A Novel Continuous Oil Seed Extraction Method for Jet Fuel Production

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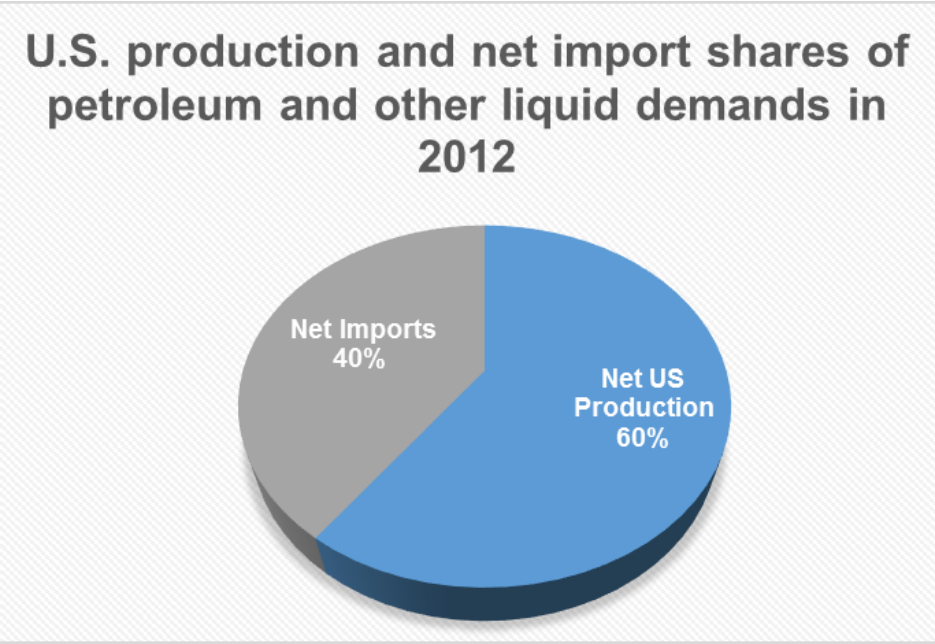
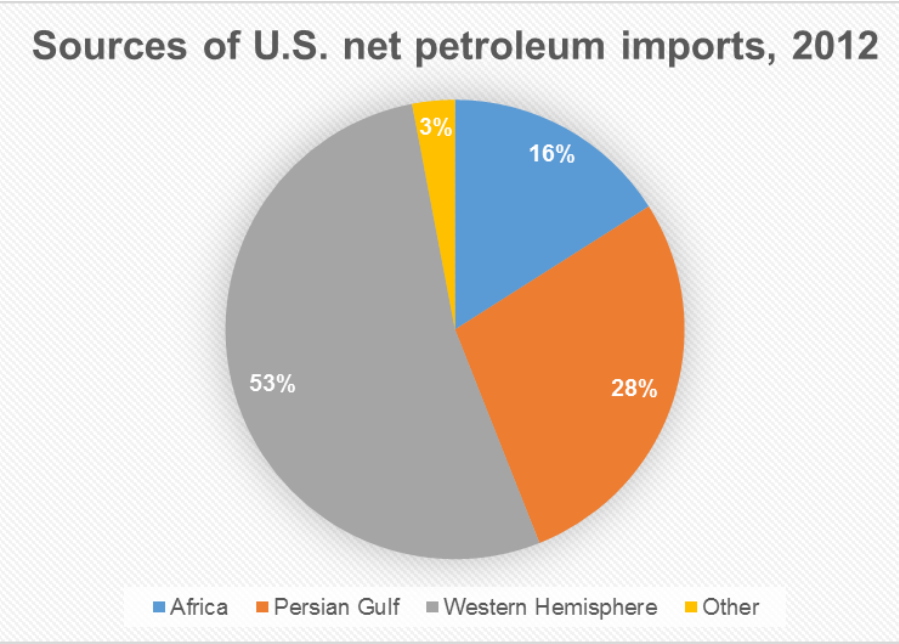
U.S. Dependence on Foreign Oil

Have Oil		Use Oil	
Saudi Arabia	26%	U.S.	26%
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Canada	4%
Venezuela	6%	Russia	3%
Russia	5%	Brazil	3%
Libya	3%	S. Korea	3%
Mexico	3%	France	3%
China	3%	India	3%
Nigeria	2%	Mexico	3%
U.S.	2%	Italy	2%

