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### Extraction of products from algae using green solvents

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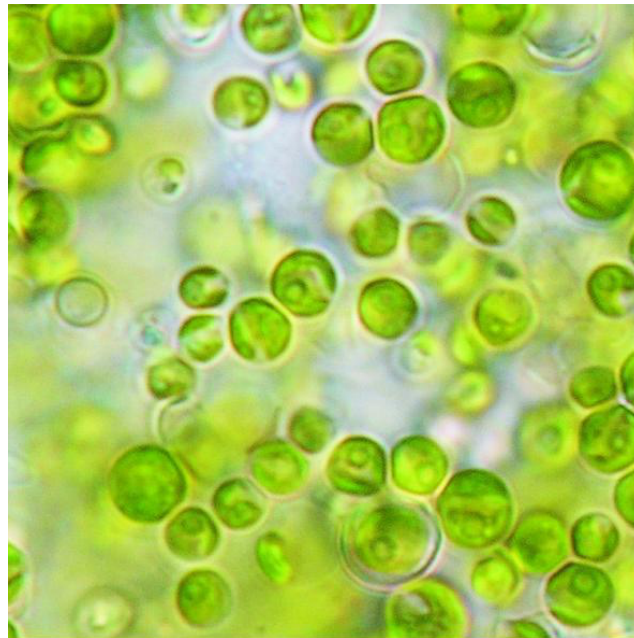
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# **Extraction of Products from Algae using Green Solvents**

**Roland Lee, Pascale Champagne and Philip G. Jessop**

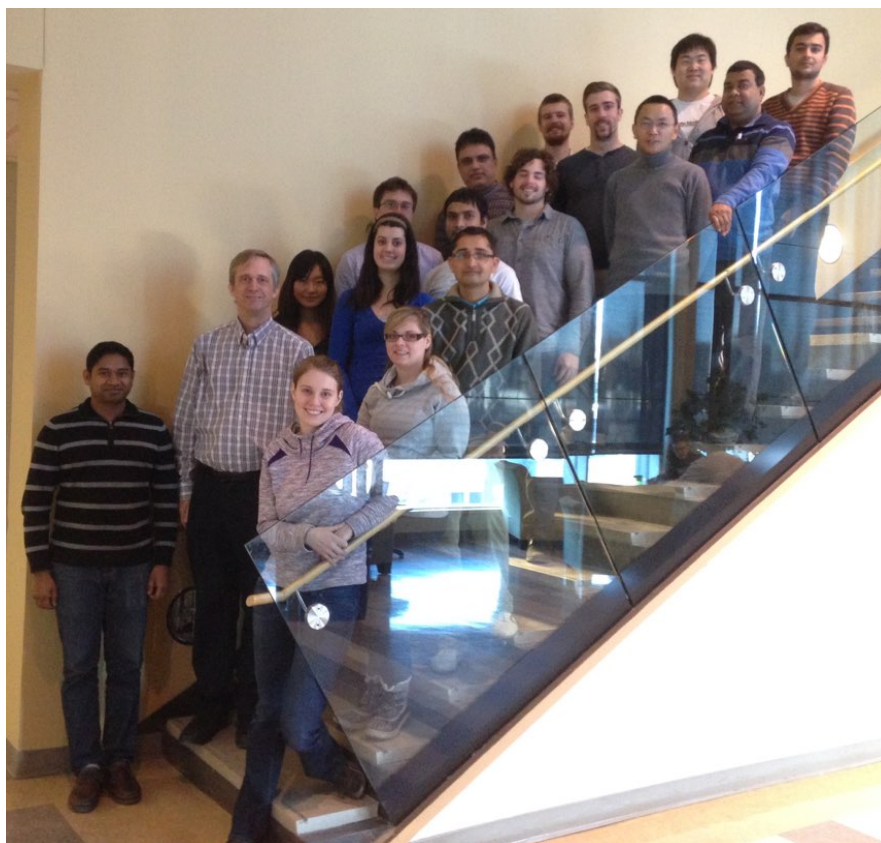
**Departments of Chemistry and Civil Engineering  
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## Recent Grad Students

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Todd Allward  
Trisha Ang  
Troy Arthur  
Marie Barnes  
Kyle Boniface  
Alaina Boyd  
Darrell Dean  
Tamara deWinter  
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Catherine O'Neill  
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Aliyah Shamrani  
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Jesse Vanderveen



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Dr. Ryan Dykeman  
Dr. Dongbao Fu  
Dr. Kazem Ghozati  
Dr. Keith Huynh  
Dr. Bhanu Mudrabovina  
Dr. Roland Lee  
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Dr. Xin Su  
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## Recent Collaborators

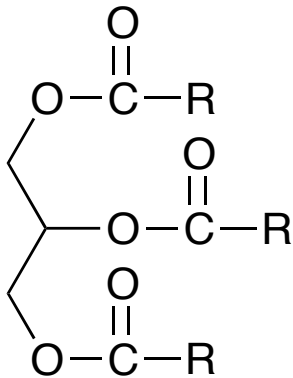
Dr. P. Champagne (Queen's)  
Dr. M. Cunningham (Queen's)  
Dr. Paul Dyson (EPFL)  
Dr. Luc Patiny (EPFL)  
Dr. R. S. Brown (Queen's)  
Dr. P. V. Hodson (Queen's)  
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Dr. G. Liu (Queen's)  
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Dr. D. Kuehne (Chevron)  
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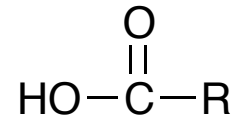
Canada Research Chairs Program  
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Queen's University  
Switchable Solutions Inc.

