Chemical Engineering

Rowan University

COLLEGE OF ENGINEERING

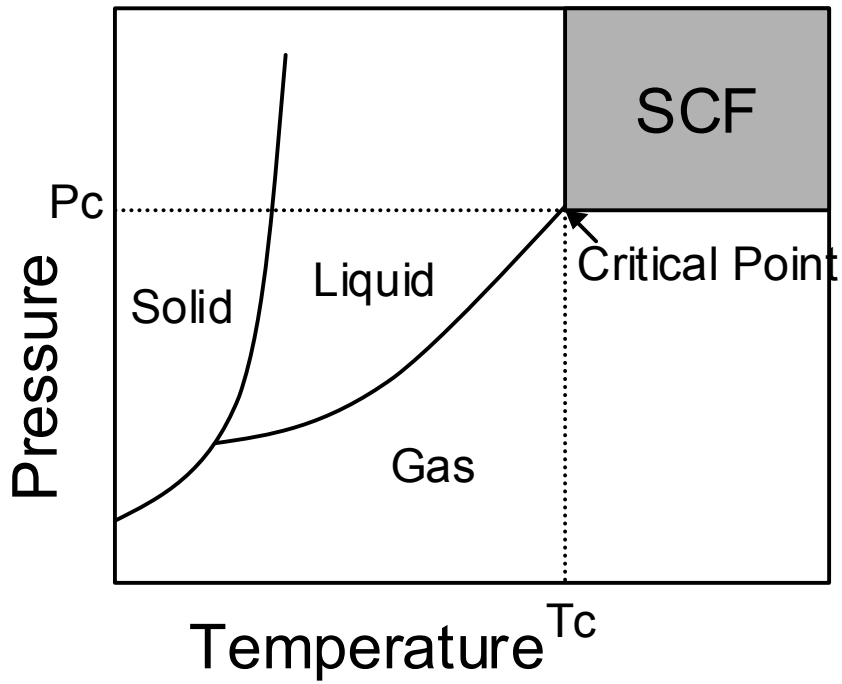
Economic Feasibility Study on the Supercritical Fluid Extraction of Edible Oils

Michael Gifford, Elizabeth Biancani, William Kearsley, Walter Maluchnik, Stephanie Farrell, Mariano J. Savelski, and Robert P. Hesketh

Supercritical carbon dioxide extraction is currently used in several food and pharmaceutical manufacturing applications. Its “greener” nature makes it a desirable option when compared with traditional organic solvent extractions. The purpose of this work is to compare the cost of using supercritical CO_2 to commercially extract peanut oil with that of the traditional hexane extraction process. Solubility values of peanut oil in supercritical CO_2 were also obtained under different conditions of temperature and pressure.

Supercritical Fluids

- Critical Temperature and Pressure
- Properties
  - Density of a liquid
  - Viscosity of a gas
  - Low surface tension
  - Adjustable density



Supercritical Fluids in Industry

- Reactions
  - SC Water Oxidation
  - Catalysis
- Pharmaceuticals
  - Particle Formulation
  - Drug Delivery
- Extraction
  - Petroleum
  - Coffee Decaffeination
  - Essential Oils