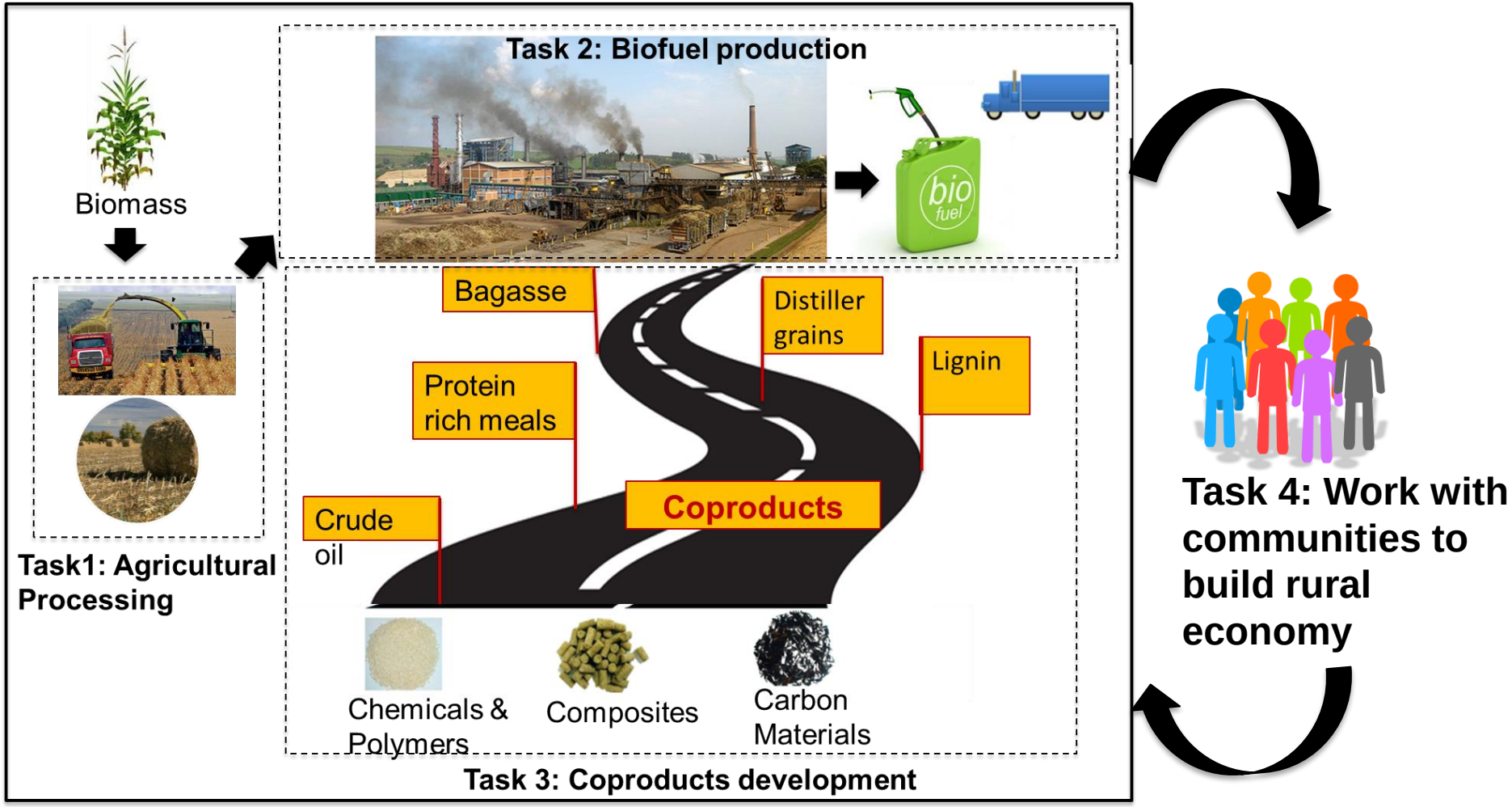
The U.S. uses more than the next 5 highest consuming nations combined.

Updated March 2003. Source: International Energy Annual 2001 (EIA), Tables 11.4 and 11.10.





Data source: http://www.eia.gov/energy_in_brief/article/foreign_oil_dependence.cfm



The Bioeconomy Roadmap

Challenges

Development of commercially viable biomass utilization technologies.

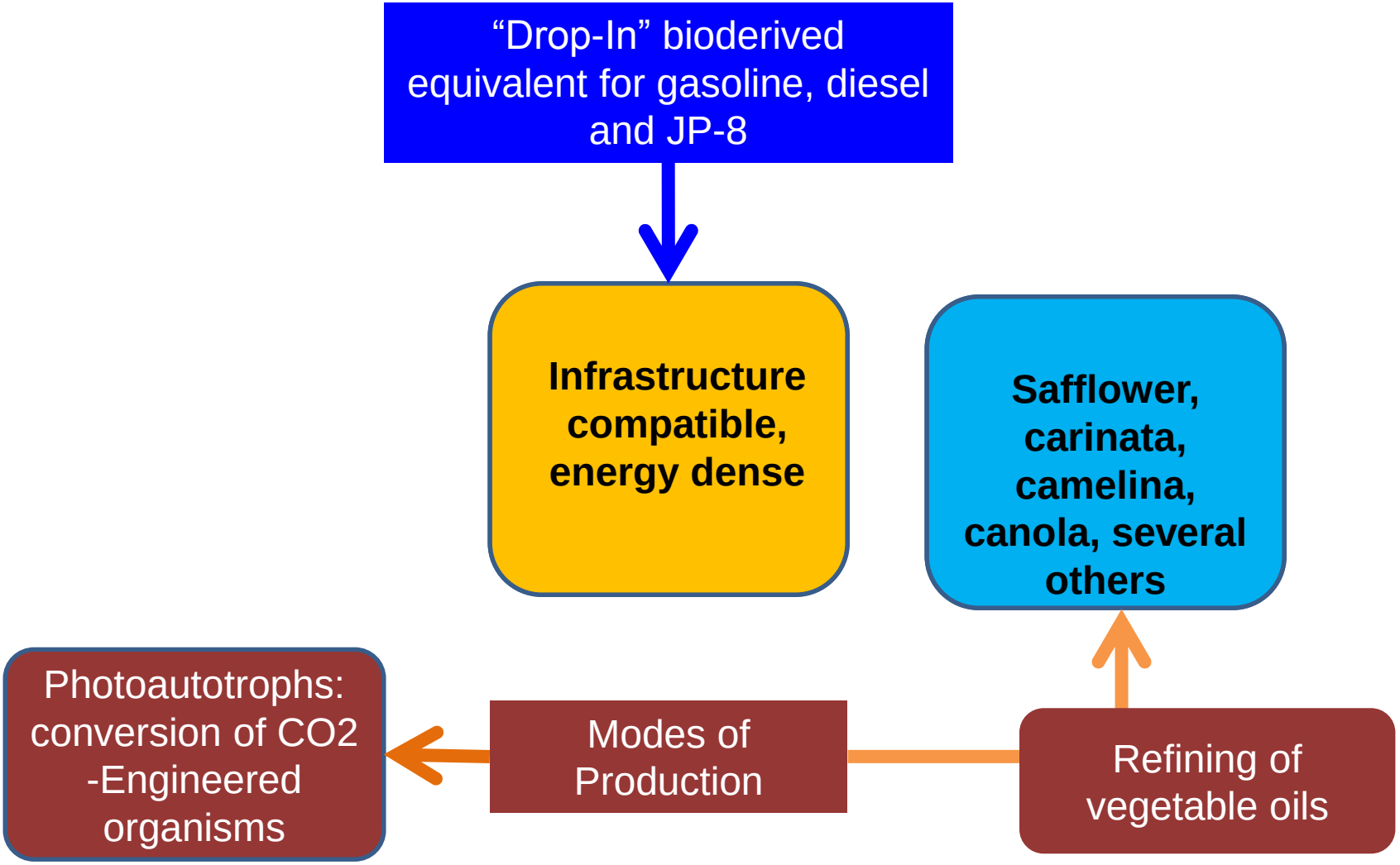
Sustainable and economic production of advanced biofuels.

