6-20-2016

Extraction of products from algae using green solvents

Philip G. Jessop
Queen's University, jessop@chem.queensu.ca

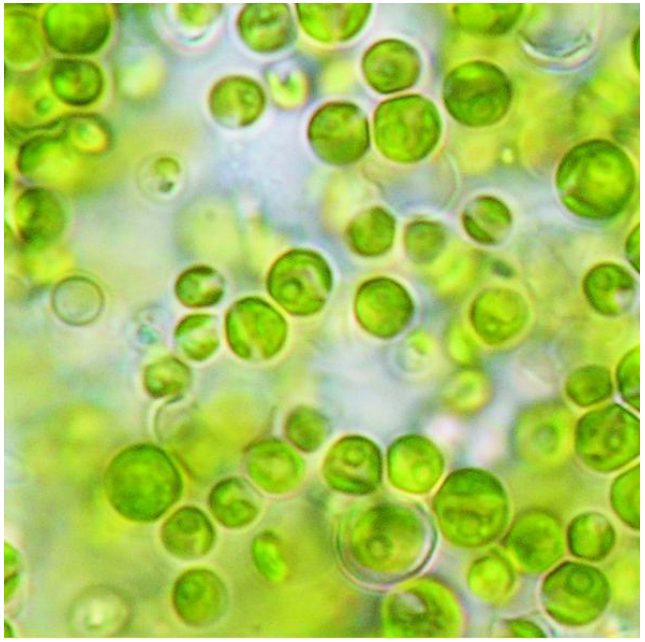
Pascale Champagne
Queen's University, champagne@civil.queensu.ca

Roland Lee
Queen's University

Extraction of Products from Algae using Green Solvents

Roland Lee, Pascale Champagne and Philip G. Jessop

Departments of Chemistry and Civil Engineering
Queen's University



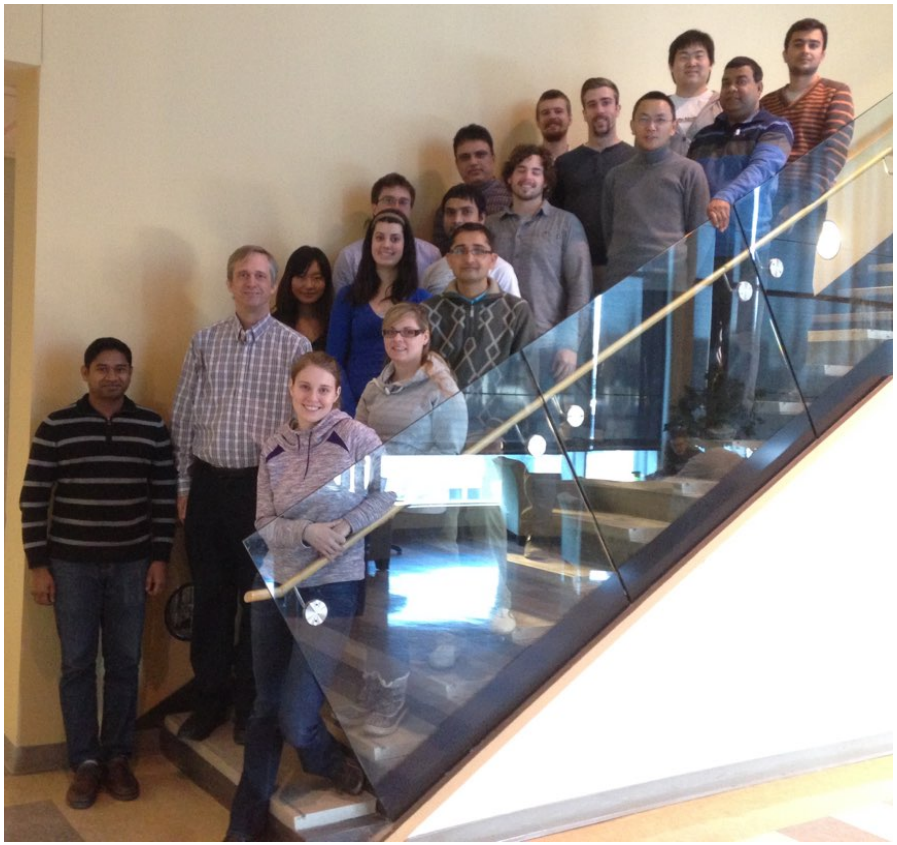
ACKNOWLEDGEMENTS

Recent Grad Students

Md Abu Affan
Todd Allward
Trisha Ang
Troy Arthur
Marie Barnes
Kyle Boniface
Alaina Boyd
Darrell Dean
Tamara deWinter
Jeremy Durelle
Candace Fowler
Vanessa Little
Sean Mercer
Catherine O'Neill
Ashok Paudel
Aliyah Shamrani
Mark Skerritt
Jesse Vanderveen

Recent PDFs

Dr. Tamer Andrea
Dr. Ryan Dykeman
Dr. Dongbao Fu
Dr. Kazem Ghozati
Dr. Keith Huynh
Dr. Bhanu Mudrabovina
Dr. Roland Lee
Dr. Tobias Robert
Dr. Xin Su
Dr. Hong-Bo Wang