# MICROALGAE

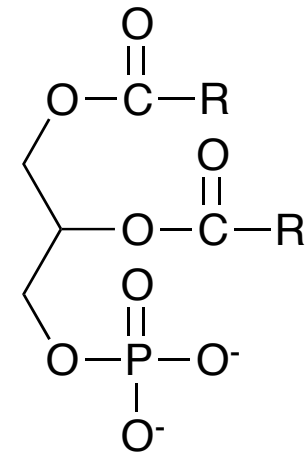
- High lipid content
- Robust
- Non-competitive (food v. fuel)
- Fast growth
- Minimal land use



Triacylglycerides (TAG)  
Diacylglycerides (DAG)  
Monoacylglycerides (MAG)

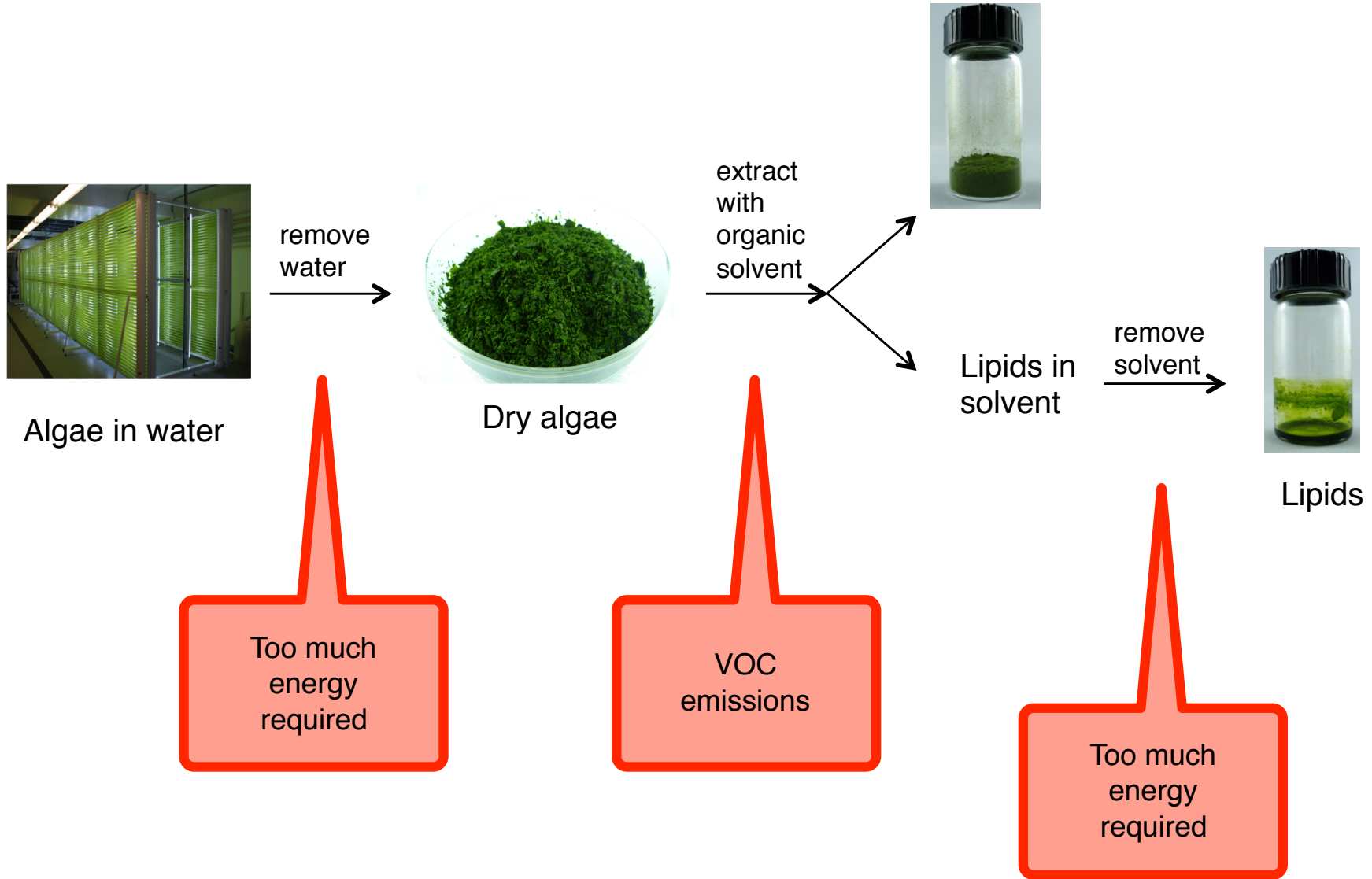


Free fatty acids (FF)