Compatability with today's transportation infrastructure.

Oil quantity and fatty acid contents in oil are two major factors responsible for suitability of oil for aviation fuel.

Advanced biofuels from algae and non-food oil seeds are promising.

3rd Generation Advanced Biofuels



Opportunity

- US Navy initiative to use 50% blends of green diesel and jet fuel by 2020
- Annual market for 336 million gallons of fuel
- Larger national market of 140 billion gallons of fuel

Department of Defense Interest in Biofuels

- Navy sailing great green fleet in 2014
  - Green FA-18 Hornet
    - http://www.youtube.com/watch?v=VMyWOBjZRZ4&feature=related
  - Green AV-8B Harrier
    - http://youtu.be/K-P9_U0SzE8

Extrusion Pretreatment

Microbial Conversion

Feeding Trial

Objective

To evaluate and compare three oil extraction technologies, solvent extraction, cold press, and novel continuous extraction, for efficiently extracting oils from different non-food oilseeds for further conversion into aviation fuels.

Oilseed Varieties

Camelina seeds

Carinata seeds

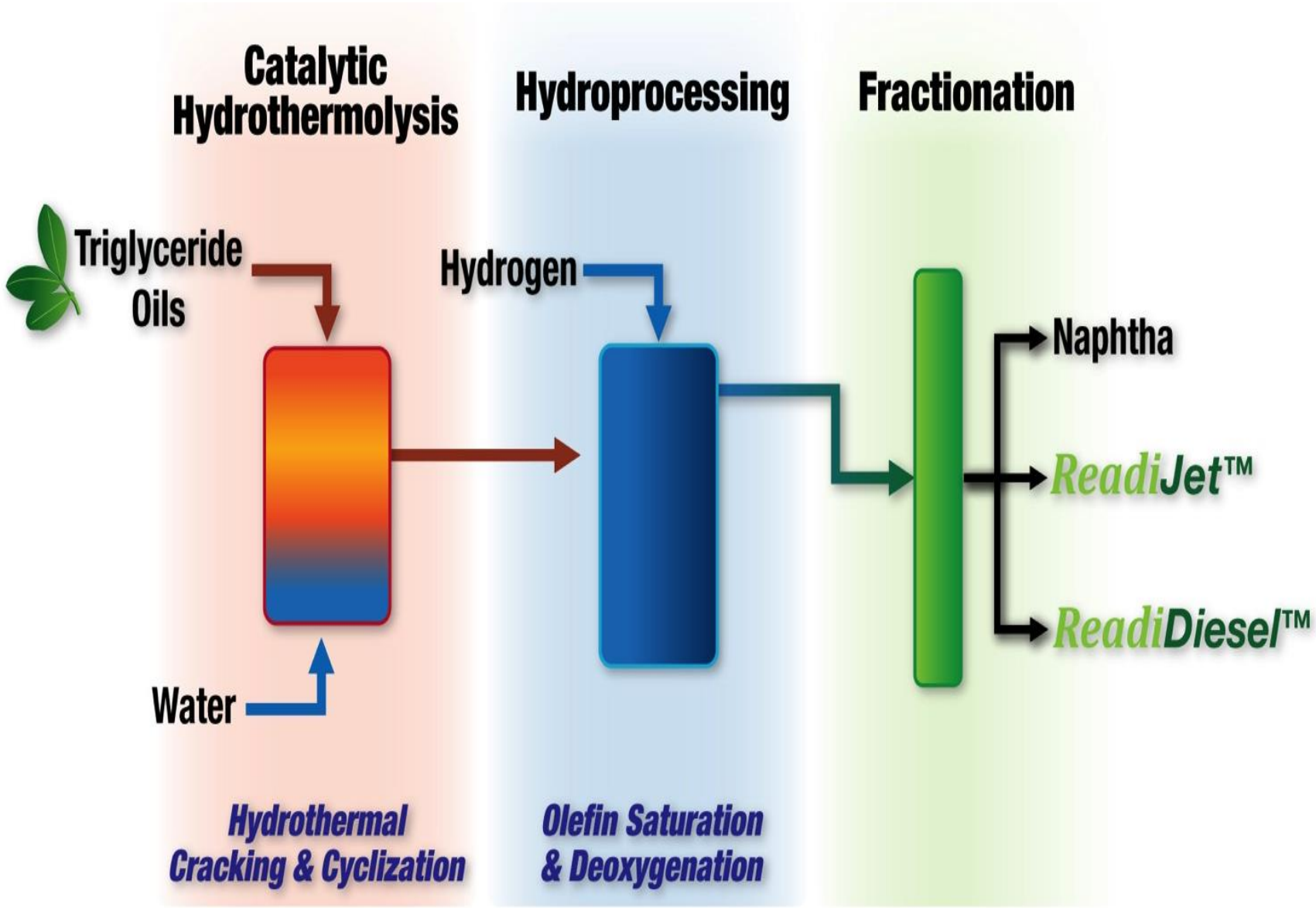
Flax seeds

Sunflower seeds

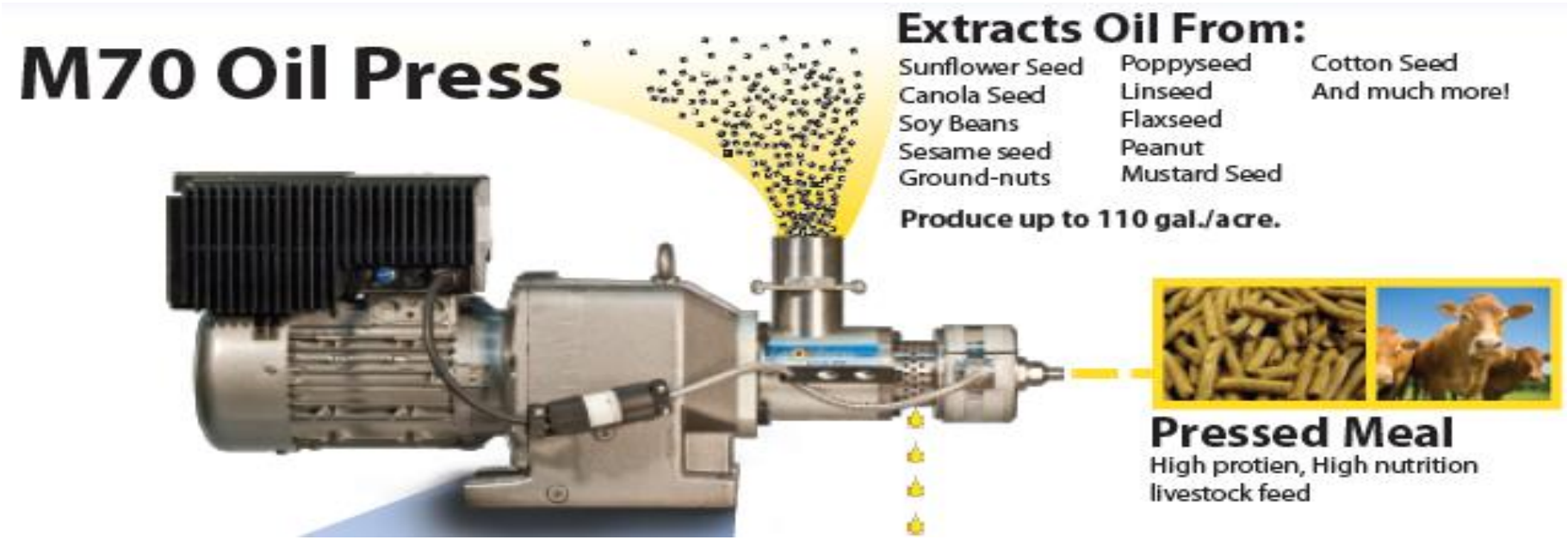
Canola seeds

Safflower seeds

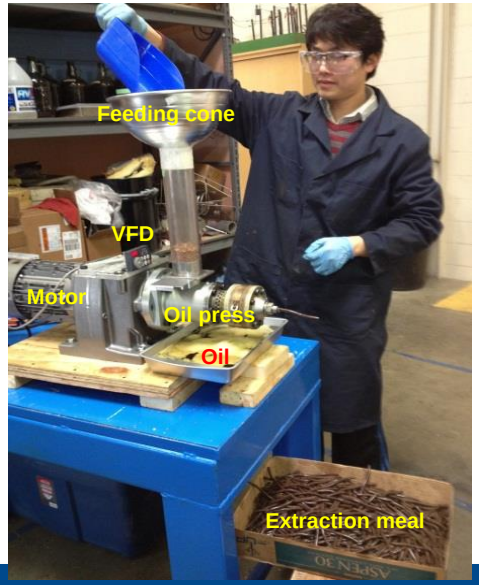
Applied Research Associates Hydrothermal Process *(patented)*



Cold press for oil extraction



http://blog.insta-pro.com/2013/02/19/is-the-stability-an-issue-in-extruded-or-extruded-expelled-oil-seed-meal-and-oil/



