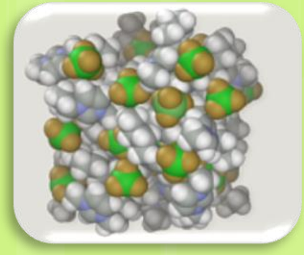
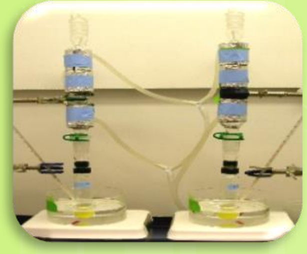




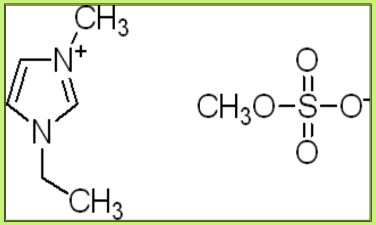
Co-Recovery of Lipids, Fermentable Sugars, and Protein from Bio-oil Bearing Biomass using Ionic Liquid co-Solvents

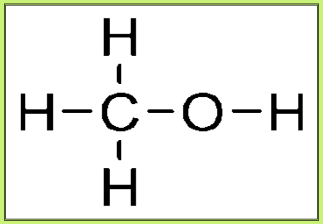
Dr. Michael Cooney, &
Dr. Godwin Severa
Hawaii Natural Energy Institute, University of Hawaii at Manoa, Honolulu HI.

SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY
UNIVERSITY OF HAWAI'I AT MĀNOA
HNEI
Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa

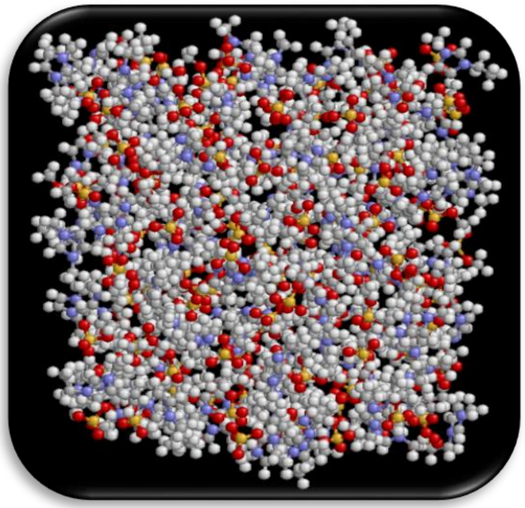
Introduction

- IL co-solvents

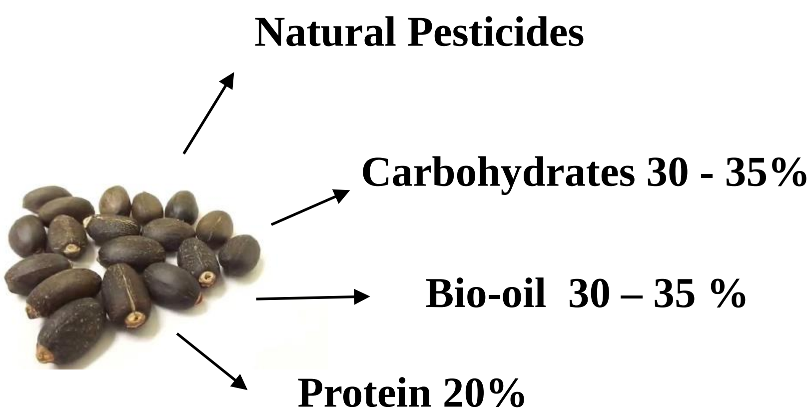




- Characterized by heterogeneous distribution of charge and hydrophobic – hydrophilic regions at molecular scale
- Emerging solvent platform
- US Patent US20090234146



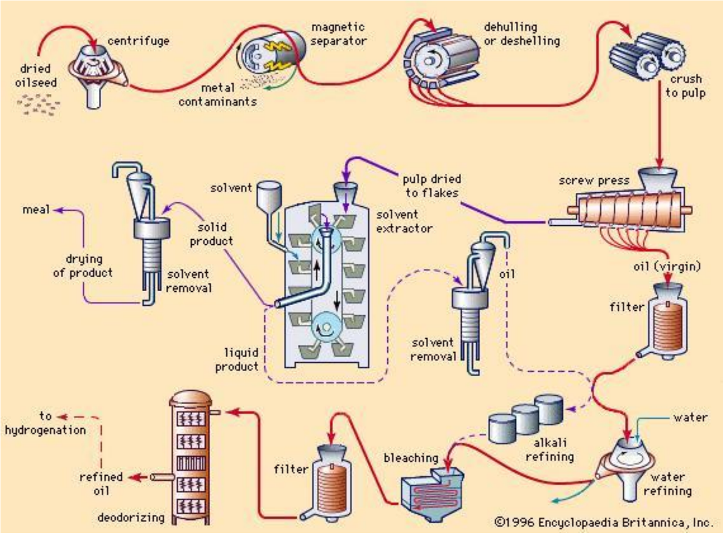
Application to Jatropha



Conventional

- Mechanical pressing with a hydraulic or single expeller press[1].
- Generally achieves yields less than 80%. In the case of mechanical pressing the residual oil left in the oil cake may be anywhere from 6% to 14%
- The seedcake can be subjected to a different number of extractions through the expeller[2].
- The combination of these operations can produce oil extraction can yield up to 98% with residual oil content in cake meal of 0.5–1.5%[3].
- There are problems, however. Screw presses induce friction, causing overheating, high energy consumption, and oil deterioration. Single-screw presses also provide insufficient crushing and mixing if they are not equipped with breaker bars, or other special equipment[4].