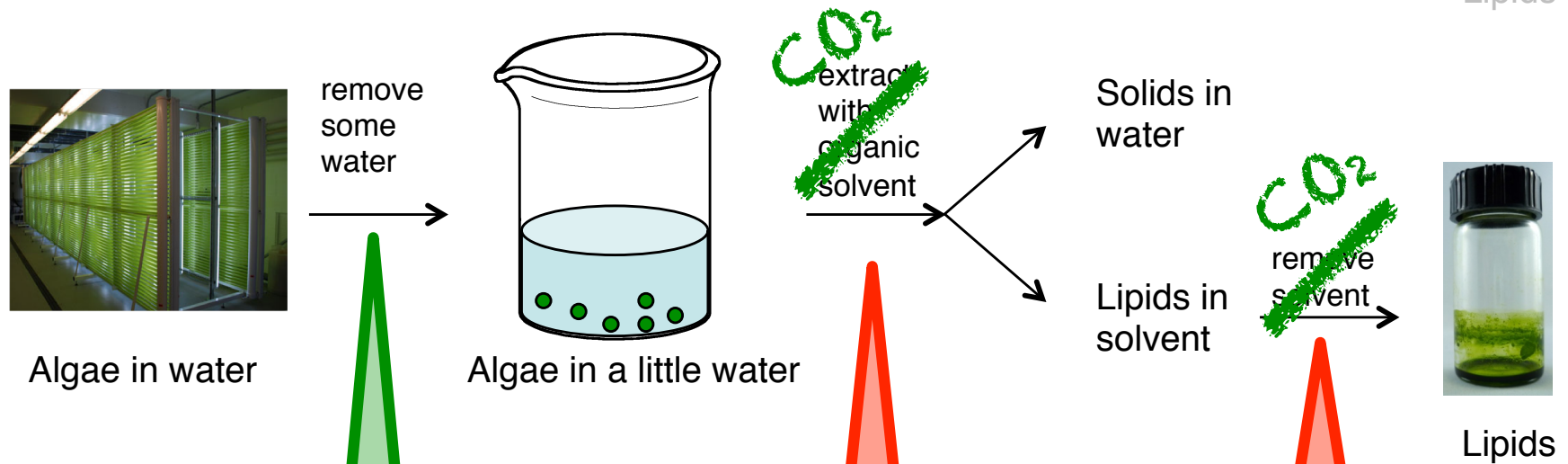


Polar lipids

# LIPID EXTRACTION STRATEGY #1: EXTRACT FROM *DRIED ALGAE*



# LIPID EXTRACTION STRATEGY #2: EXTRACT FROM *WET ALGAE*



Less energy required

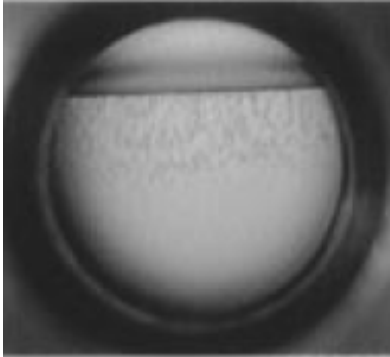
~~VOC emissions & solvent loss to water~~

Too much energy required

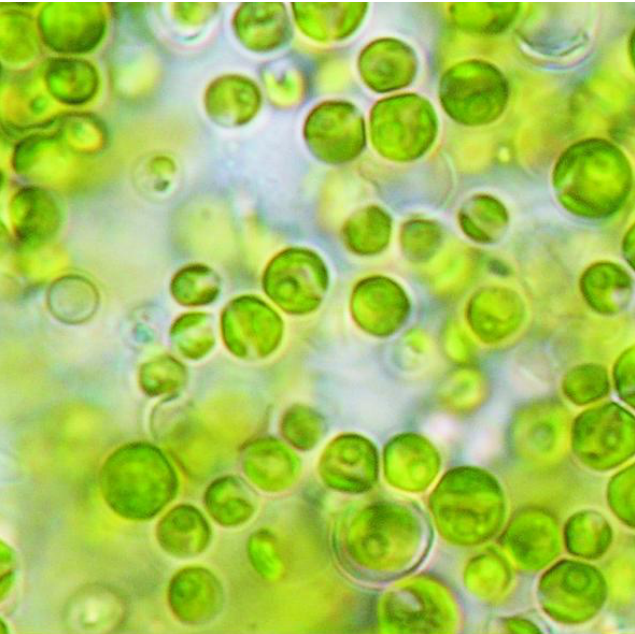
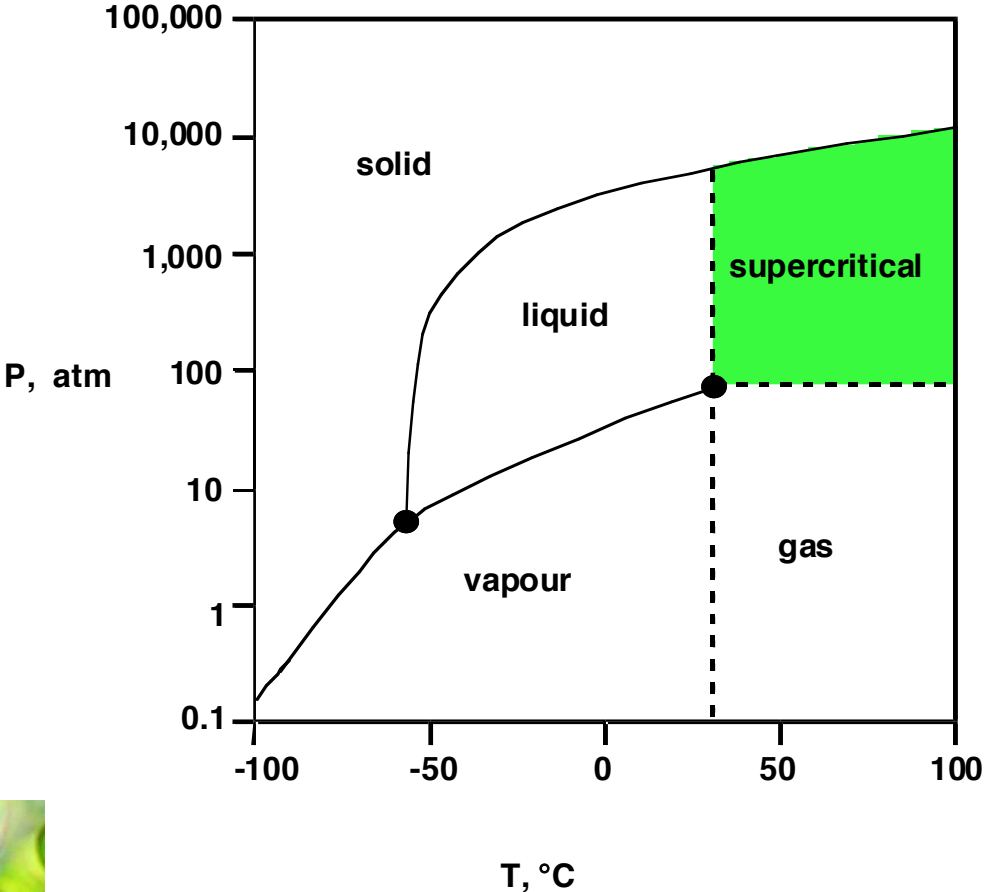
# MICROALGAE EXTRACTION SOLVENTS