Oil Characterization

Oil extraction from canola seeds at different speeds

Extraction speed	pH value	Seed water content, %	Oil water content, %	Density (g/ml)	Viscosity (cP @20C)	Extraction efficiency, %
25HZ	6	4.89	0.06	0.833	85.57	84.25
20HZ	6	4.89	0.06	0.82	84.97	84.73
15HZ	6	4.89	0.05	0.893	87.23	86.25

Oil extraction from flax seeds at different speeds

Extraction speed	pH value	seeds water content, %	Oil water content, %	Density (g/ml)	Viscosity (cP@ 20°C)	Extraction efficiency (%)
27HZ	5	6.27	0.06	0.894	51.7	70.54
22HZ	5	6.27	0.09	0.900	50.2	74.9
17HZ	5	6.27	0.07	0.907	50.3	77.56

- **Different oilseeds required different extraction conditions.**
- **Extraction speed and time affect oil yield and properties.**
- **Higher speed and shorter time led to lower oil yield.**

Characterization of Cold Pressed Camelina Oil

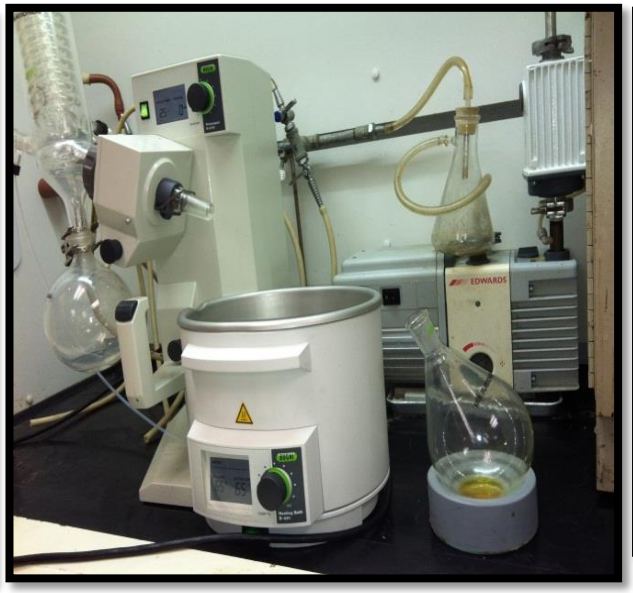
Screw speed, Hz	Die Dia, inch	Extraction Efficiency, %	Heating value, MJ/kg	Viscocity, cP	Density, kg/m3
15	0.22	78.6	39.72 ± 0.1	56.1 ± 0.1	913.7 ± 11.9
20	0.22	83.3	39.73 ± 0.1	57.0 ± 0.1	908.3 ± 5.9
25	0.22	81.0	39.74 ± 0.2	56.4 ± 0.3	910.0 ± 14.2
15	0.25	76.2	39.78 ± 0.2	56.1 ± 0.2	914.0 ± 4.6
20	0.25	76.2	39.77 ± 0.2	56.2 ± 0.1	912.3 ± 11.6
25	0.25	73.8	39.96 ± 0.2	55.9 ± 1.1	908.7 ± 3.8
15	0.28	73.8	39.95 ± 0.1	55.2 ± 1.2	911.7 ± 6.5
20	0.28	73.8	39.90 ± 0.2	56.0 ± 0.6	907.3 ± 6.7
25	0.28	71.4	39.95 ± 0.2	56.2 ± 0.3	903.7 ± 12.8