Recent Collaborators

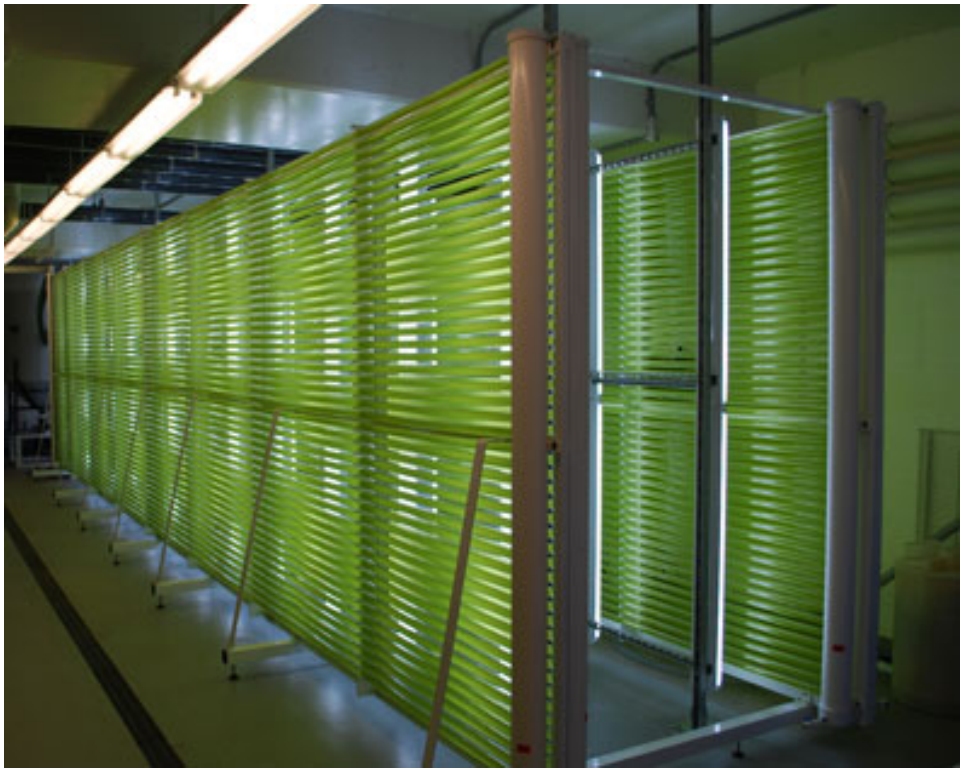
Dr. P. Champagne (Queen's)
Dr. M. Cunningham (Queen's)
Dr. Paul Dyson (EPFL)
Dr. Luc Patiny (EPFL)
Dr. R. S. Brown (Queen's)
Dr. P. V. Hodson (Queen's)
Dr. R. H. Horton (Queen's)
Dr. G. Liu (Queen's)
Dr. C. Ovalles (Chevron)
Dr. D. Kuehne (Chevron)
Mr. D. Wallace (Shell)
Dr. D. Heldebrant (PNNL)

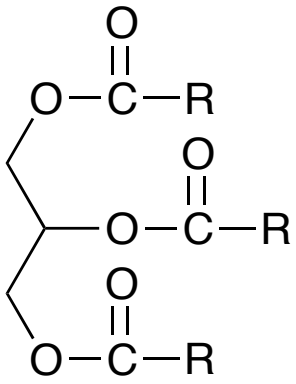
Funding

Canada Research Chairs Program
CFI/OIT (Canada)
Chevron
EPFL
Fielding Chemical Technologies
GreenCentre Canada
Killam Foundation/Canada Council for the Arts
Landolt & Cie
Ministry of the Environment, Ontario
MITACS
NSERC (Canada)
Ontario Centres of Excellence
Queen's University
Switchable Solutions Inc.

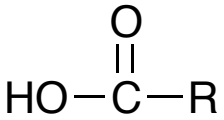
MICROALGAE

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

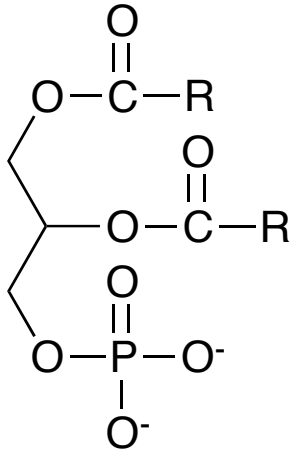




Triacylglycerides (TAG)
Diacylglycerides (DAG)
Monoacylglycerides (MAG)



Free fatty acids (FF)



Polar lipids

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

Algae in water

remove water

Dry algae

extract with organic solvent

Lipids in solvent

remove solvent

Lipids

Too much energy required

VOC emissions

Too much energy required

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

Algae in water

remove water

Dry algae

extract with organic solvent

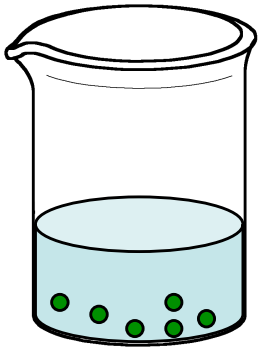
Lipids in solvent

remove solvent

Lipids

Algae in water

remove some water



Algae in a little water

~~CO_2~~ ~~extract with organic solvent~~

Solids in water

Lipids in solvent

~~CO_2~~ ~~remove solvent~~

Lipids

Less energy required

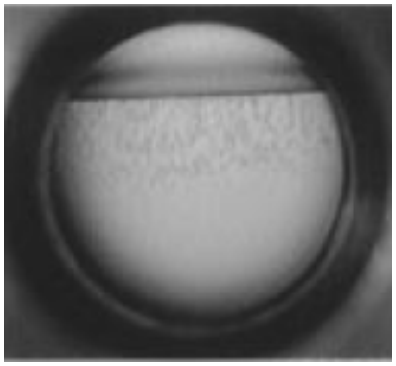
~~VOC emissions & solvent loss to water~~