http://www.expsep.co.uk/

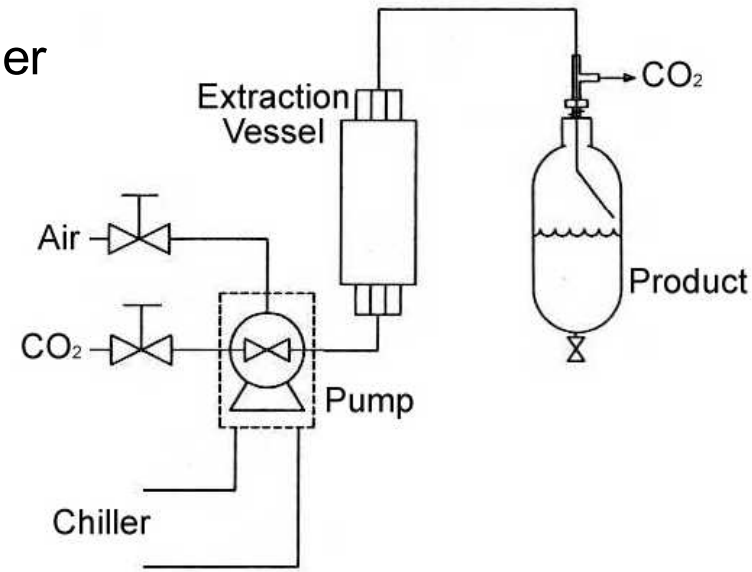
Carbon Dioxide Extraction

- Why CO_2?
  - "Greener" alternative to organic solvents
    - Non-toxic
    - Nonflammable
    - Relatively Inert
    - No detectable residue
  - Nonpolar solvent
  - Low critical conditions
    - Tc = 31.1ºC
    - Pc = 72.8 atm
  - Low cost

Rowan Environmental Engineering Department

Experimental Apparatus

- Supercritical Fluid Technologies SFT-150
  - LED Temperature display/controller
    - Precision: ± 0.5ºC
  - Max Vessel Temperature: 300ºC
  - Max Operating Pressure: 680atm
  - Max Flowrate: 250g/min CO_2
  - Rupture disc safeguard
  - External Collection Vessel
  - Hand-tight vessel seals