Characterization of Cold Pressed Carinata Oil

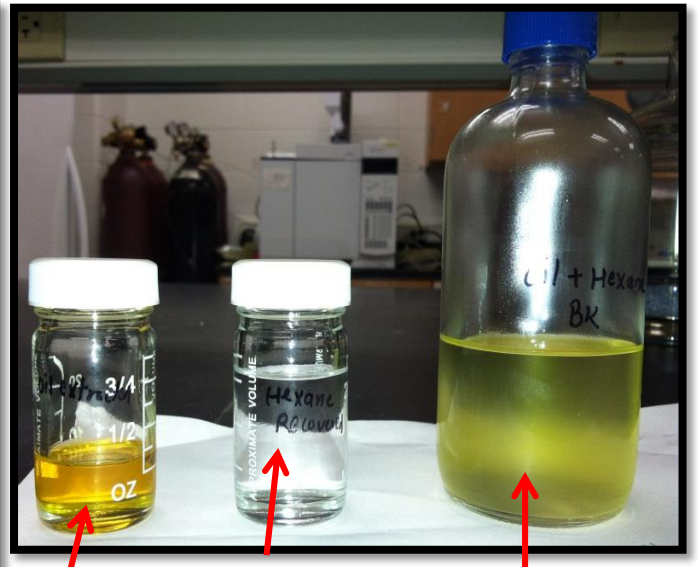
Screw speed, Hz	Die Dia, inch	Extraction Efficiency, %	Heating value, MJ/kg	Viscocity, cP	Density, kg/m3
15	0.22	79.1	40.40±0.2	70.0 ± 0.8	872.7 ± 8.5
20	0.22	81.4	40.32±0.2	70.4 ± 1.2	870.7 ± 2.8
25	0.22	79.1	40.57±0.3	70.5 ± 1.3	874.6 ± 10.4
15	0.25	79.1	40.19±0.7	70.3 ± 0.8	878.3 ± 6.2
20	0.25	76.7	40.51±0.1	71.5 ± 1.1	874.7 ± 4.9
25	0.25	74.4	40.47±0.1	71.4 ± 0.9	871.4 ± 10.5
15	0.28	86.0	40.44±0.1	69.9 ± 0.9	875.1 ± 6.3
20	0.28	65.1	40.36±0.3	70.5 ± 1.1	876.9 ± 11.2
25	0.28	65.1	40.48±0.1	69.5 ± 0.7	879.5 ± 2.6

Accelerated Solvent Extraction (ASE)

ASE System
For oil extraction



RotoVap System
Separates Oil and solvent mixture



Oil

Hexane recovered

Oil+Hexane mixture

- Effect of extraction temperature, extraction time and solvents on oil recovery was evaluated for canola seeds using ASE method

Physical properties of canola oil produced by solvent extraction

No.	Solvent	Boiling point (°C)	Density (g/ml)	Viscosity (cp) at 25 °C	Flash point (°C)	Auto ignition temperature (°C)
1	Hexane	69	0.6548	0.294	- 26	234
2	Ethanol	78	0.789	1.074	14	363
3	Ethyl acetate	77	0.897	0.426	- 4	460
4	1-butanol	118	0.81	3.0	35	343

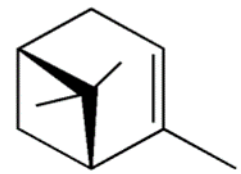
Oil extraction from canola seeds using different solvents

S No	Temp	Time	% Extraction Efficiency				
	[°C]	[min]	Hexane	Pinene	Ethanol	Ethyl Acetate	Butanol
1	80	40	69.3	50.7	51.2	62.4	41.2
2	120	40	81.7	70.0	54.9	87.6	71.2
3	80	90	74.6	56.1	36.6	76.6	16.6
4	120	90	87.1	77.1	69.5	99.4	51.7
5	80	40	72.9	51.0	51.5	65.6	58.8
6	120	40	87.1	67.8	22.2	90.2	86.1
7	80	90	65.4	60.5	42.0	80.2	76.8
8	120	90	100.2	77.8	50.2	100.0	68.0
9	100	65	84.9	66.6	47.6	93.2	76.6

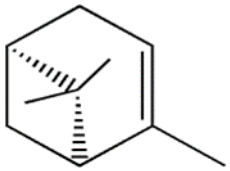
- Increase in temperature and extraction time improved the oil recovery for all the solvents
- After hexane, acetate showed high potential for oil extraction followed by pinene, butanol and ethanol.

Green Solvent - Terpene

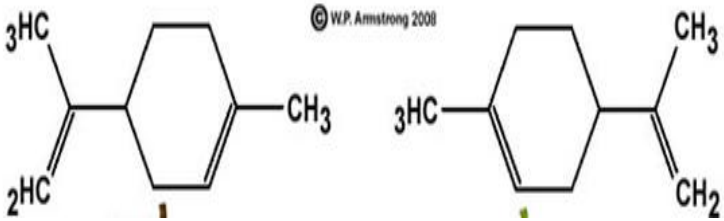
- Environmentally safer than Hexane
- Natural solvents existing both in citrus fruits and in many other plants
- Include hydrocarbons with C5H8 isoprene units
- d-Limonene: derived from citrus peels
- α-Pinene: from gum turpentine in pine gum

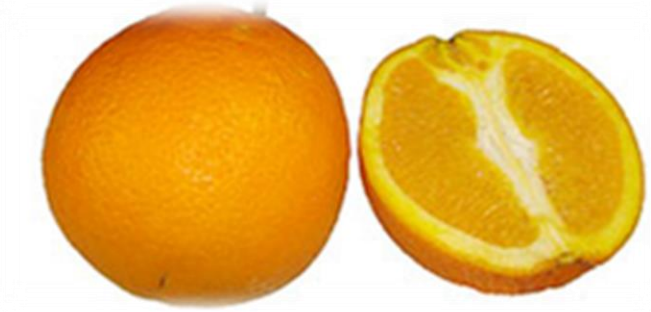


(−)-α-Pinene



(+)-α-Pinene





Solvent-Assisted Extrusion (SAE)

