

- Uses high Mechanical Pressure
- Recovers 70-75%
- Palm Oil extraction cost \$0.50/kg



<http://www.instructables.com/files/deriv/FHN/XUD4/F54HMG7B/FHNXUD4F54HMG7B.MEDIUM.gif>

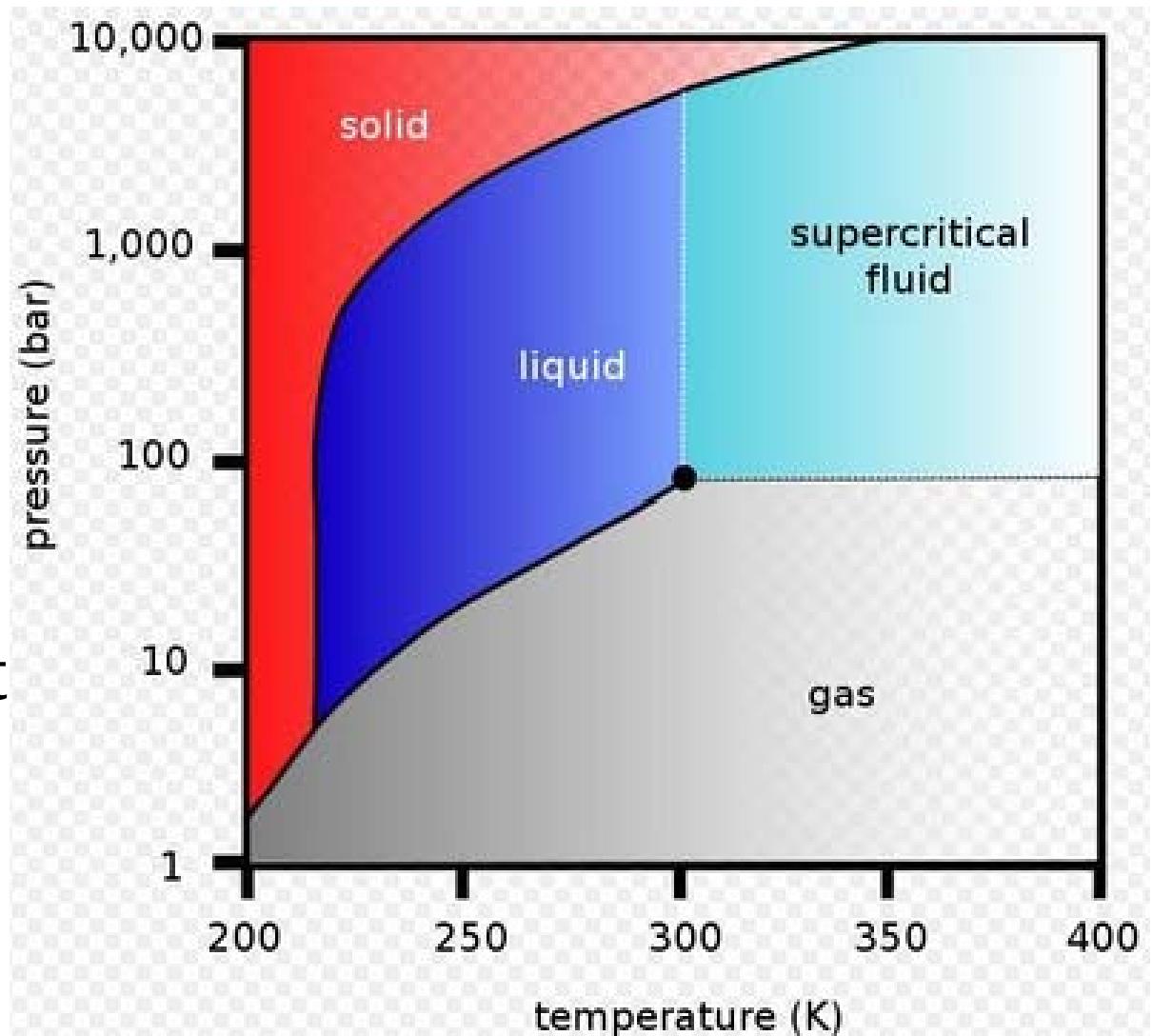
Algae Oil Extraction Methods: Solvent Extraction

- **Most common solvent is Hexane**
- **95% recovery**
- **Disadvantages:**
 - **Toxicity**
 - **Explosion... \$**



