Supercritical Fluid Extraction _ New Innovations

Contents

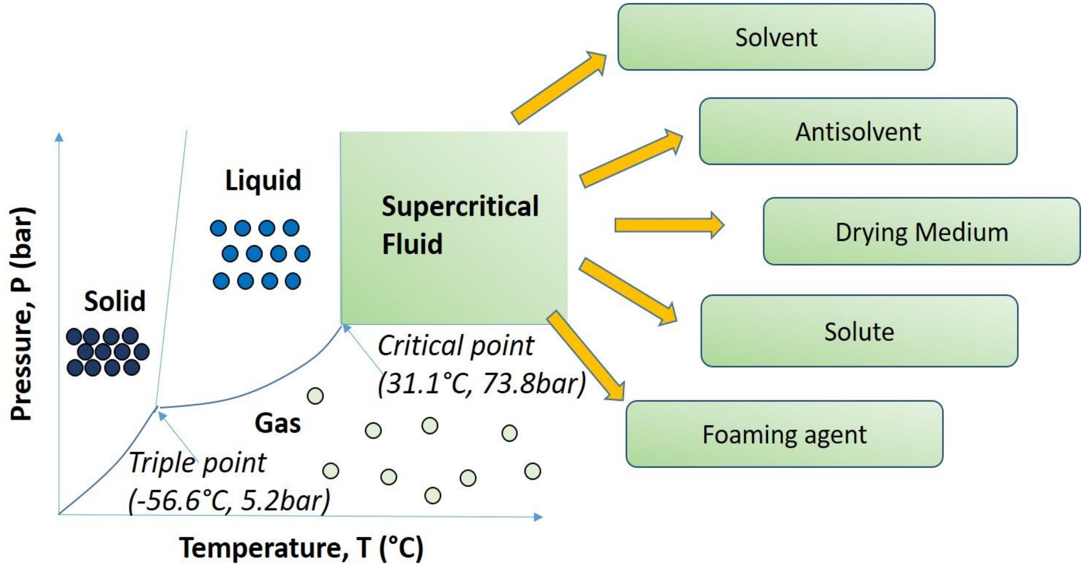
1. Introduction

- The innovations in SCF technology leads to improvement in extraction using,
  - Enhanced Equipment Design,
  - Novel Extraction Methodologies, And
  - Advanced processing techniques
- As SCF technology is very specific, researchers working hard to explore new possibilities for extracting a wide range of compounds with **greater efficiency, selectivity, and sustainability.**

1. Introduction (Cont.)

a. Advancement in equipment design have **improved efficiency and versatility.**
   - **Modular and customizable systems** offer flexibility for different sample sizes and types.
   - **Automation and control systems** streamline operations, improving reproducibility

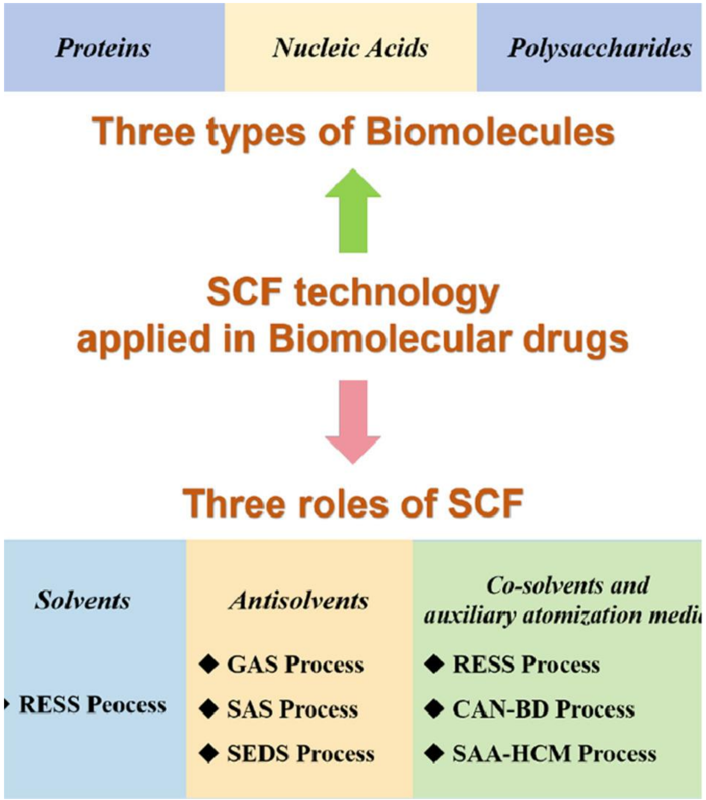
b. Materials science advancements have **improved durability and safety,** allowing for handling aggressive solvents and higher operating pressures, expanding the range of applications for SFE technology.