- Oil extraction methods
  - Using **single screw extruder** to determine the upper limit of available oil from the oilseeds
  - Using **single screw extruder and green solvent simultaneously to** extract the oil from the oil seeds
  - Quality analysis of the extracted oils

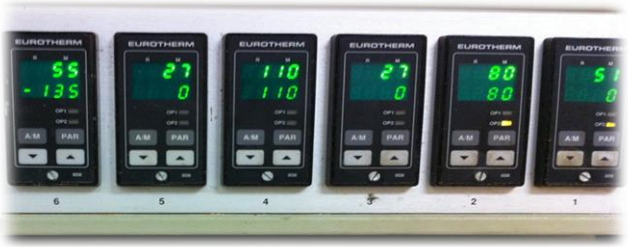
Experimental Designs

- Evaluating of the effect of extrusion parameters on oil extraction yield & quality

T (˚C)	40-60-60	40-60-80	40-60-100
SS (rpm)	40	60	80

- Evaluating the effect of green-solvent assisted extrusion parameters on oil extraction yield & quality.

T (˚C)	40-80-80	40-80-120
SS (rpm)	80	150
R(W/W%)	10	15
solvents	α-Pinene	L-Limonene

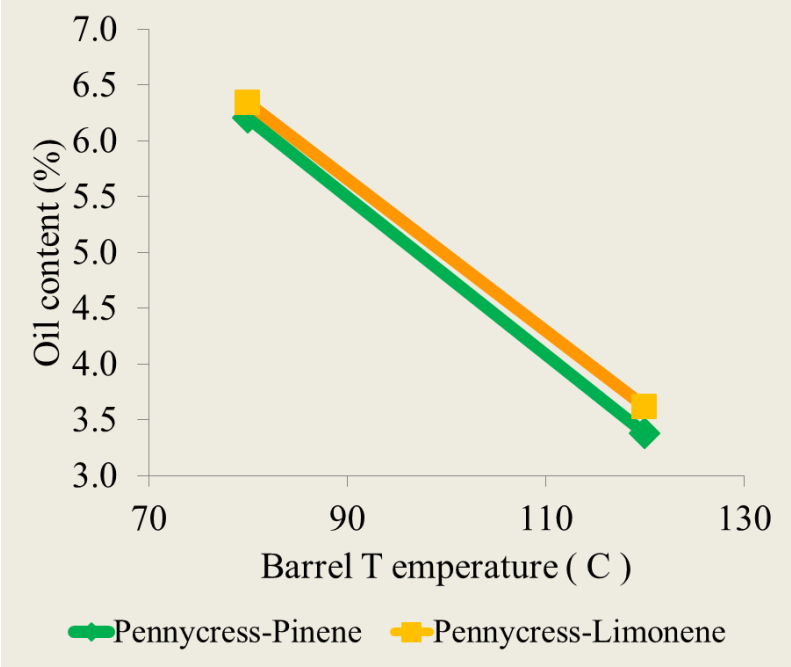


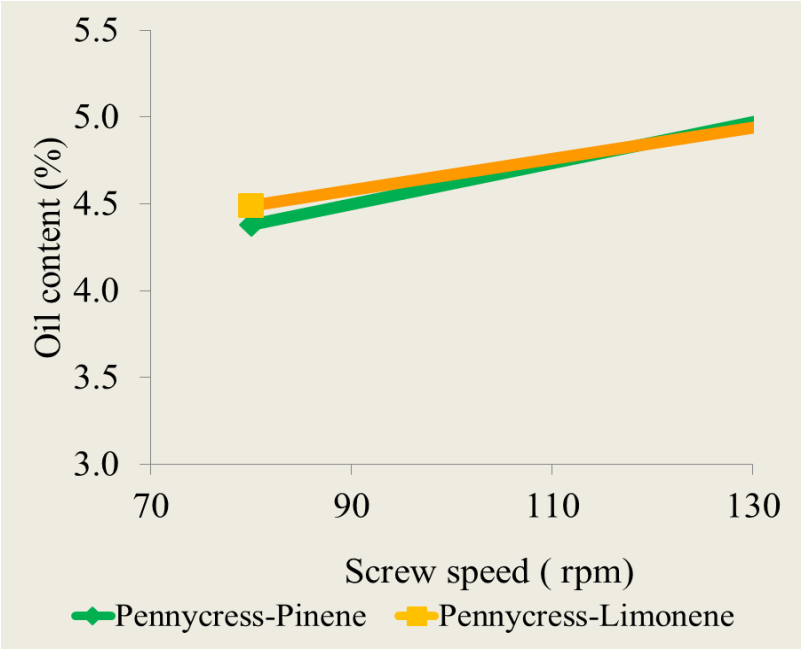
Single-screw (Brabender, Plasti-Corder (PL 2000)