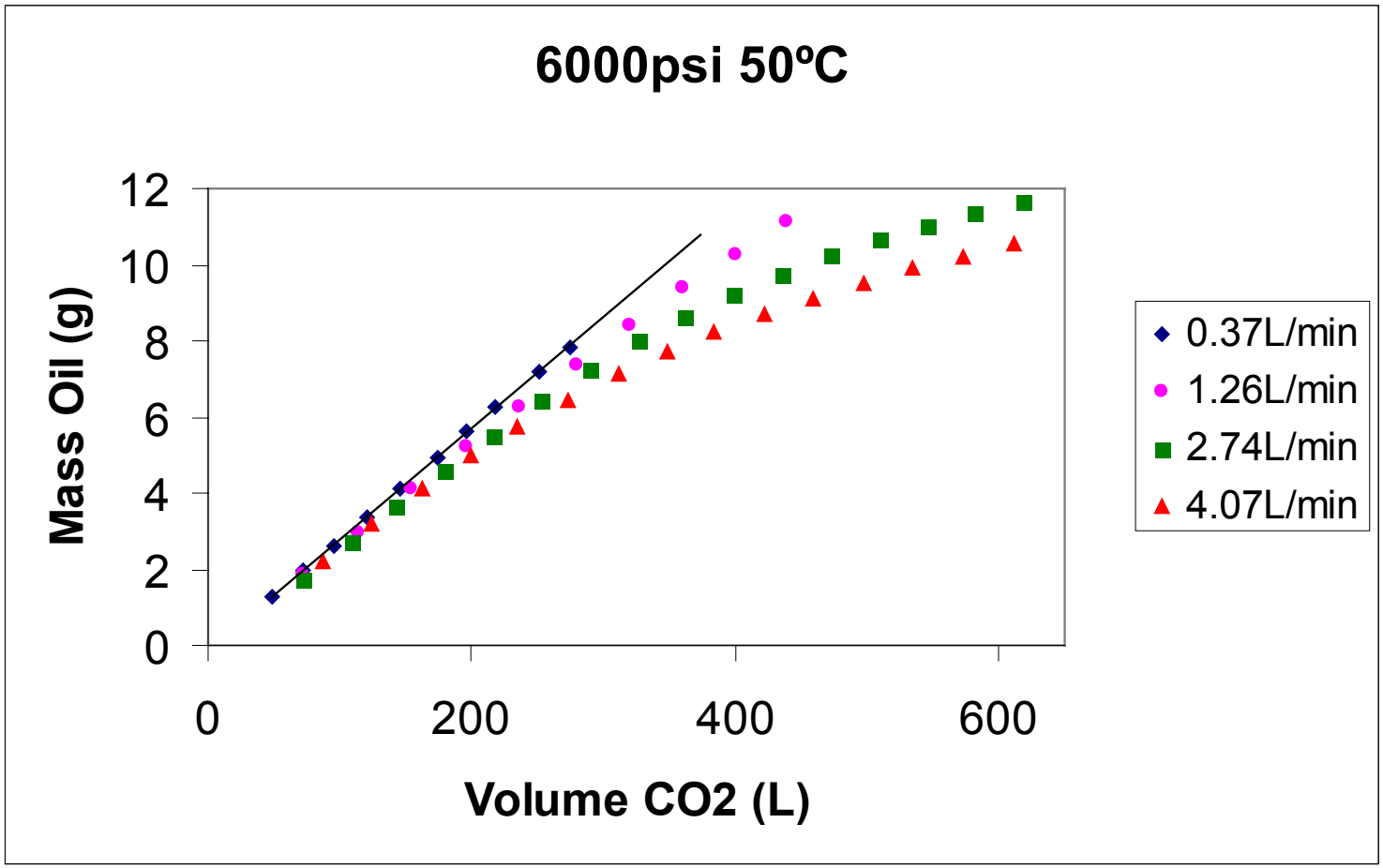
Materials

- Peanuts
  - Extra large, raw, unsalted
  - Supplied by Natural Health, Clementon, NJ
- Carbon Dioxide
  - Bone dry liquid with educator tube
  - 99.8% purity
  - Supplied by Messer Gas Technologies & Service Group