Conventional

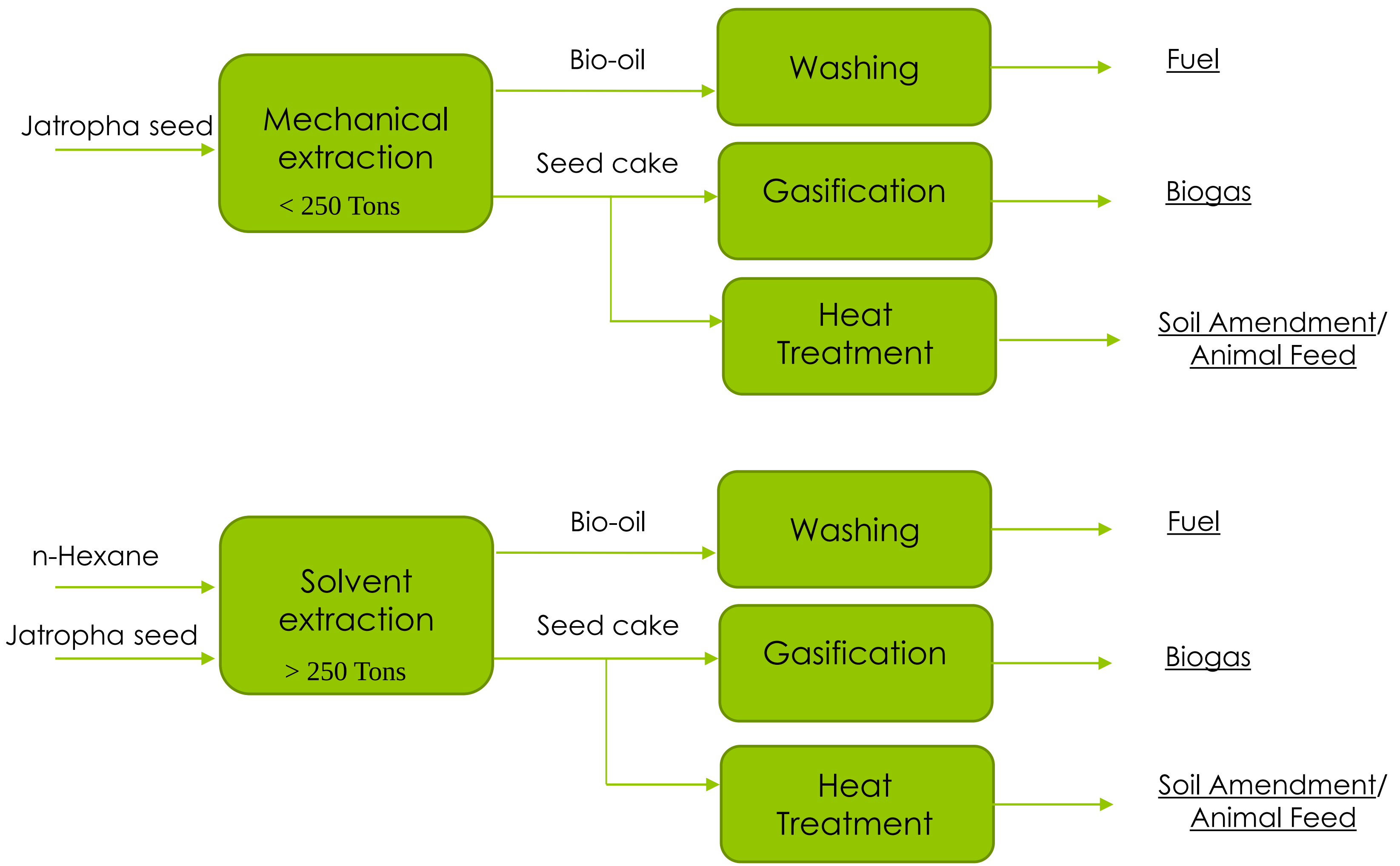


- The solvent extraction most commonly used today is percolation extraction with a countercurrent flow using hexane as a solvent[5].
- The solvent extraction method recovers almost all the oils and leaves behind only 0.5% to 0.7% residual oil in the raw material.
- Solvent extraction is only economical at a large-scale production of more than 50 t bio-diesel per day.
- *n*-hexane solvent extraction possesses negative environmental impacts (generation of waste water, higher specific energy consumption and higher emissions of volatile organic compounds) and human health impacts (working with hazardous and inflammable chemicals)[6].