Solvent	Advantage	Disadvantage
chloroform/methanol (Bligh & Dyer)	<ul style="list-style-type: none"><li>• high yield</li></ul>	<ul style="list-style-type: none"><li>• chlorinated</li><li>• flammable</li><li>• polar lipids extracted</li></ul>
supercritical CO <sub>2</sub> (Zimmerman)	<ul style="list-style-type: none"><li>• easily removed</li><li>• not flammable</li><li>• selective for nonpolar lipids</li></ul>	<ul style="list-style-type: none"><li>• high pressure</li></ul>
switchable-polarity solvents (Samori)	<ul style="list-style-type: none"><li>• easily removed</li><li>• not flammable</li></ul>	<ul style="list-style-type: none"><li>• must be dry</li></ul>
switchable-hydrophilicity solvents (Jessop)	<ul style="list-style-type: none"><li>• easily removed</li><li>• not flammable</li></ul>	<ul style="list-style-type: none"><li>• poor separation</li></ul>

# LIQUID CO<sub>2</sub>



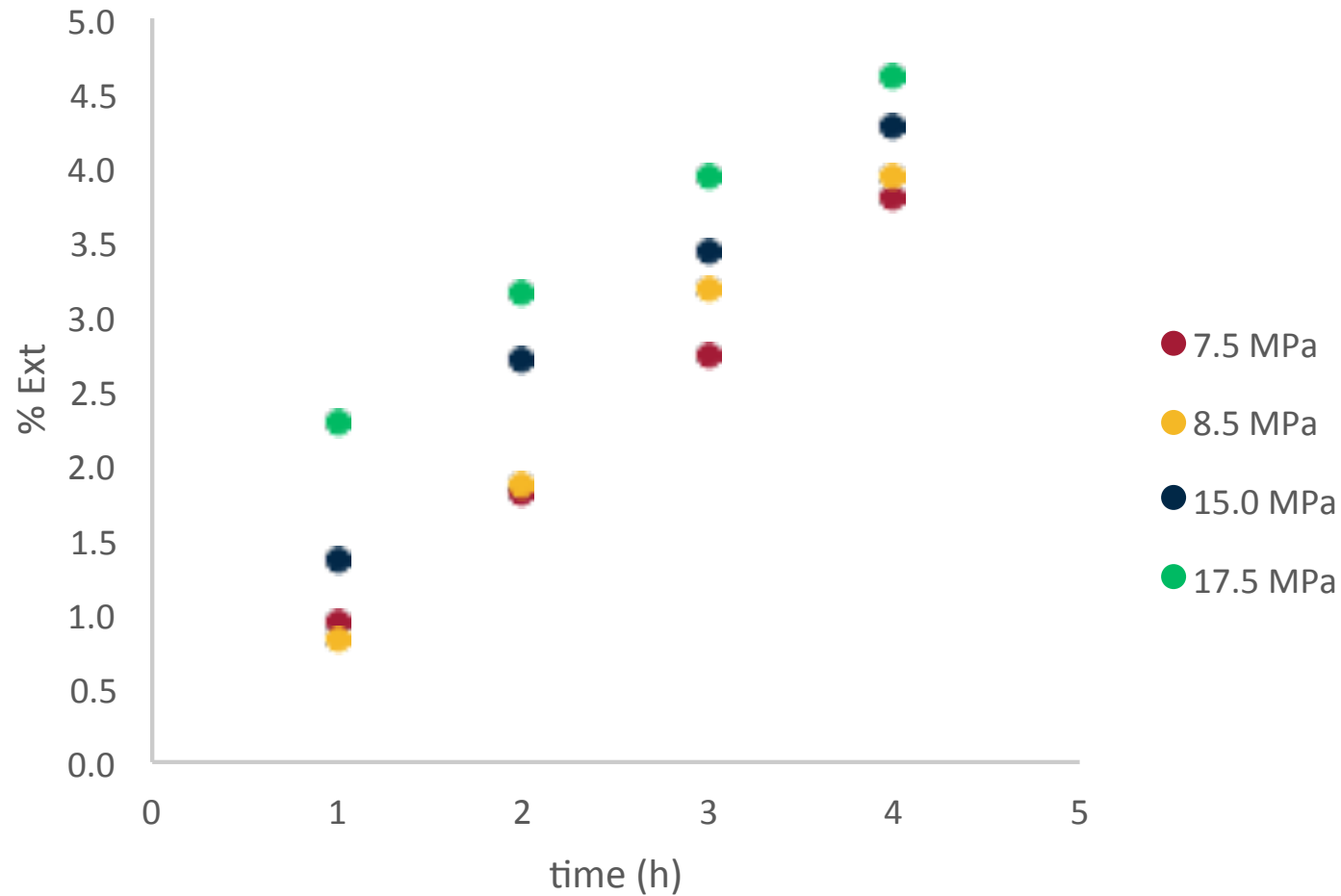
Liquid CO<sub>2</sub>



*Chlorella vulgaris*

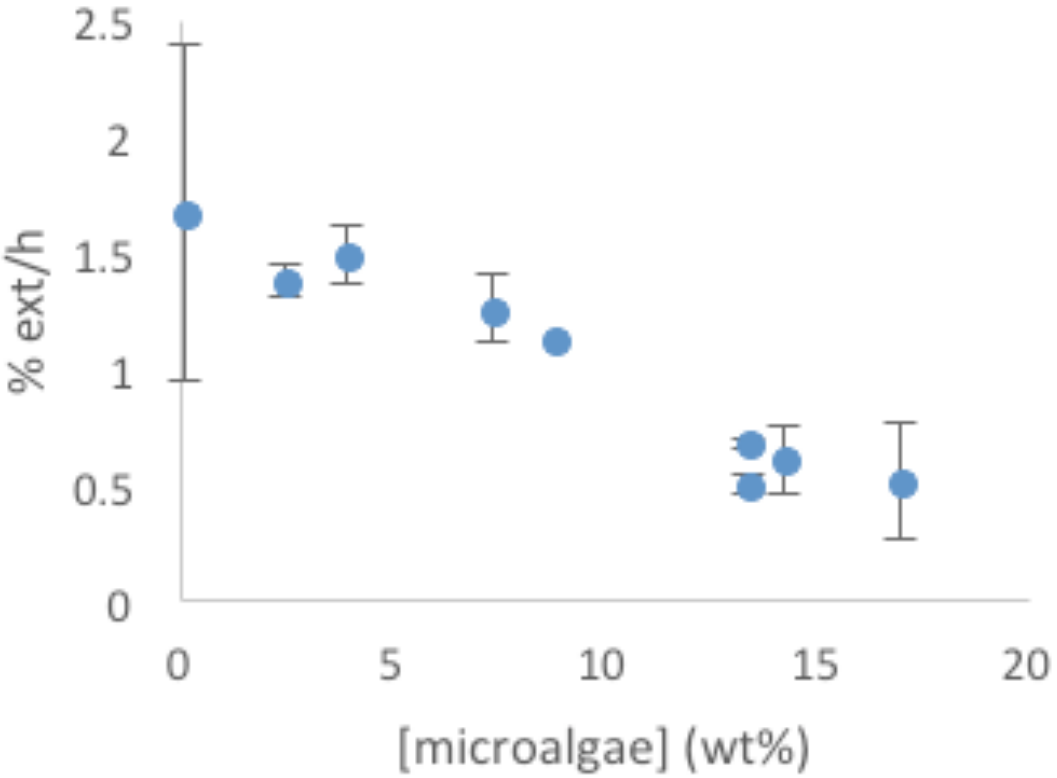


# EXTRACTION FROM *WET ALGAE* WITH LIQUID CO<sub>2</sub>



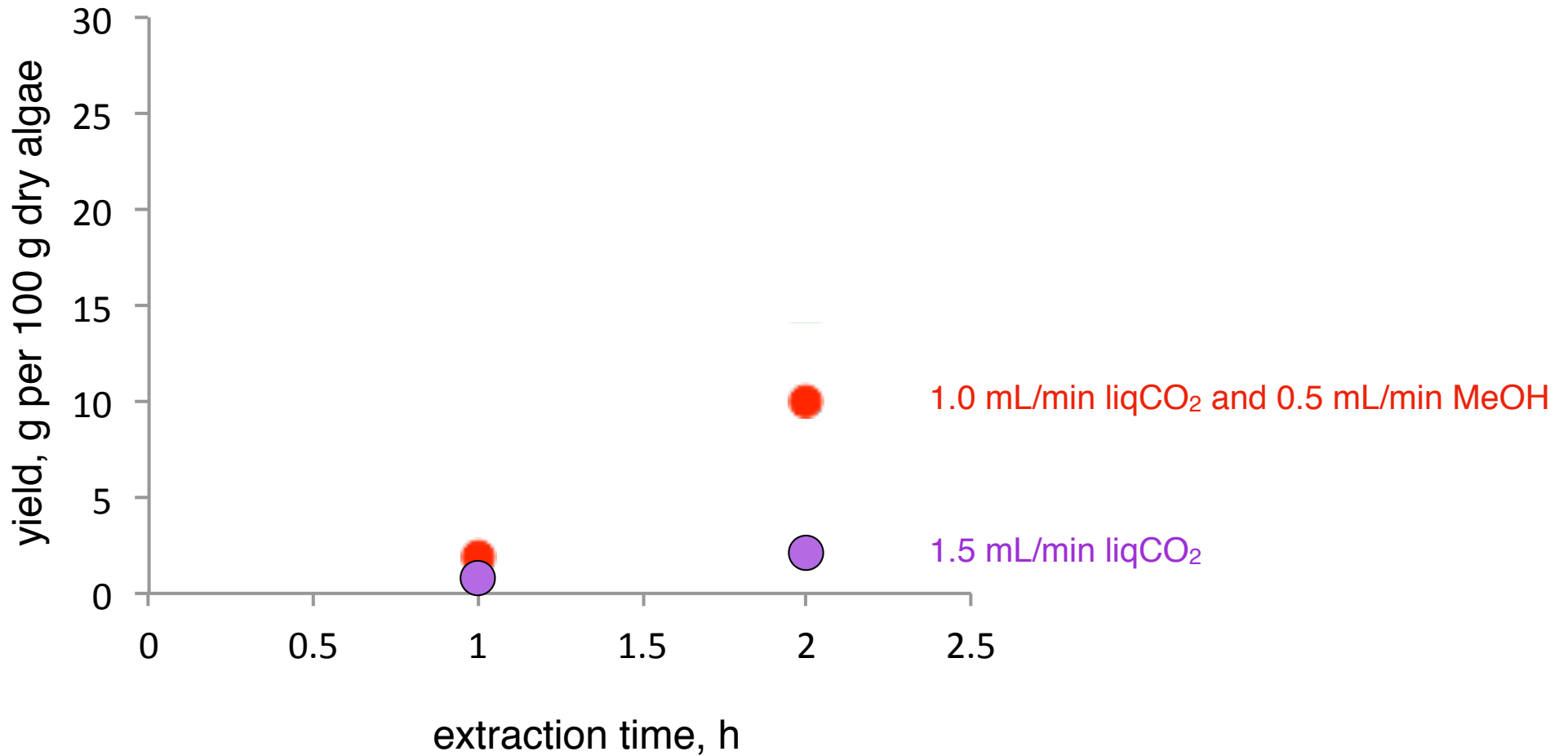
25 °C, 14.3 wt% chlorella vulgaris slurry, 1.5 mL/min of liquid CO<sub>2</sub>