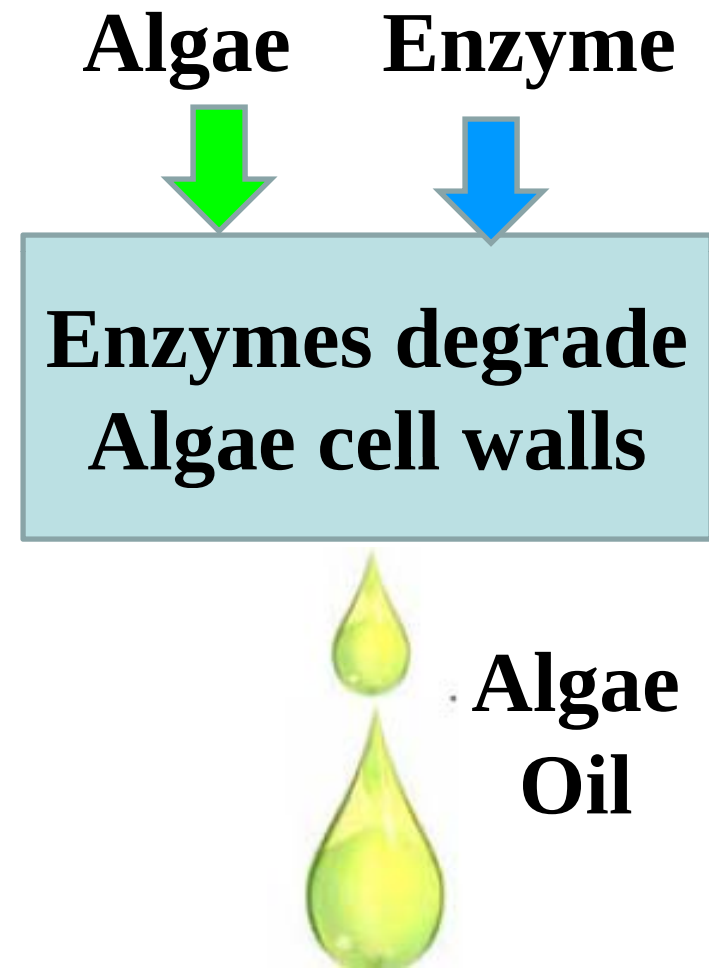
Algae Oil Extraction Methods: Supercritical Extraction

- CO₂ is liquefied under pressure and heated to the point that it becomes supercritical allowing it to act as a solvent
- Extracts almost 100%
- Special equipment for containment and pressure



Algae Oil Extraction Methods: Enzymatic Extraction

- Enzymes degrade the cell walls with water acting as the solvent.
- Costs are estimated to be much greater than hexane extraction.



Algae Oil Extraction Methods: Ultrasonic Cavitation Mixing

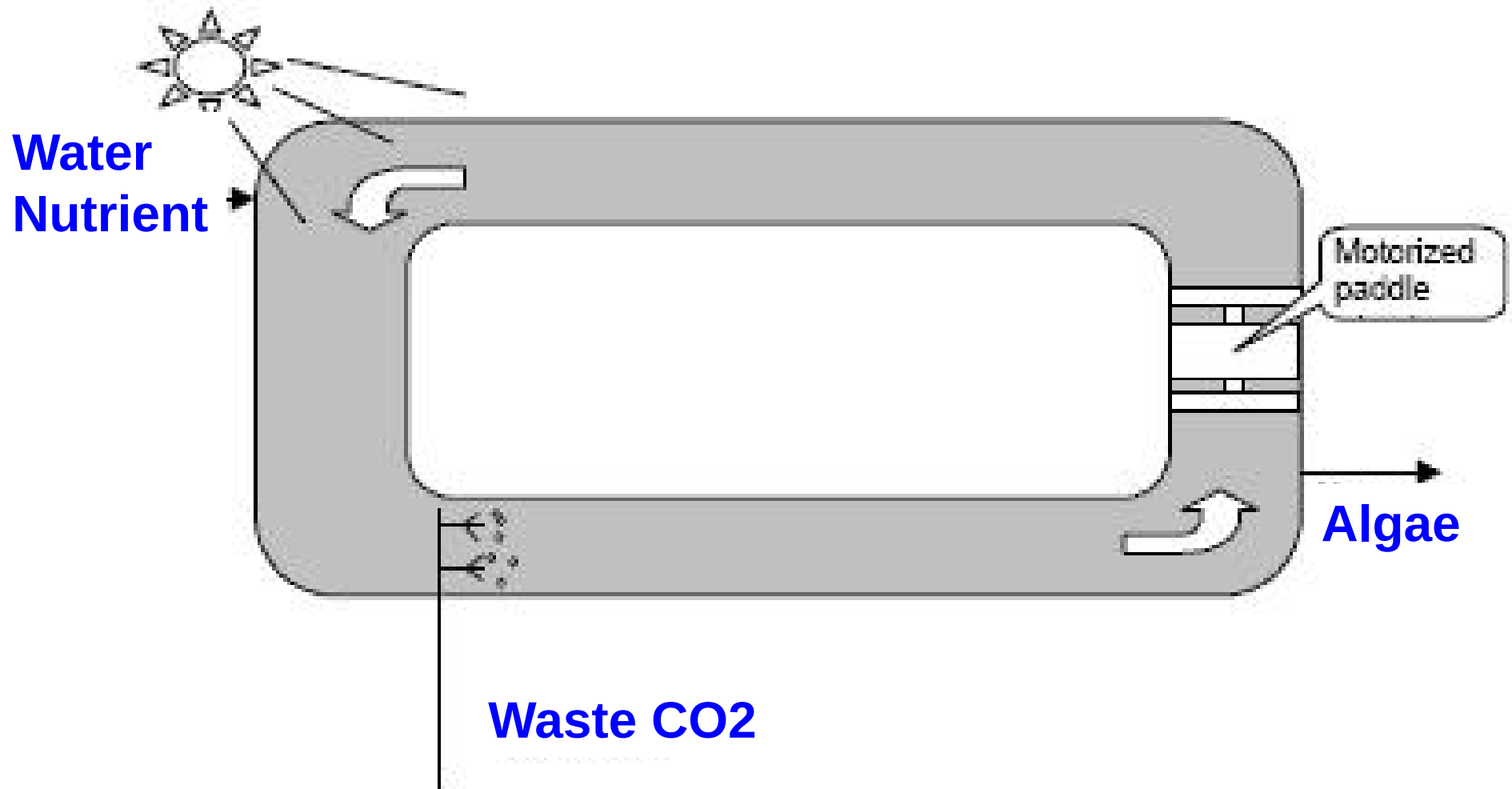
- **Ultrasonication helps to break down the algae cell structure and expose more of the oil for extraction.**
- **Solvent diffuses to the cell structure and transfer the lipids from the cell into the solvent.**