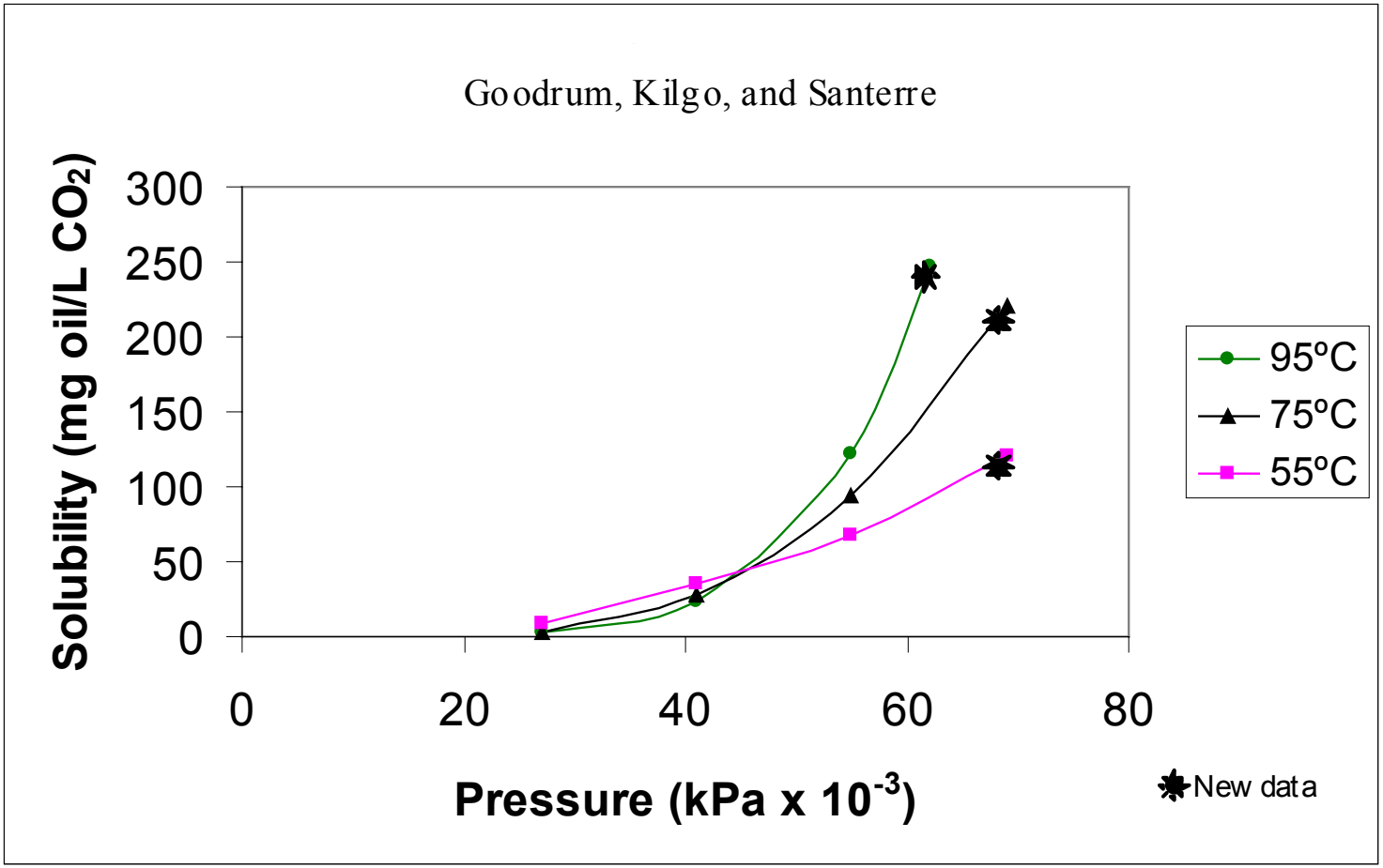
Procedure

- Setup
  - Sample chopped in food processor for 1min ± 0.1s
  - Loaded and packed into vessel
    - Glass wool used to prevent entrainment
  - Temperature and pressure set
  - CO_2 flow initiated
- Sampling
  - Sample weighed at volume increments
  - Gas volume recorded