Too much energy required

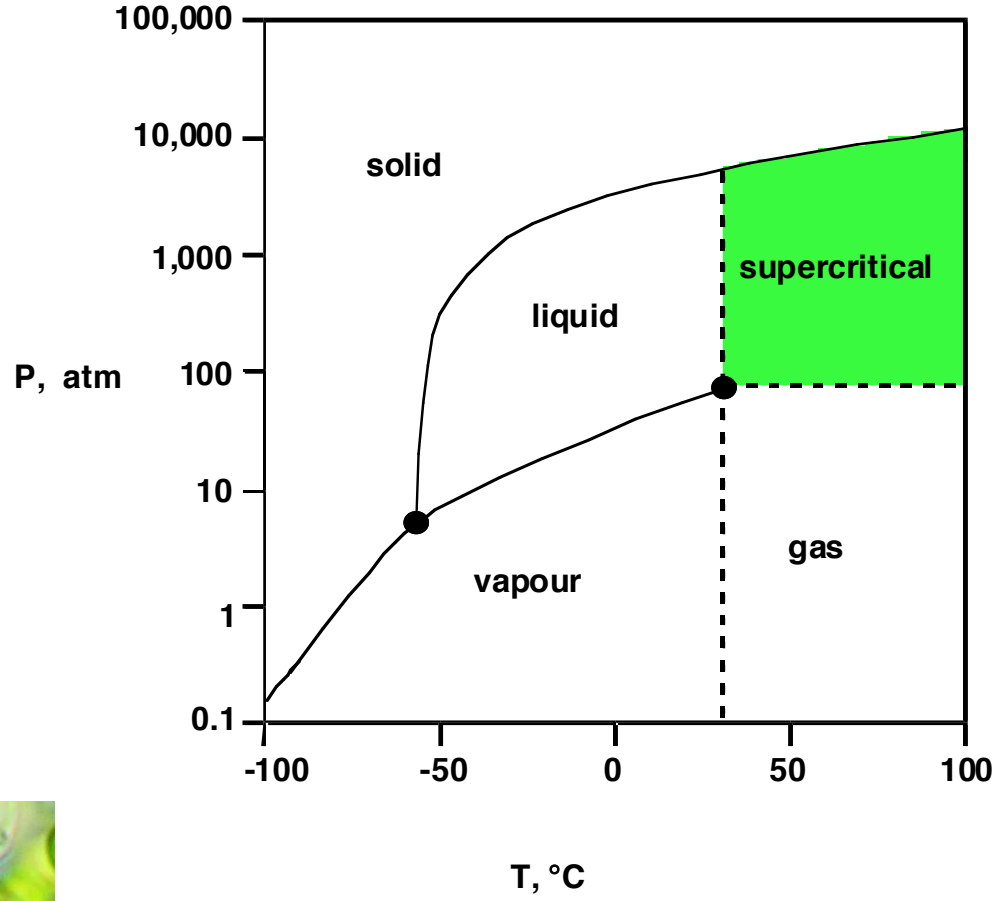
MICROALGAE EXTRACTION SOLVENTS

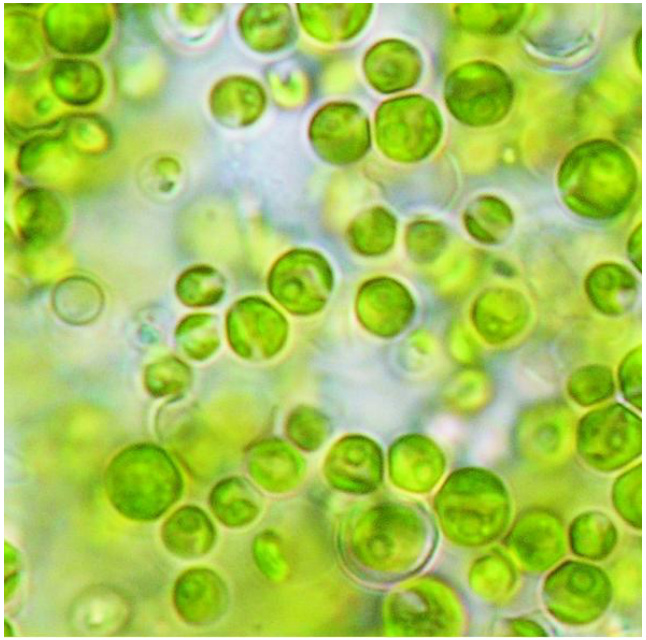
Solvent	Advantage	Disadvantage
chloroform/methanol (Bligh & Dyer)	• high yield	• chlorinated • flammable • polar lipids extracted
supercritical CO_2 (Zimmerman)	• easily removed • not flammable • selective for nonpolar lipids	• high pressure
switchable-polarity solvents (Samori)	• easily removed • not flammable	• must be dry
switchable-hydrophilicity solvents (Jessop)	• easily removed • not flammable	• poor separation