Algae Oil Extraction: Cost

- Algae Oil extraction is one of the more costly processes which determines the sustainability of algae-based biodiesel.
- Breakthroughs are anticipated to effectively extract oil from algae.

Large Scale Algae Growth: Raceway Ponds



Raceway Ponds Problems

- **Takeover by low oil strains**
- **Vulnerability to Temperature Fluctuations**
- **High Evaporation Losses**
- **Sunlight can only penetrate the pond water to a limited depth.**
- **Hard to control light exposure**
- **Minimum Depth about 15 cm**

Algae Growth: 80 L Photobioreactor



UNH Biodiesel Lab

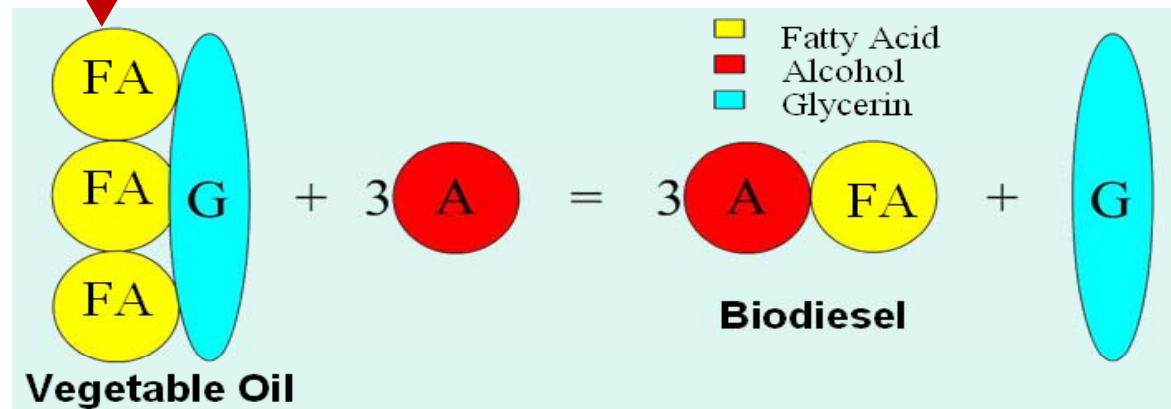
Algae Oil to Biodiesel



Oil Extraction



Transesterification



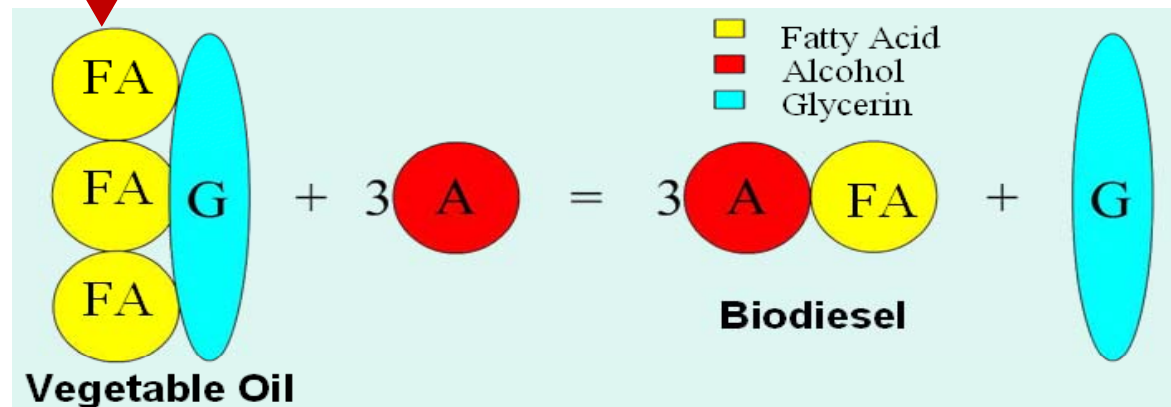
Algal Biodiesel Energy Balance



Oil Extraction



Transesterification



Algal Biodiesel Energy Balance

Energy Input

Mixing of Culture

Temperature Control

Supply Nutrient

Harvesting

Dewatering

Oil Extraction

Transesterification

Transportation, others

Energy Output

Algal Oil or

Biodiesel

Left Over meal

**Energy
Output >?
Energy
Input**

Water more precious than Oil. Fact

**“Two out of every three
people in the world will be
facing water shortages by
2025...**

**Global Conflict will
inevitably result... “**

- United Nations

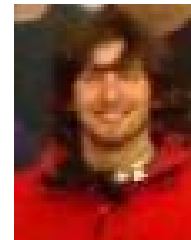
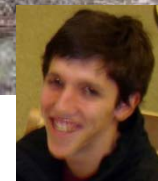
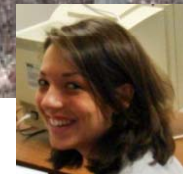


Non-Fresh (Impaired) Water use in Algae

- Municipal Wastewater
- Agriculture Wastewater
- Brakish Water
- Geothermal water & heat

Algae Farming in Wastewater

- **Environmental Benefit: Using Nutrient Rich wastewater**



Biodiesel from Algae

- **Environmental Benefit: Using Sea water**



<http://www.coping.org/travels/leaf/nhsea/sea21.jpg>

http://www.americaheartland.org/episodes/episode_422/really_going_green.htm

Stories

[HOME](#) | [STORIES](#) | [RECIPES & TIPS](#) | [SCHEDULE](#) | [EDUCATION](#) | [BLOG](#) | [ABOUT THE SHOW](#) | [AG IN YOUR STATE](#) | [SHOP](#)