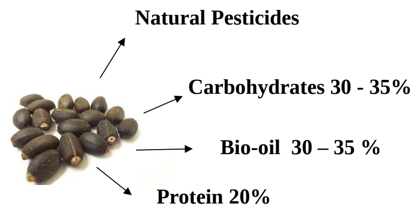
Conventional

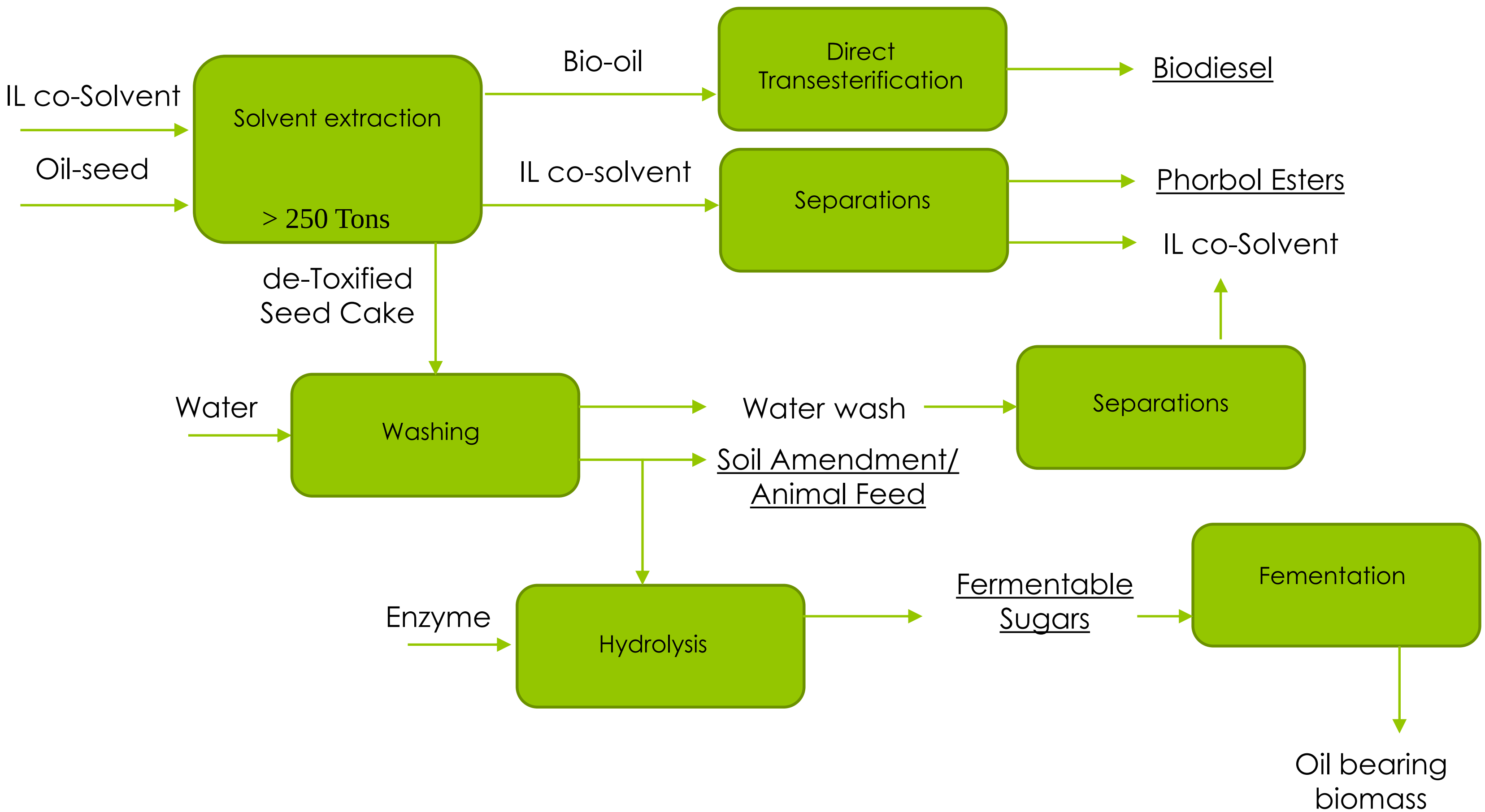
- New generation *n*-hexane extraction units are very efficient and produce far less environmental burdens than the older units,
- n-hexane extraction does not detoxify the seedcake, however.
- Due to its toxic nature, the seed cake must be used for animal feeding nor can be used in agricultural farming[7].
- Seed cake can be used for energy production - 93.8% total solid (TS) out of which 92.5% is volatile solid (VS). The cake is high in organic matter and has good potential for biogas generation[8].