Solubility Determination

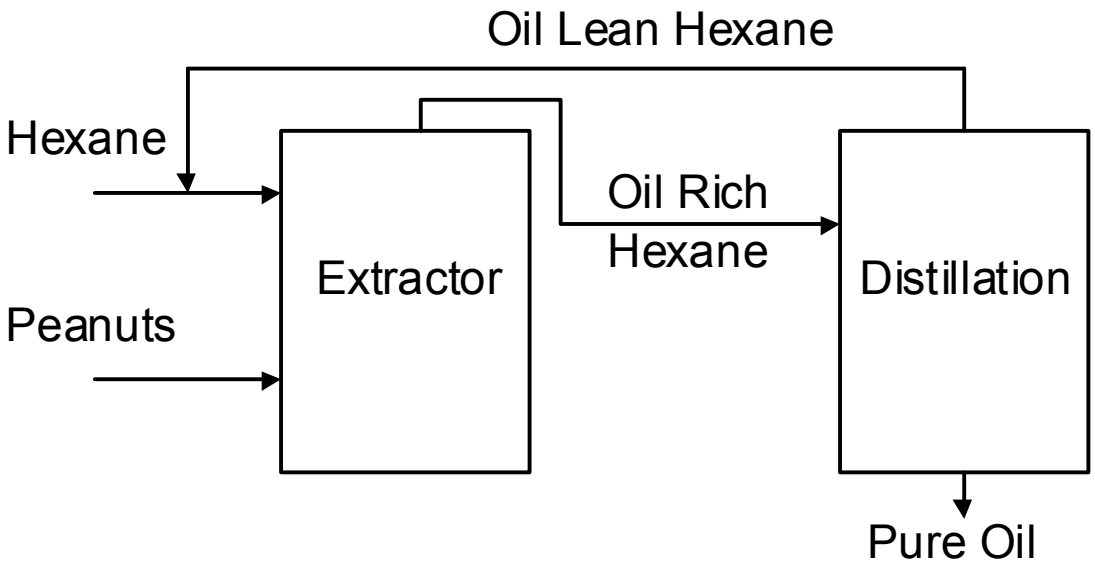


Peanut Oil Solubility



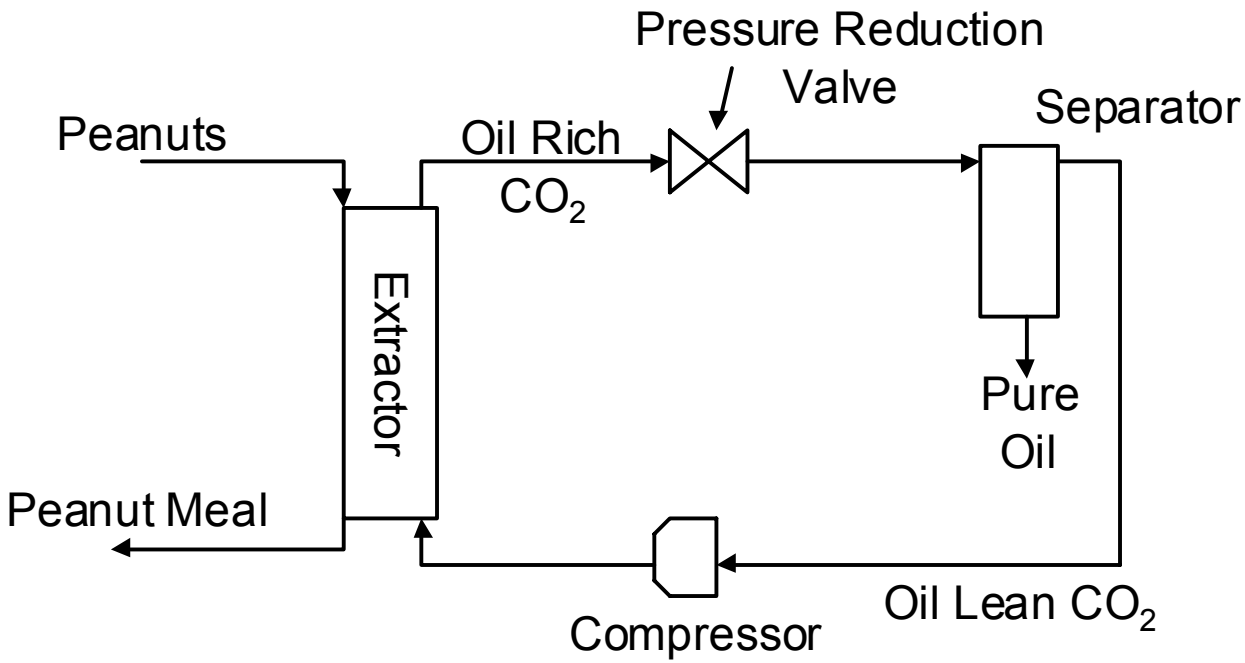
Hexane

- Major Process Costs
  - Materials (Peanuts, Hexane)
  - Distillation



Supercritical

- Major Process Costs
  - Materials (CO_2, Peanuts)
  - Compression



Results

- CO_2
  - 0.07$/lb
  - Max Solubility
    - 38 mg/g
  - CO_2 Flow
    - 87 million lb/yr
  - Energy input
    - 1.8 GWh/yr
  - Operating Cost
    - 6.2 million $/yr
- Hexane
  - 0.07$/lb
  - Max Solubility
    - 80mg/g
  - Hexane Flow
    - 38 million lb/yr
  - Energy input
    - 4.6 GWh/yr
  - Operating Cost
    - 14 million $/yr

Cost Comparison Hexane vs. CO_2

- Conditions
  - Peanut feed = 10 million lb/yr
  - Yeild = 30% (3 million lb/yr oil)
  - Supercritical extraction conditions
    - P = 550bar
    - T = 55°C
  - For separation, P = 270bar
- Use mass and energy balances with solubility data to determine the more energy efficient process

Conclusion

- SCFE Advantageous for Oil Extraction
  - Economical, uses half the energy of distillation
  - More environmentally friendly than hexane
  - Improved plant safety
  - One-step process

Future Plans

- Further Economic Studies
  - More detailed, broader analysis
  - Compare product qualities
- Improve Solubility Data
- Explore Other Oilseeds
- Develop Undergraduate Experiment