# EXTRACTION FROM *WET ALGAE* WITH LIQUID CO<sub>2</sub>



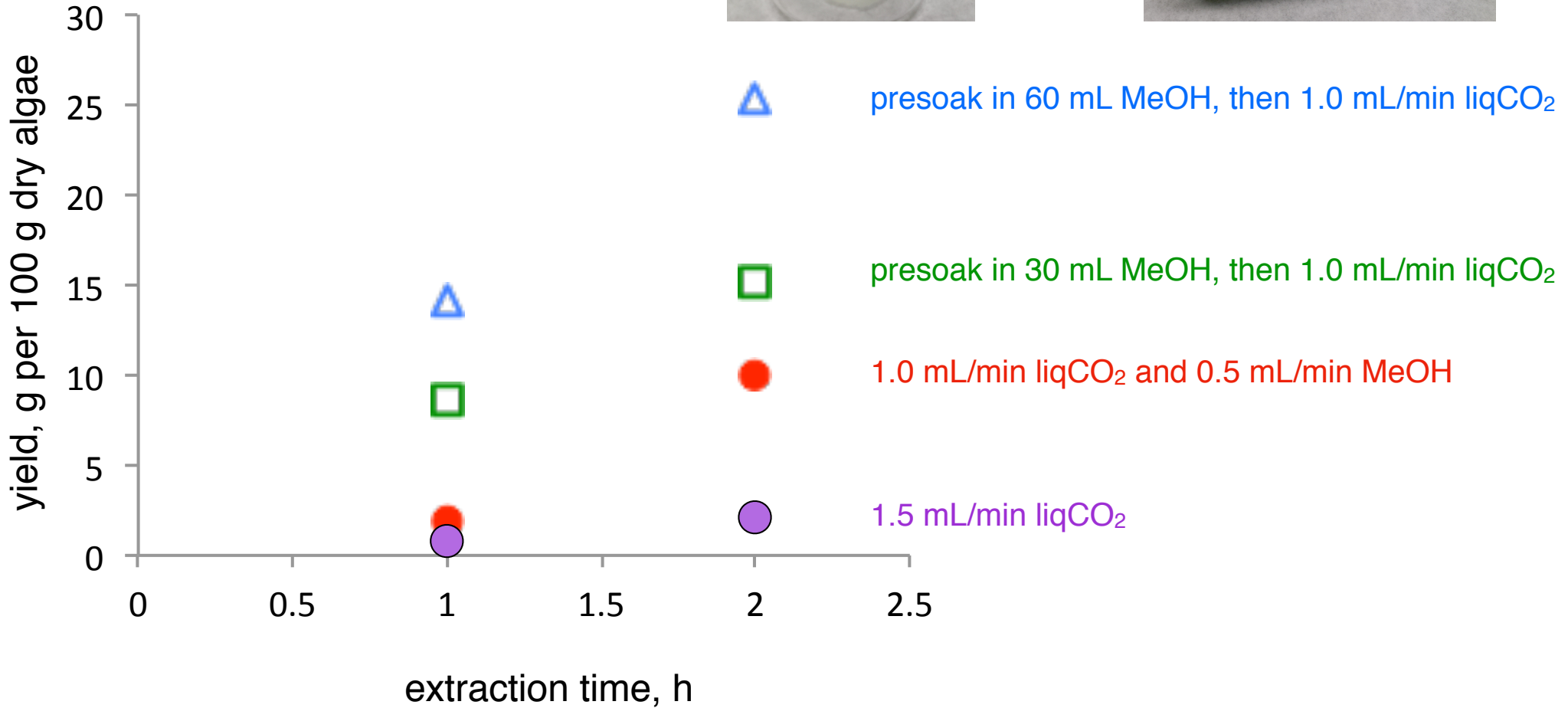
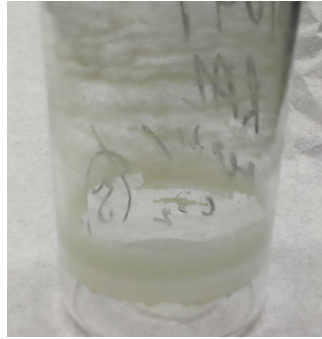
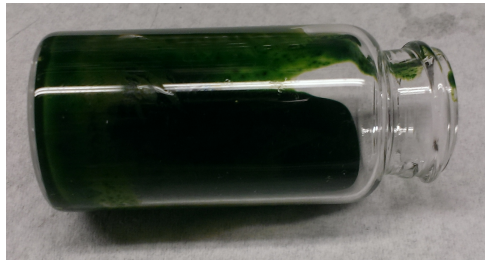
25 °C, chlorella vulgaris, 15 MPa of liquid CO<sub>2</sub>