Conventional

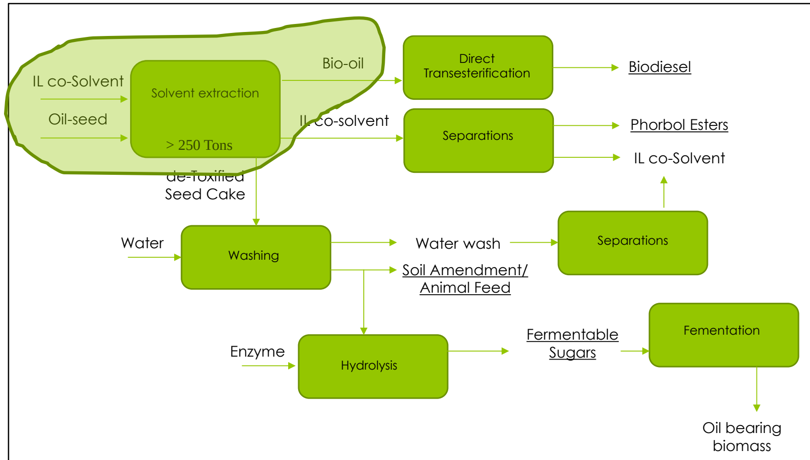


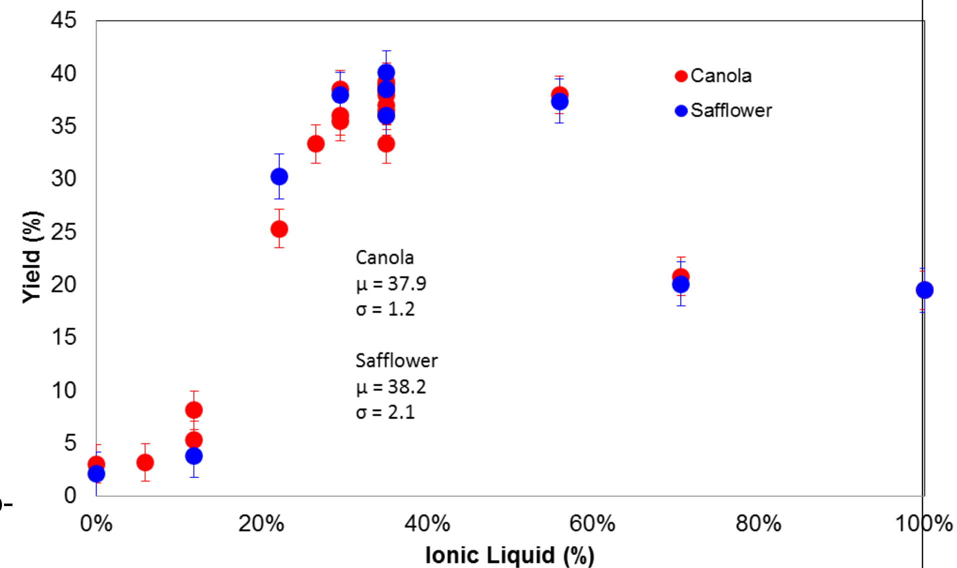
IL solvent pathway





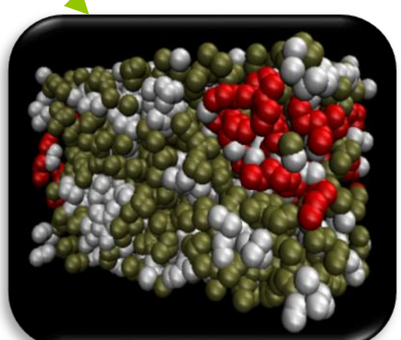
Bio-oil extraction





Visualization of macro-scale lipid aggregate formed in [EMIN] [$MeSO_4$]-methanol mixture.

Yield of bio-oil from oil seeds as a function of IL/co-solvent ratio



Visualization of molecular-scale lipid aggregate formed in [EMIN] [$MeSO_4$]-methanol mixture.

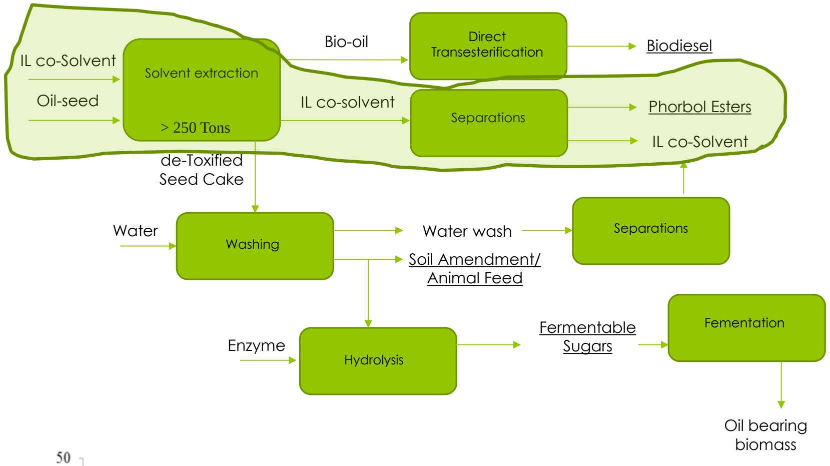
Table 2. The effect of PCM on extraction

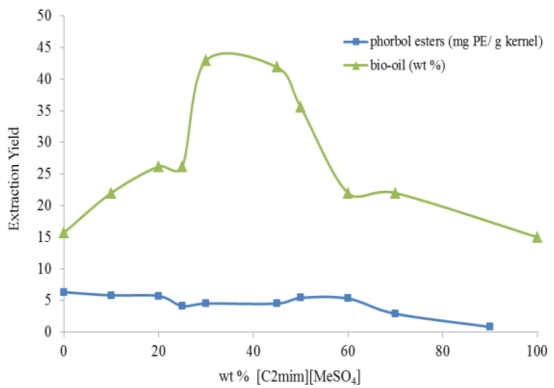
PCM	Yield (wt %)*	Comments
Dimethyl sulfoxide	6.0	Low yield, highly viscous product
Acetic Acid	5.6	Low yield, highly viscous product
Methanol	7.9	Baseline PCM
Acetone	9.2	High yield, with a solid precipitate
Chloroform	8.4	High yield, with a solid precipitate
Isopropyl Alcohol	8.5	Product very similar to methanol

*The biomass used in this study, *Duniella* microalgae, had a lipid content of approximately 8-11% (wt %).