LIQUID CO_2



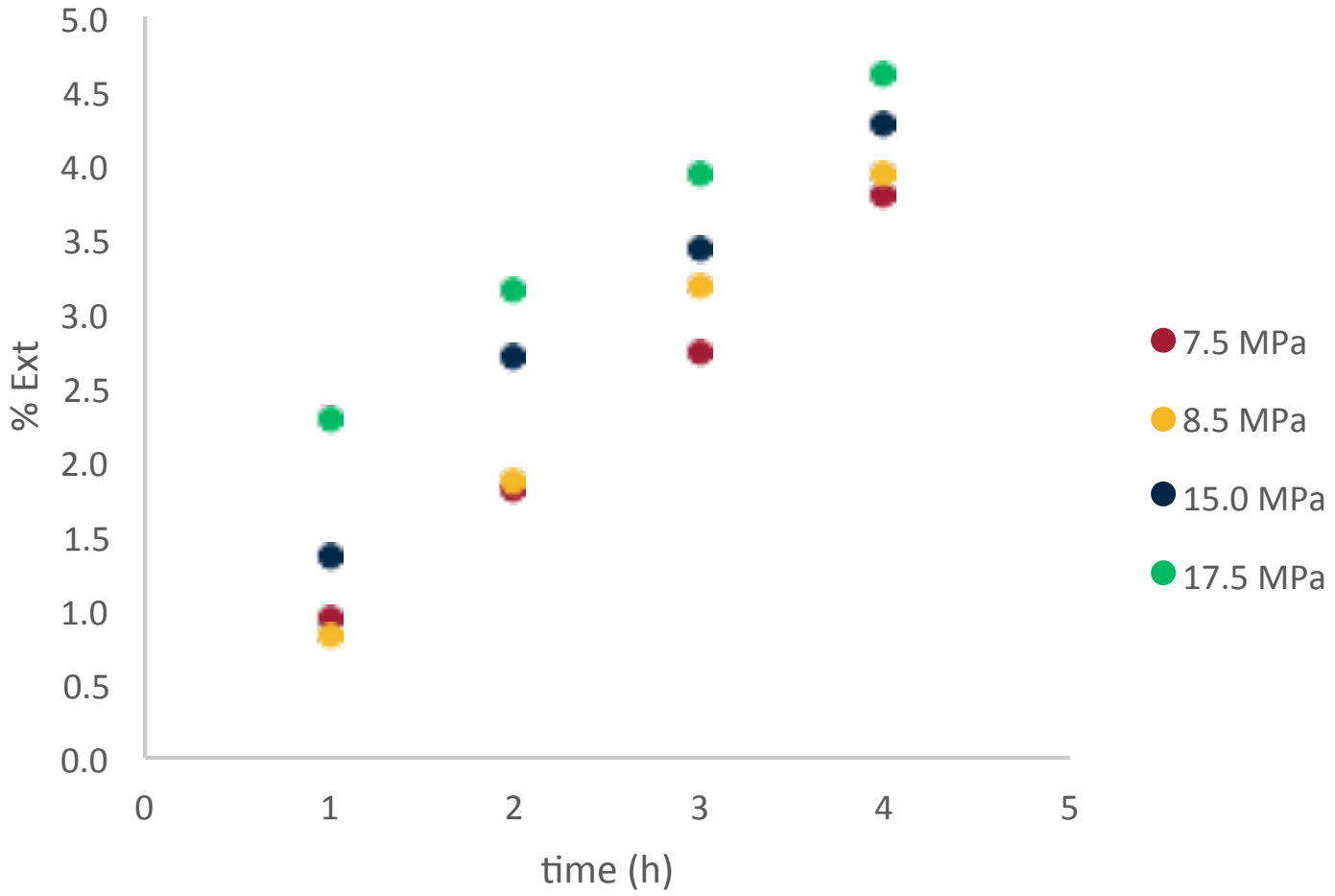
Liquid CO_2





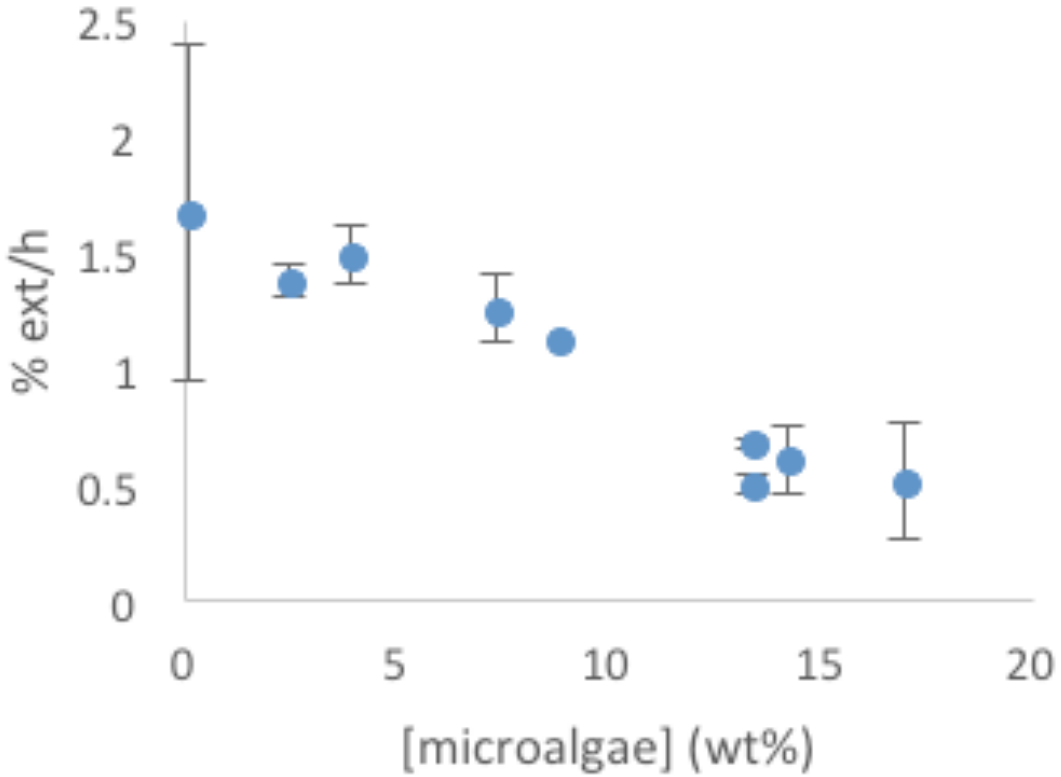
Chlorella vulgaris