# EXTRACTION FROM *WET ALGAE* WITH CO<sub>2</sub> & MeOH



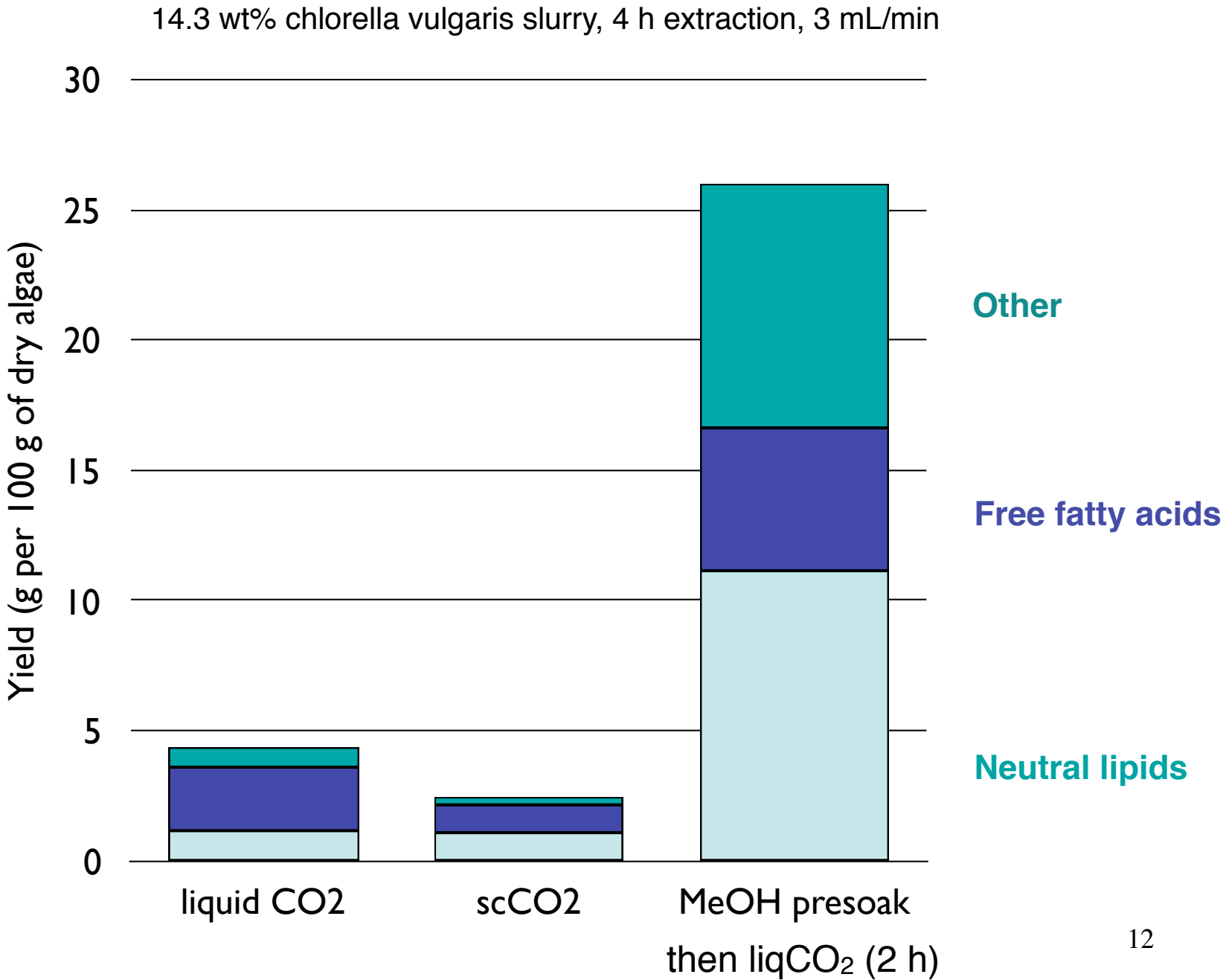
25 °C, liquid CO<sub>2</sub>, 7.5 MPa, 14 wt% chlorella vulgaris slurry