1. Introduction (Cont.)

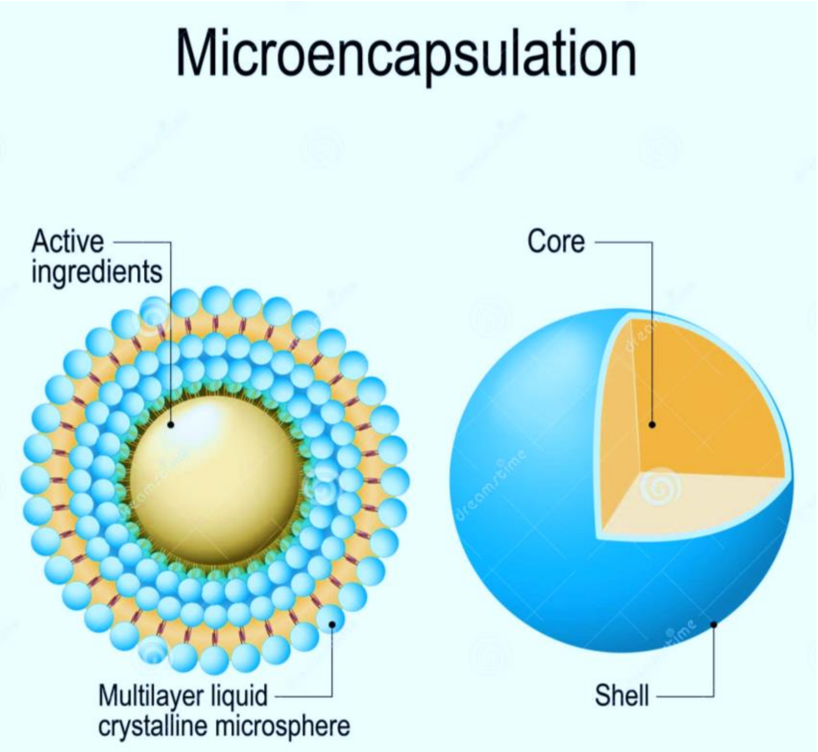
Role of SCF in different technology

- Technologies using SCF as solvent
  i. **RESS** (Rapid Expansion of Supercritical Solution)
  ii. **RESOLV** (Rapid Expansion Using SCF As A Solvent Into A Liquid Solvent)
- Technologies using SCF as Anti-solvent
  i. **GAS** (Gaseous Anti-solvent)
  ii. **PCA** (Particles by Compressed Anti-solvent)
  iii. **SAS** (Super-critical Anti-solvent)
  iv. **ASES** (Aerosol Anti-solvent Extraction System)
  v. **SEDS** (Solution Enhanced Dispersion into a liquid Solvent)