EXTRACTION FROM *WET ALGAE* WITH LIQUID CO_2



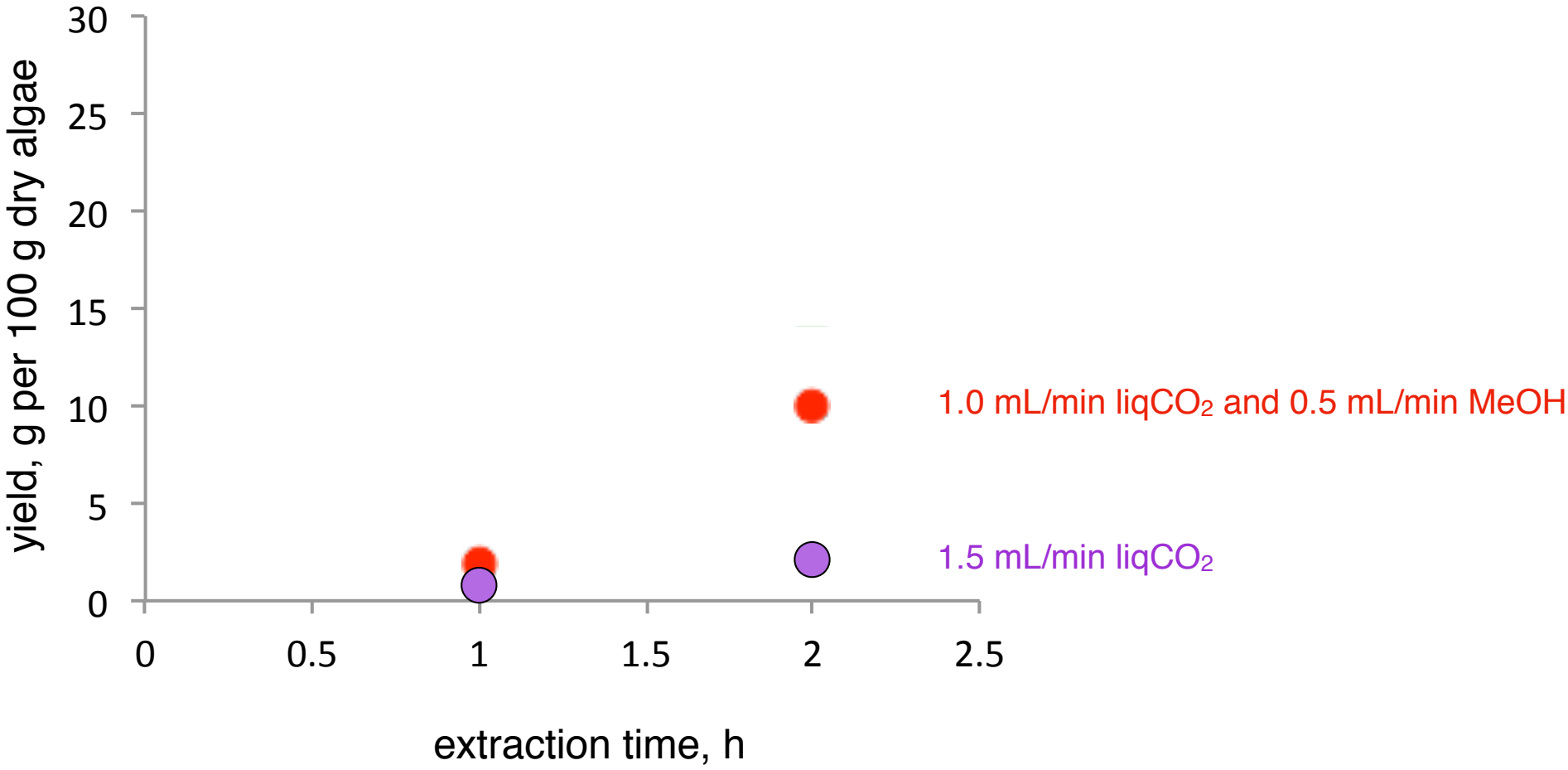
25 ˚C, 14.3 wt% chlorella vulgaris slurry, 1.5 mL/min of liquid CO_2