# EXTRACTION FROM *WET ALGAE* WITH CO<sub>2</sub> & MeOH

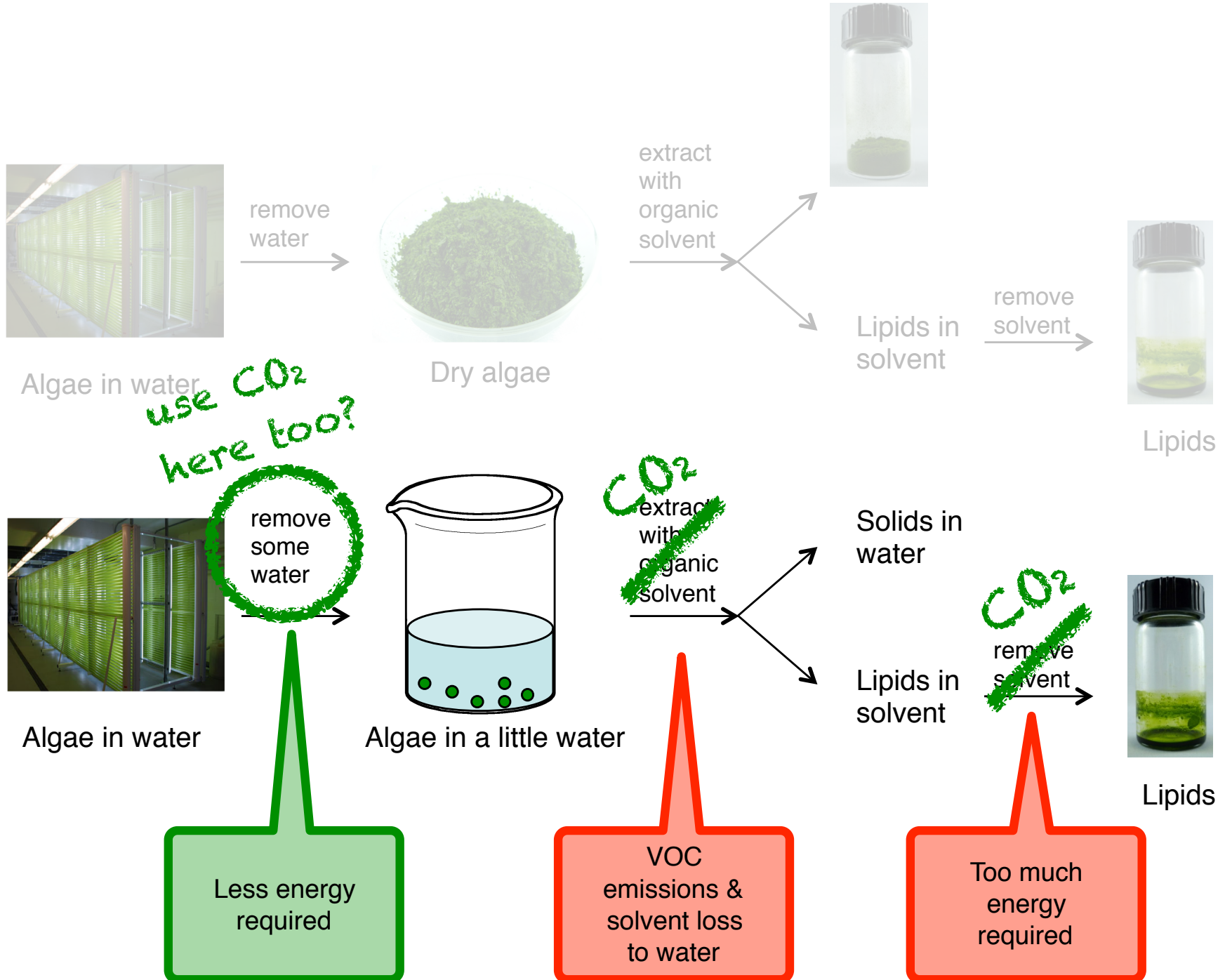


25 °C, liquid CO<sub>2</sub>, 7.5 MPa, 14 wt% chlorella vulgaris slurry

# EXTRACTION FROM *WET ALGAE*



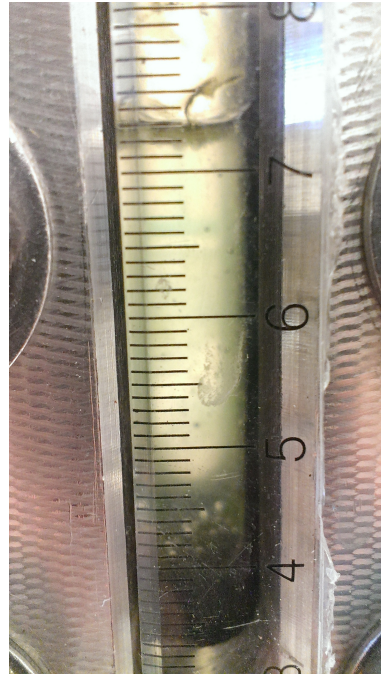
# LIPID EXTRACTION STRATEGY #2: EXTRACT FROM *WET ALGAE*



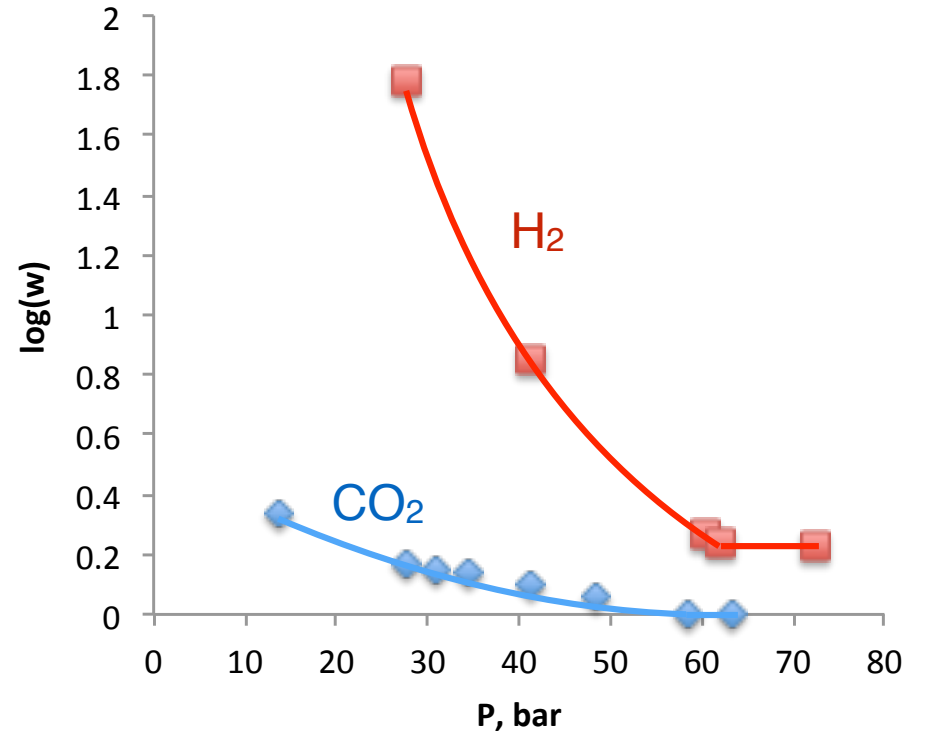
# PARTIAL DEWATERING



Start



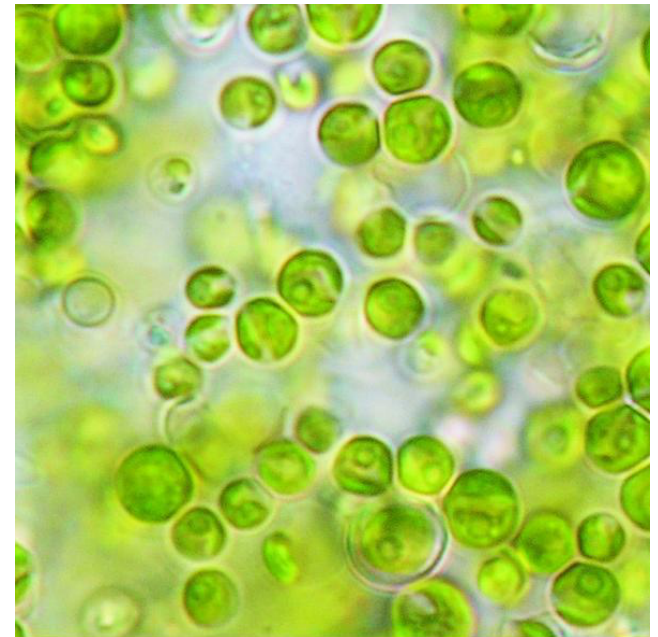
17 h at 61 bar CO<sub>2</sub>



$$\text{stability ratio} = W = \frac{1}{\sigma} = \frac{k^*}{k_l}$$

# CONCLUDING THOUGHTS

- Presoaking the wet algae in MeOH followed by liqCO<sub>2</sub> extraction gives excellent yields, but MeOH recovery issue remains (50% loss).
- CO<sub>2</sub> can help the dewatering process.





**CONCLUDING THOUGHTS**

*Thank You*