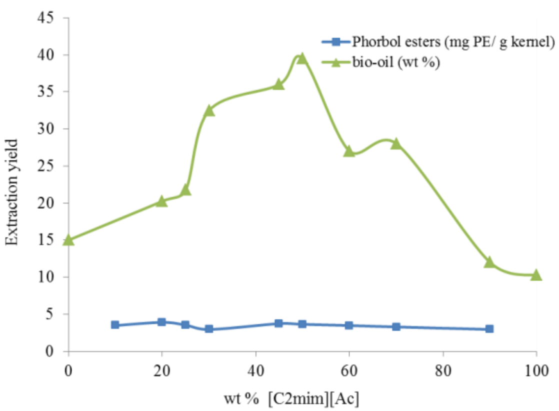
Red = Lipid Green = Methanol White = IL

Phorbol Esters

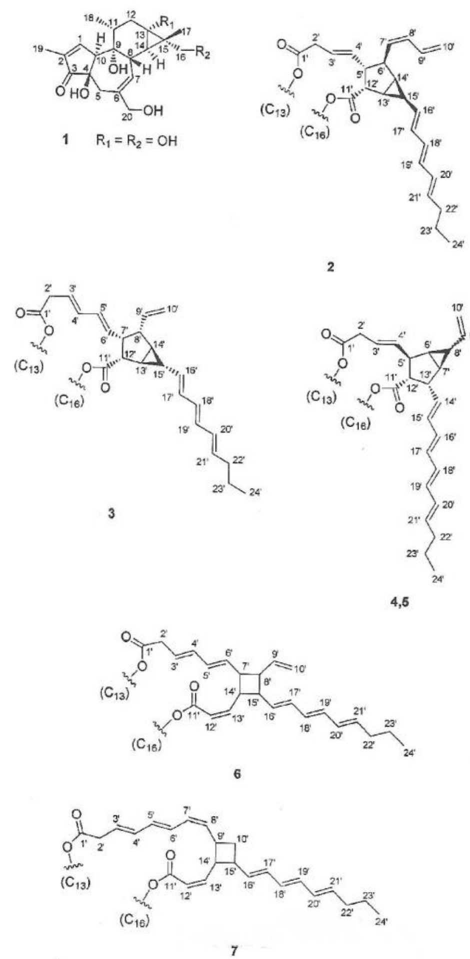




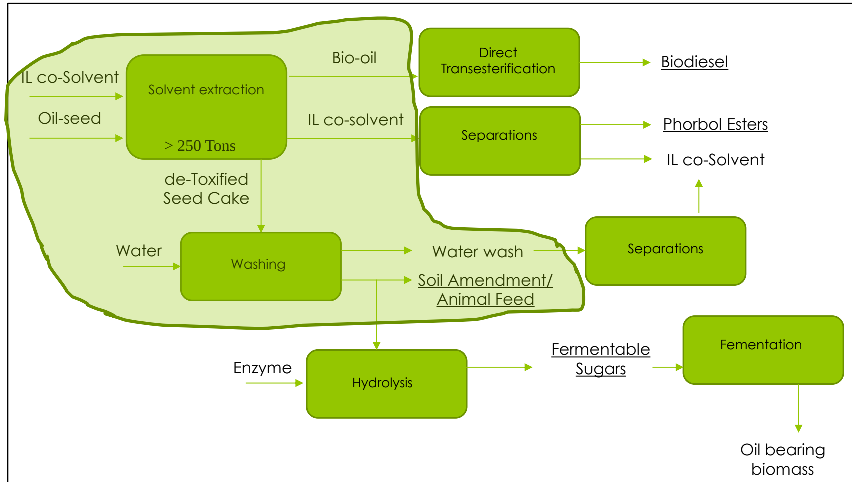
Yields of extracted phorbol esters and bio-oil as a function of [C2mim][$MeSO_4$] weight %.

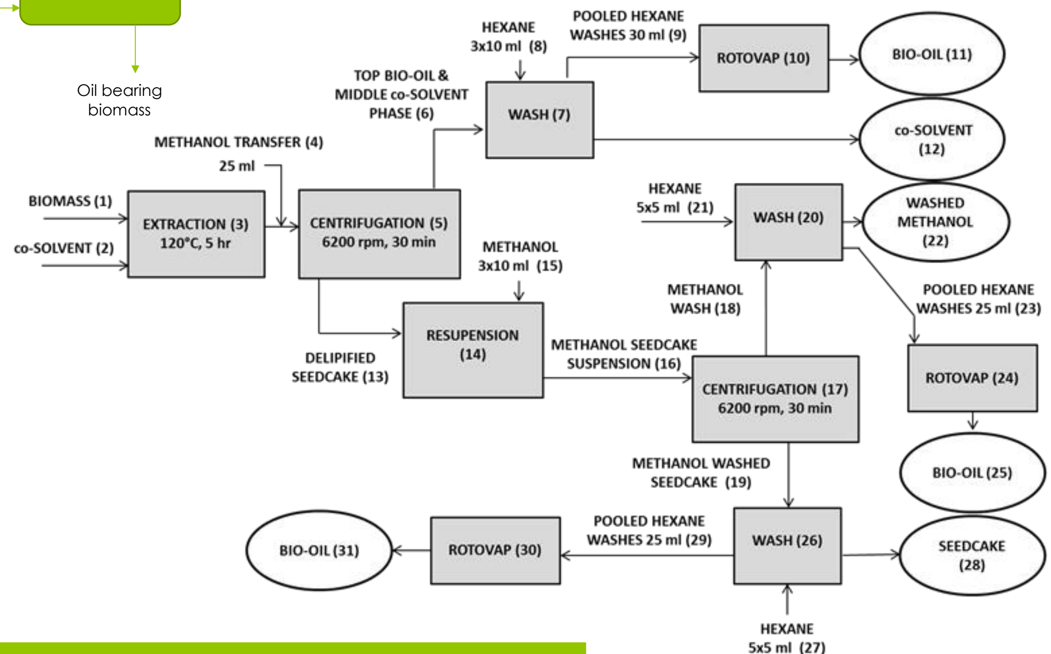


Yields of extracted phorbol esters and bio-oil as a function of [C2mim][Ac] weight %.