EXTRACTION FROM *WET ALGAE* WITH LIQUID CO_2



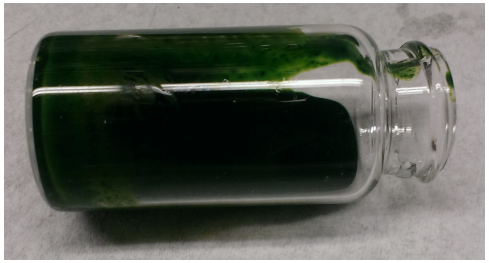
25 ˚C, chlorella vulgaris, 15 MPa of liquid CO_2

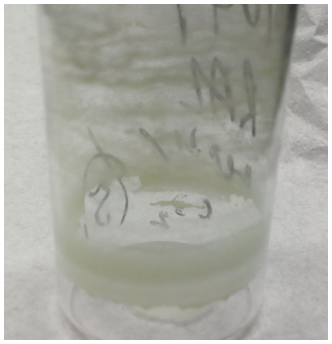
EXTRACTION FROM *WET ALGAE* WITH CO_2 & MeOH



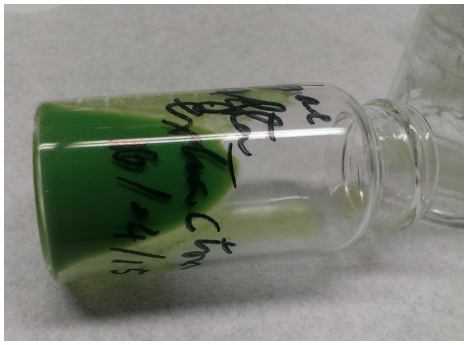
25 ˚C, liquid CO2, 7.5 MPa, 14 wt% chlorella vulgaris slurry

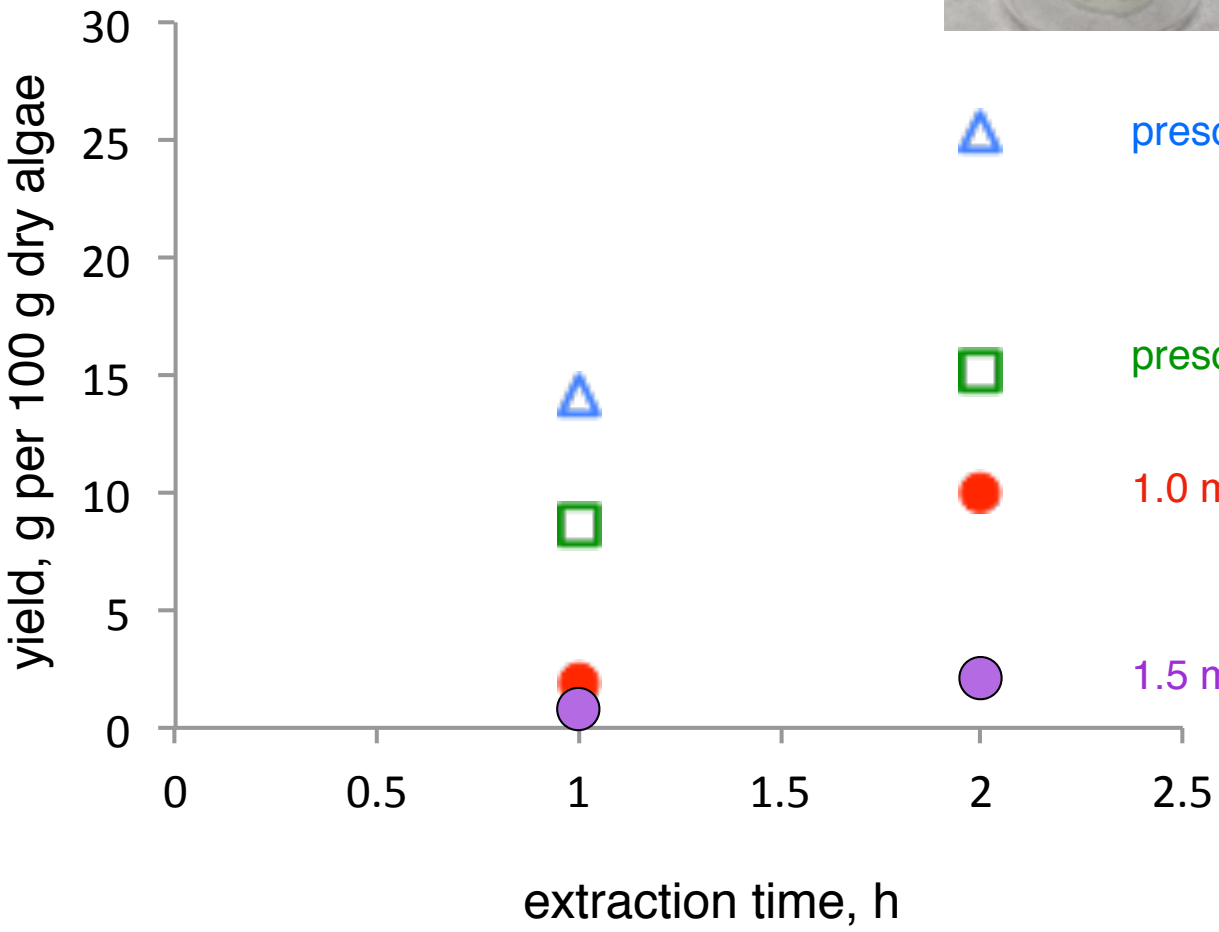
EXTRACTION FROM *WET ALGAE* WITH CO_2 & MeOH