Episode 422



SHARE

Really Going Green [Watch Video](#)

You might not recognize these super heroes of tomorrow. Found in unlikely places like this bio-diesel lab at the University of New Hampshire. They forsake traditional mask and cape; they might be disguised by a lab coat and safety goggles or simply a passion to save planet earth. But these superheroes are working to rehabilitate scum and slime. Not the human variety, but algae! Converting that green goo into energy for the future! Chemical Engineering student, Danah Hashem says, "I feel this is extremely important. The political ramifications, the financial ramifications, the environmental ramifications are huge in reducing our usage, our dependency on oil as an energy source."

One way to reduce that dependency is with bio fuels made from renewable plant material, like corn whose sugars are distilled into ethanol. Or soy, whose oils are made into bio-diesel. Danah adds, "This is just one of the many ways that I think we can slowly begin to branch out and utilize our environment more, and utilize the resources that the earth provides for us."

Going green has gone really green, as in this single celled scum of a plant. Good old algae, filled with oil, called "lipids"; meaning it is also filled with huge potential. Chemical Engineering student,

Summary

- **Algae is a promising alternative feedstock for Biodiesel Production**
- **Algae Oil extraction is a key factor of having viable Algal biodiesel**
- **Developing cost-effective techniques for oil extraction is very important**

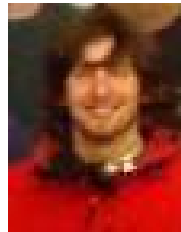
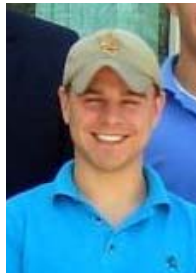
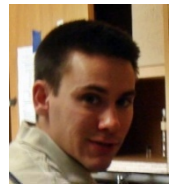
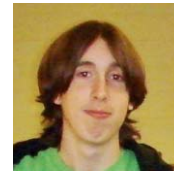
Recap

- **Biodiesel Advantages & Challenges**
- **Algae Importance**
- **Algal Growing & Harvesting**
- **Algae Oil Extraction**
- **Large Scale production**
- **Other areas of research**



Acknowledgment

➤ **Members of the Biodiesel Group at UNH**



**Thank you
for your time.**