Crambe oil, 80 ˚C, 80 rpm

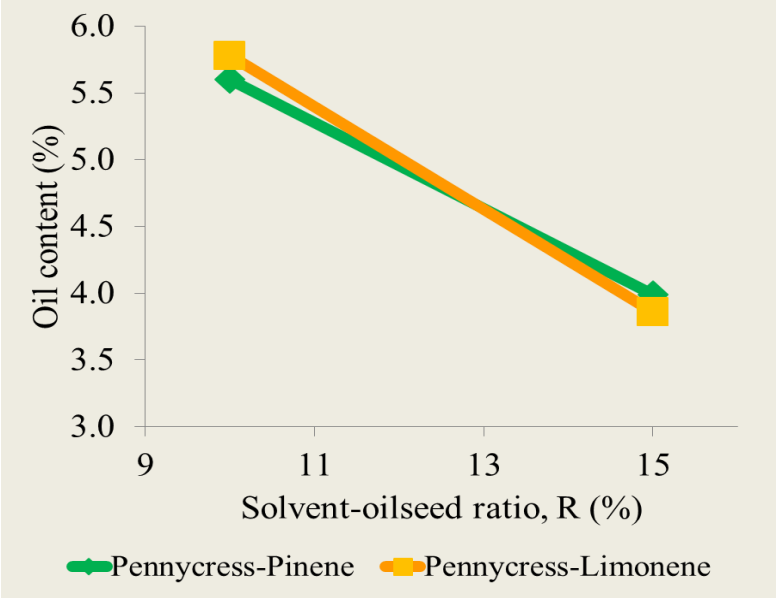
Pennycress oil , 80 ˚C, 80 rpm

Effect of SAE Parameters on Oil Extraction

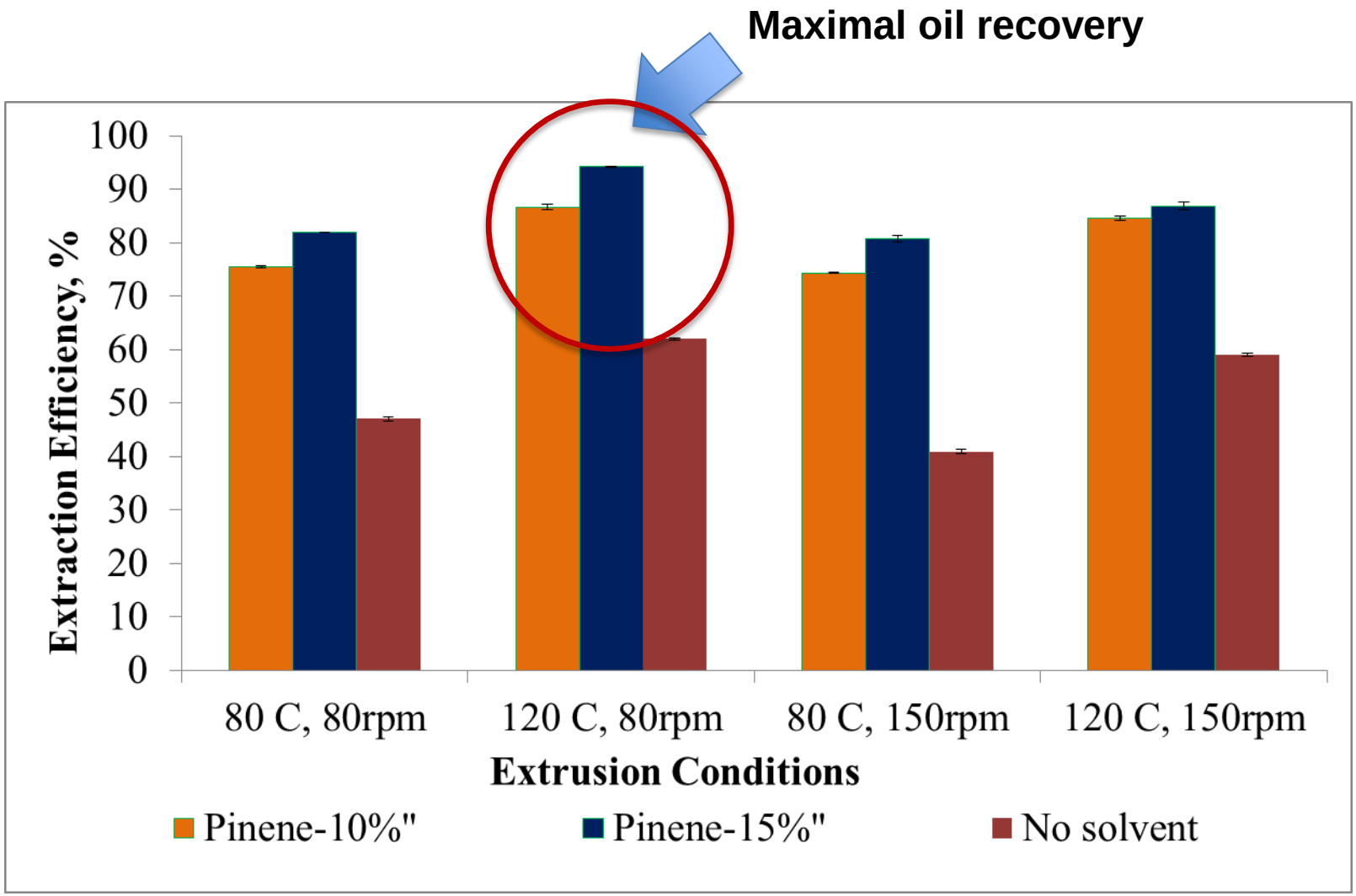




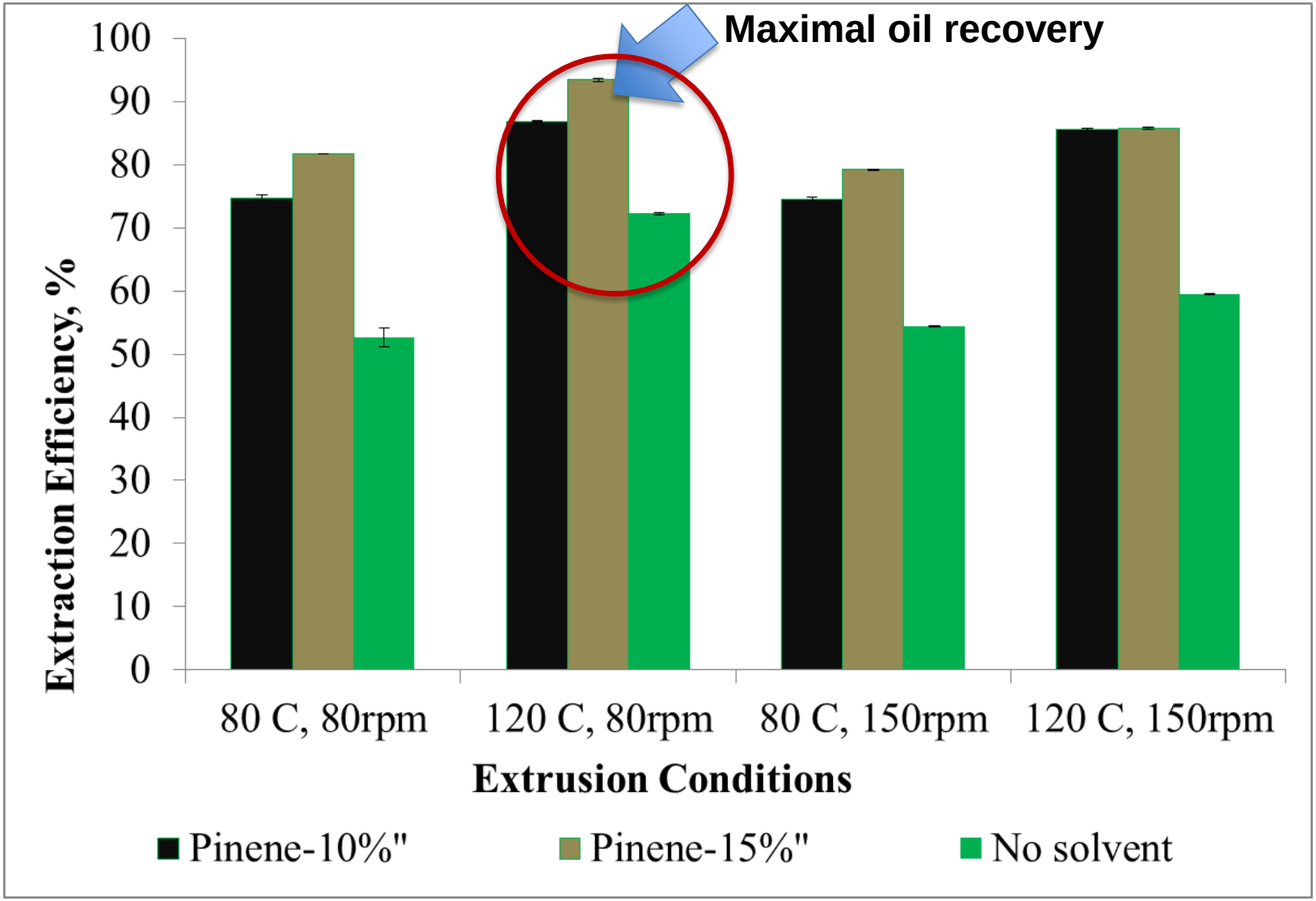
- Increasing T and SS reduced and increased the residual oil content of the extruded meal, respectively. Perhaps, the diminution of the SS increased the mean residence time of the extruding seeds and resulted in more oil release from the broken cell walls.
- Increasing R, reduced the oil residual content in extrudates implying the positive effect of R on SAE processing.
- Type of solvent did not show significant effect on oil residual content of the extrudates (α=0.05)