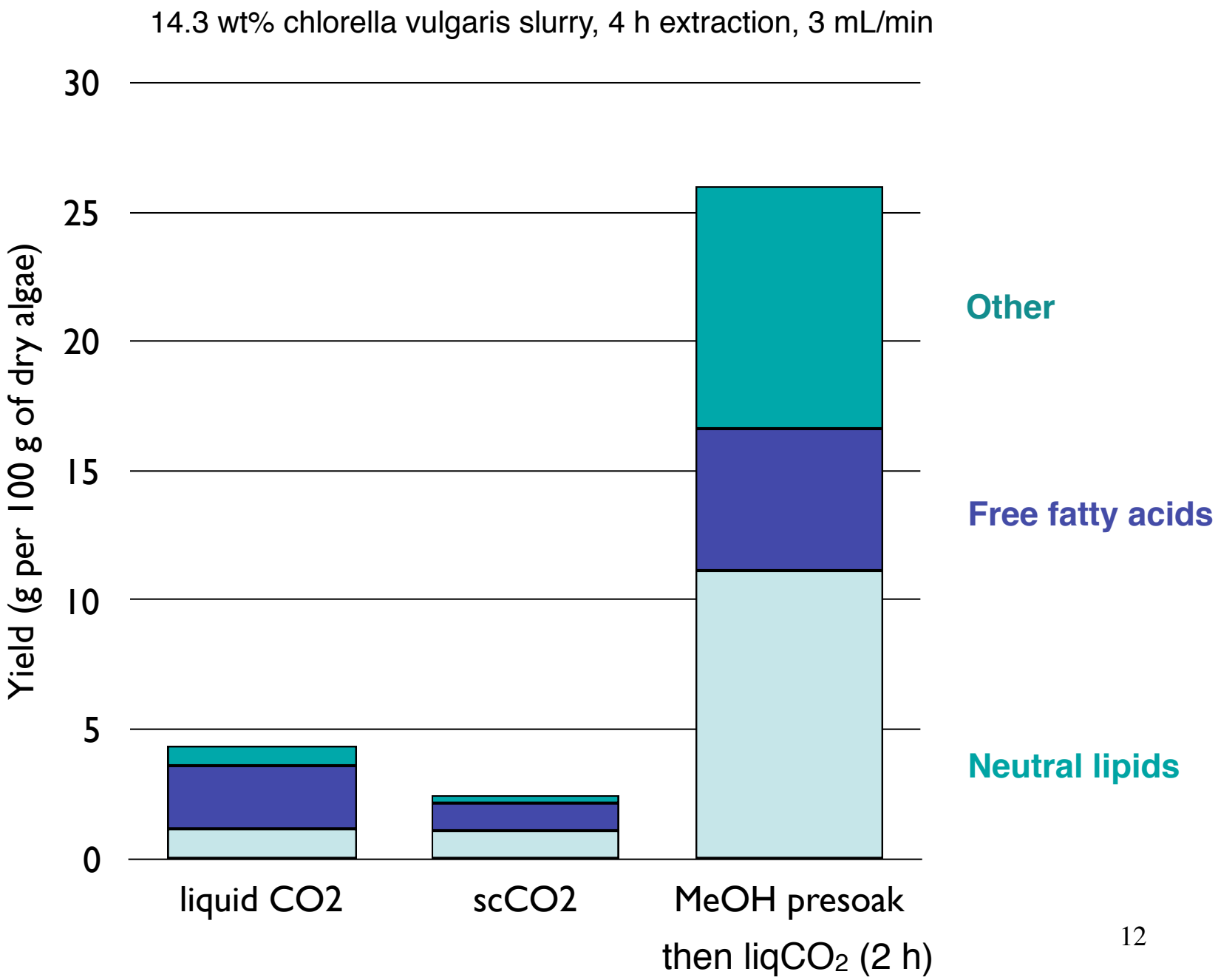
+





25 ˚C, liquid CO2, 7.5 MPa, 14 wt% chlorella vulgaris slurry

EXTRACTION FROM *WET ALGAE*



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

Algae in water

remove water

Dry algae

extract with organic solvent

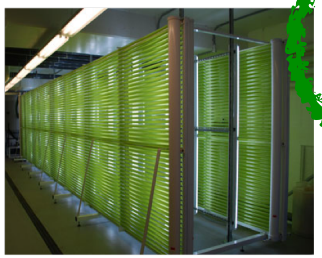
Lipids in solvent

remove solvent

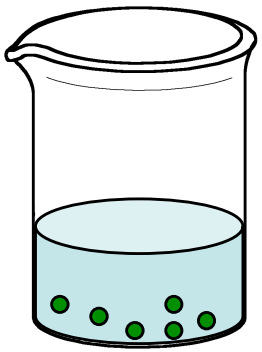
Lipids

use CO_2 here too?