Nitrogen Tracking



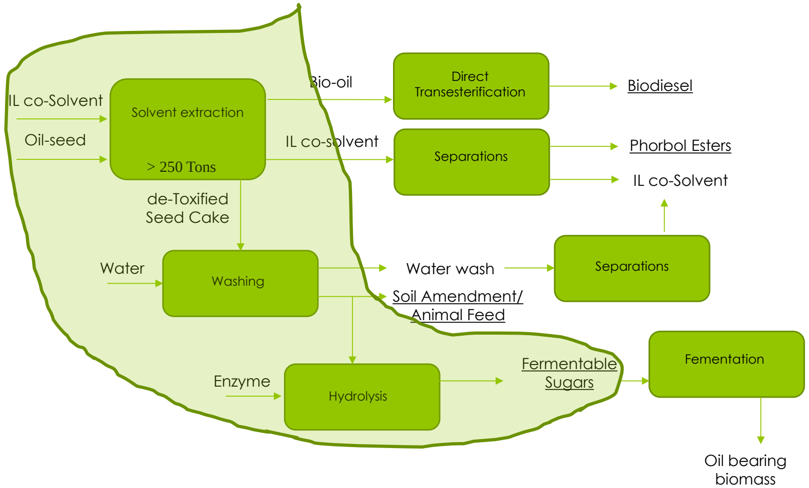


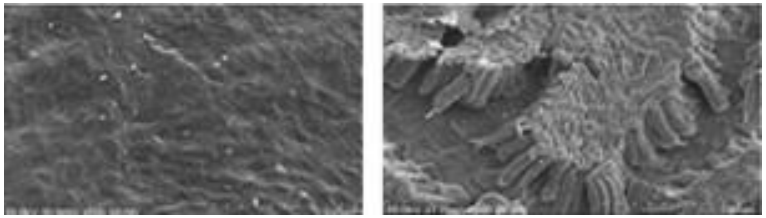
Treatment Pathway for nitrogen tracking

Table 1. Percent of Starting Material in End Phases

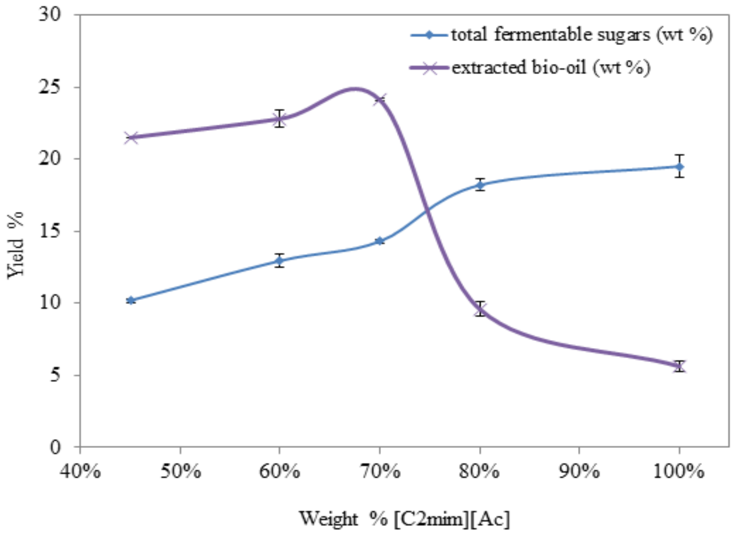
	Bio-oil (11)	Co-solvent (12)	Washed Methanol (22)	Bio-oil (25)	Bio-oil (31)	Seed Cake (28)	Total
Protein (BM) (%)[1]:	0	12	1.3	0	0.004	86.6	99.9
Lipid (BM) (%):	55	0	0	14.9	20.6	0	90.5
Ionic liquid (CS) (%):	0.04	59.4	9.4	0.04	0	31	99.88