Pennycress seeds



Crambe Seeds

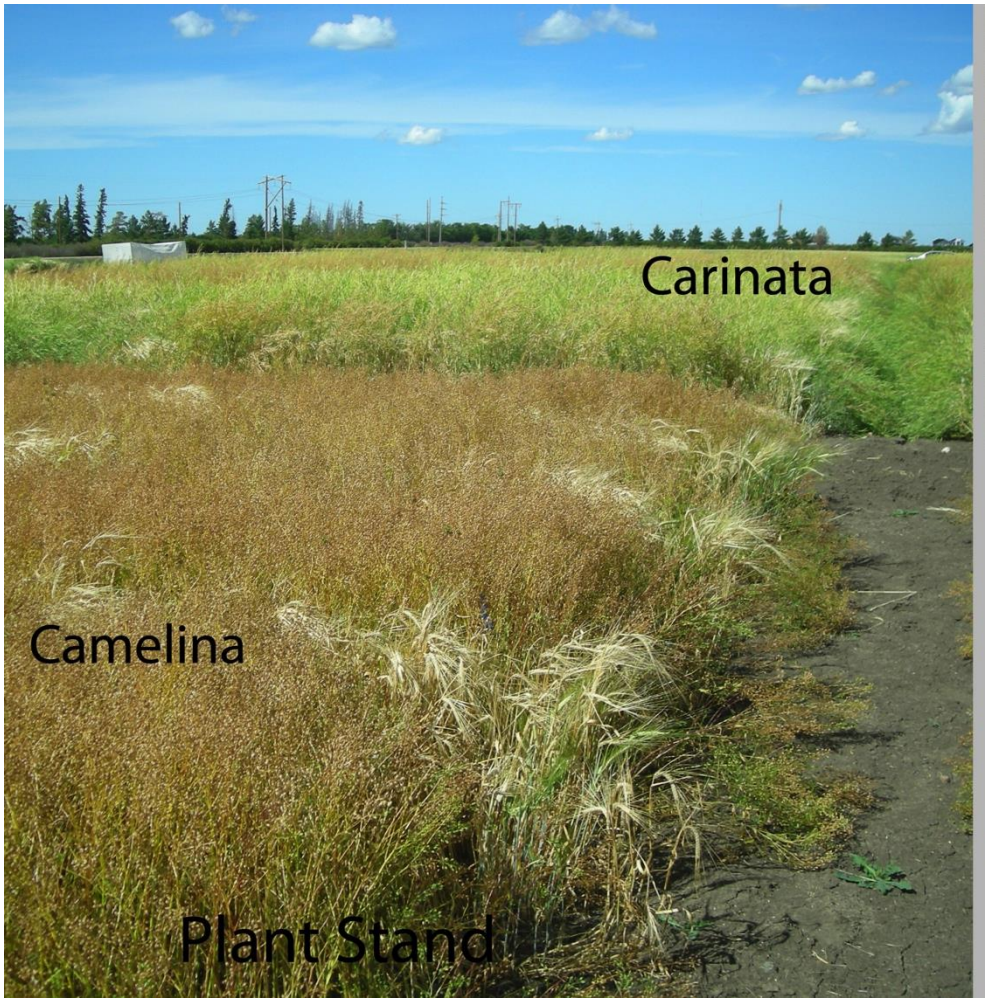


Properties of Pennycress and Crambe Oils extracted using SAE (120 °C, 80 RPM)

	Pennycress		Crambe	
	Pinene			
	10%	15%	10%	15%
Density, (Kg/m3)	898 a± 20	901 a±20	868 a±30	858 a±20
Acid value (mgKOH/g)	0.61 a± 0.02	0.62 a±0.01	0.51 a±0.0	0.52 a±0.0
Heating Value (MJ/kg)	39.45 a± 0.13	39. 39 a±0.14	40.53a±0.11	40.498 a±0.08

- **SAE operating parameters had no significant effect on solvent-extruded oil qualities, in terms of density, acid value, and heating value**

CH Pilot System



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Questions???

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