remove some water



Algae in water



Algae in a little water

~~CO_2~~

~~extract with organic solvent~~

Solids in water

Lipids in solvent

~~CO_2~~

~~remove solvent~~

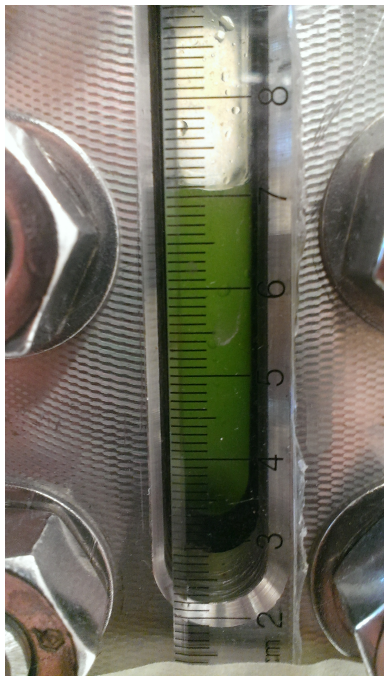
Lipids

Less energy required

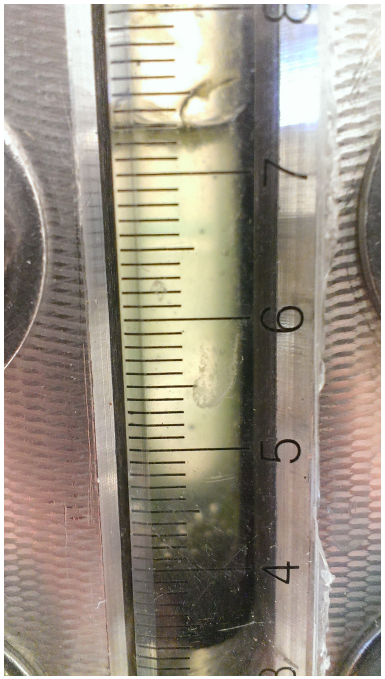
VOC emissions & solvent loss to water

Too much energy required

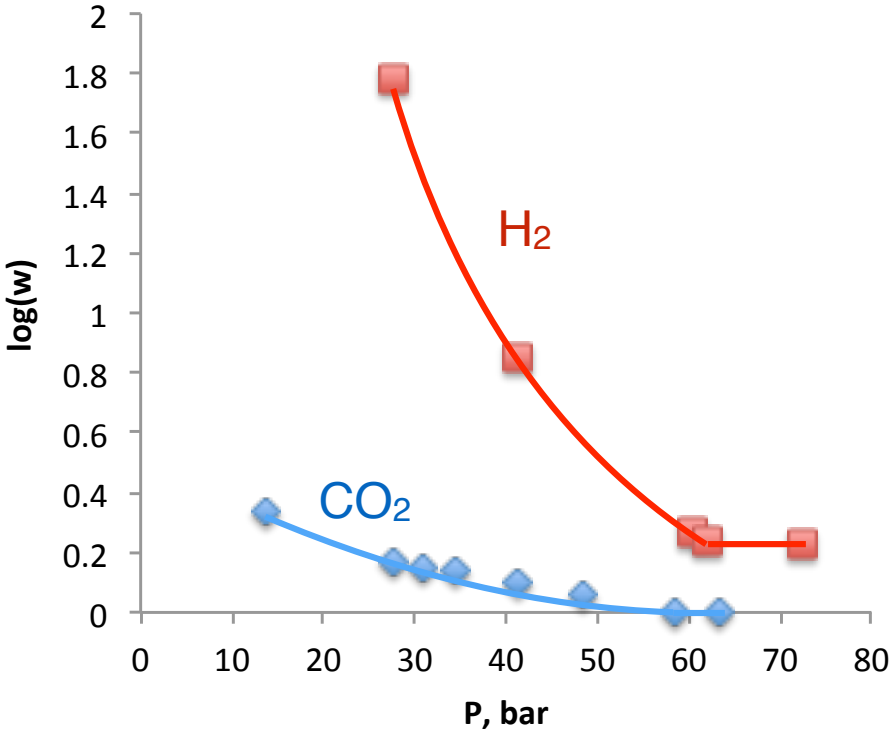
PARTIAL DEWATERING



Start



17 h at 61 bar CO_2

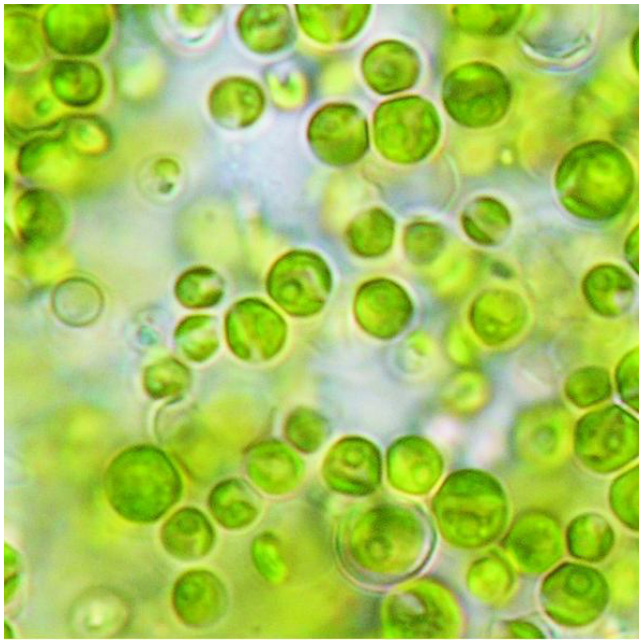


stability ratio = $W = \frac{1}{\sigma} = \frac{k^*}{k_i}$

CONCLUDING THOUGHTS

- Presoaking the wet algae in MeOH followed by liqCO_2 extraction gives excellent yields, but MeOH recovery issue remains (50% loss).

- CO_2 can help the dewatering process.



CONCLUDING THOUGHTS

Thank You