Carbohydrate Hydrolysis

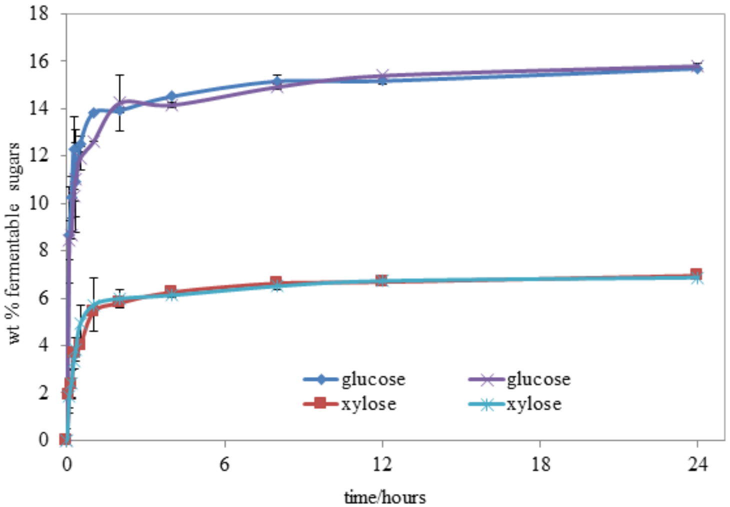




Jatropha shell before and after IL co-solvent treatment

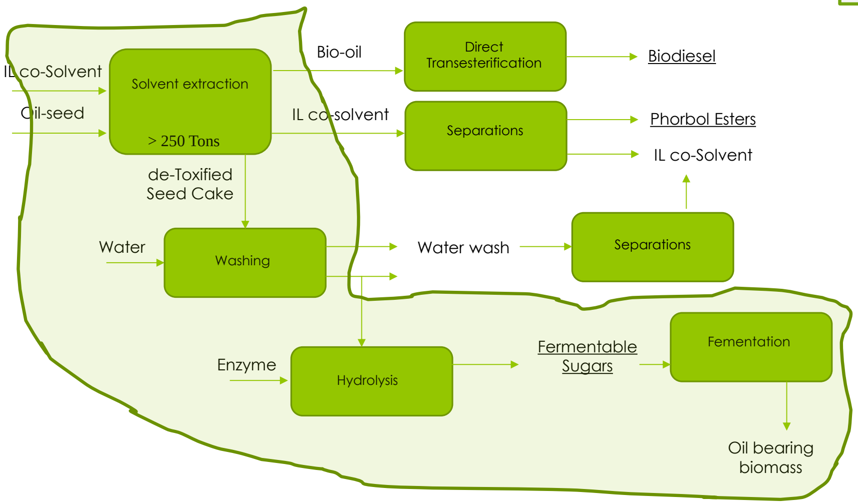


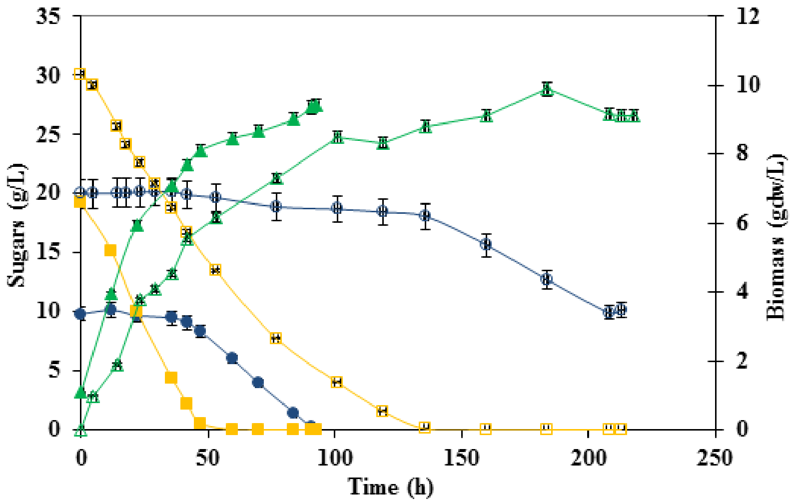
Total fermentable sugars and bio-oil yields relative to weight of whole seed obtained from pretreated *jatropha* whole seed (kernel plus shell) at different concentrations of [C2mim][Ac].



Effect of ionic liquid concentration on hydrolysis kinetics of *safflower* whole seed, using pure and 70 wt% [C2mim][Ac] at 120^{o}C.

Fementable sugars recycle



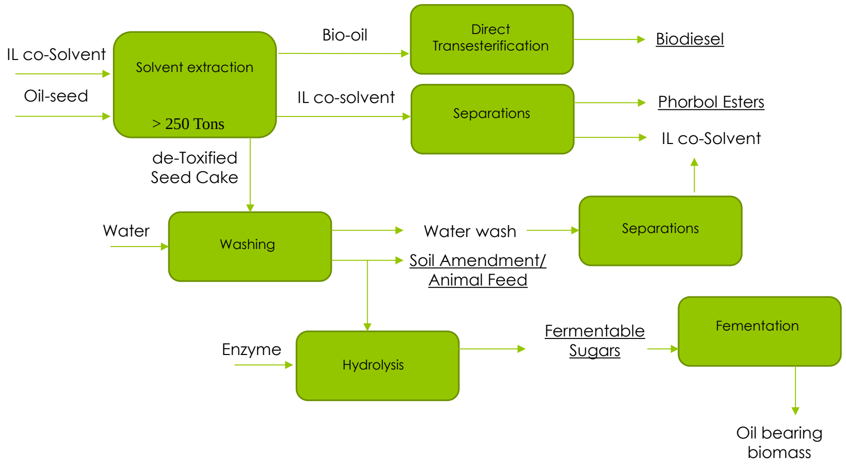


Biomass production and carbohydrate consumption by *R. toruloides*: batch one (open symbols) and batch two (closed symbols). Circles: xylose; Squares: glucose; triangles: cell mass.

Batch fermentation data

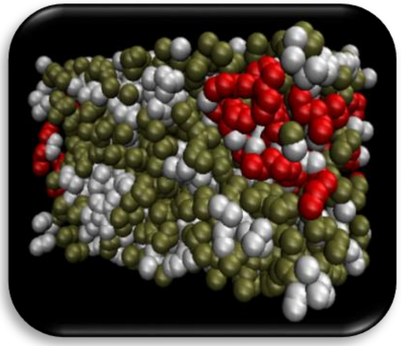
Batch	Cell mass	Cell mass fermentable sugars		Cell mass to lipid yield ($Y_{P/X}$)	Substrate to lipid yield ($Y_{P/S}$)
	(gdw/L)	Glucose % (w/w)[1]	Mannose % (w/w)[1]	% (w/w)[1]	(g/g)
1	9.1 (±0.2)	8.6 (±0.2)	0.9 (±0.1)	60.5 (±1.5)	0.12 (±0.07)
2	9.4 (±0.2)	9.8 (±0.2)	1.4 (±0.1)	57.4 (±0.3)	0.16 (±0.07)[2]

Summary

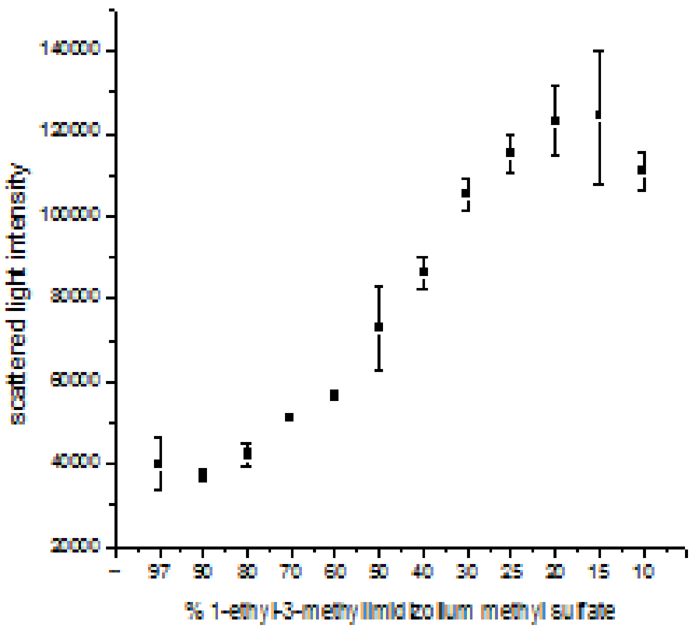


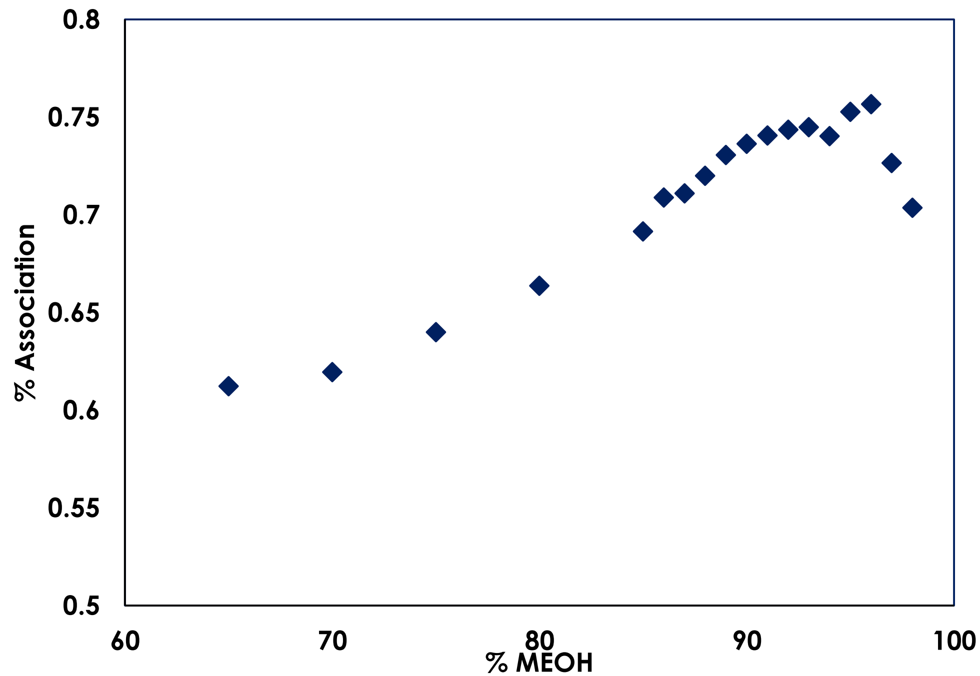
- IL co-solvents offer unique opportunities to expand treatment of bio-oil seeds.
- Co-solvents expand the number of solvent properties achieved at the molecular scale.
- By changing the nature of the polar co-solvent molecule, or the identify of the cation or anion, co-solvent systems can be tailored for uniqiue applications.
- The combination of methanol and hydrophilic IL's with a strong hydrogen bond disrupter provide a unique combination to extract and separate bio-oil as well as to pretreat biomass.
- The heterogeneous distribution of charge and hydrophobic/hydrophilic regions within the micro-scale solvent structure offers ability to extract and absorb polar molecules.
- IL co-solvents permit a novel platform to expand upon the products available from bio-oil bearing biomass

Related work



Red = Lipid
Green = Methanol
White = IL ions





(Left) scattered light intensity as function of concentration of MEOH, (right) clustering analysis of the same

Courtesy: Ken Benjamin SDSM&T

Acknowledgments

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Collaborators:

Greg Young, Guneet Kumar, Franz Nippgen, Sebastian Titterbrand, Melisa Imbrahovic.

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Presenter

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QUESTIONS?