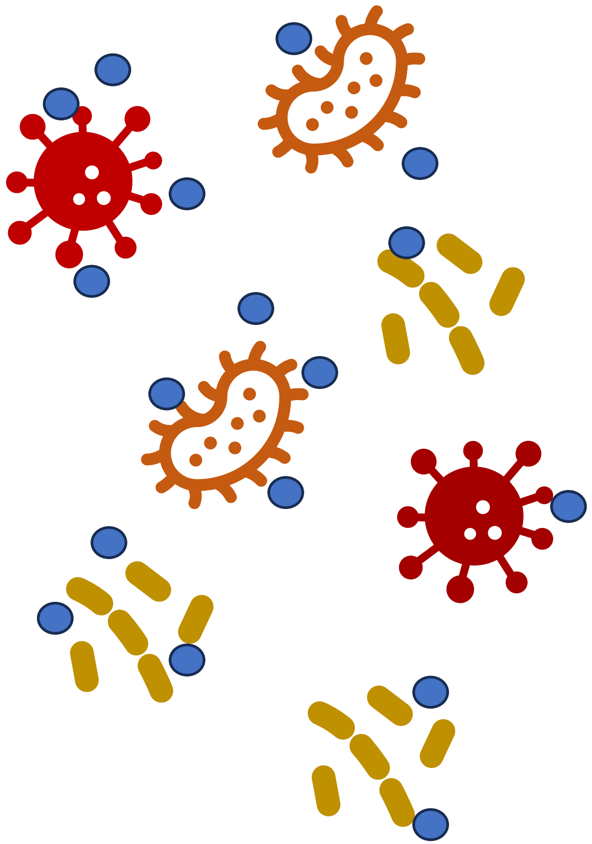
2. Microencapsulation Tool

- SFE as a microencapsulation tool for **Rapid Expansion of Supercritical Solution** is a great technological contribution
  - Dissolve active & coating ingredient
  - Holding SCF having solute at high pressure
  - Expansion through orifice or capillary device
  - Due to supersaturation, coating material deposited on the active ingredient followed by solvation.
  - Resulting formation of micro-capsule.



3. Microbial Inactivation

- In year 2017, Berenhauser et al., found that microbial reduction is greater at being exposed with CO_2 as a solvent at high pressure of 20 Mpa for 120 min.
  - Reduction in **intracellular/interstitial pH** of bacterial cell
  - Deceases **microbial resistance**
  - Affect **permeability** of internal lipophilic layer with structural and functional disorders due to CO_2 accumulation.
  - Inhibit or **inactivate essential enzymes** need by organism.
  - **Production of carbonic acid and bicarbonate** ion leading Lethal damage to the biological system of the microbes.
  - **Extraction of vital component** from the cell membrane of bacteria.

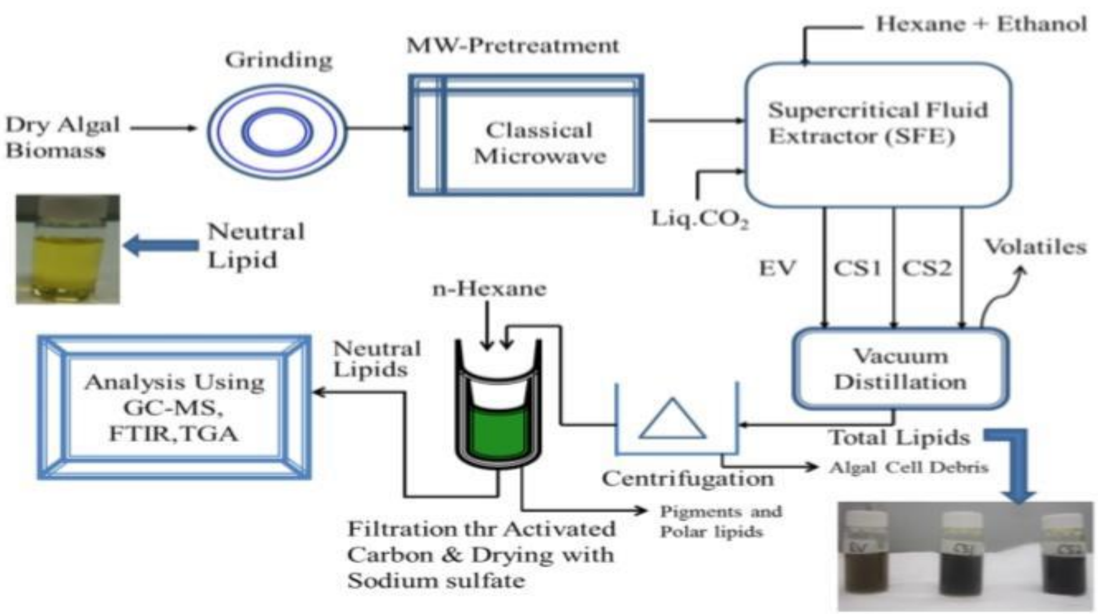


Accumulation of CO_2 on microbes

4. Novel Extraction Methodologies

- As per study coined by patil et al.(2017) on "**Extraction of bio-oils from algae with supercritical carbon dioxide and co-solvents**" in which extractions were carried out at 370 bar and 80 °C, then CS1and CS2 operated at 100-370 bar, 25°C and 0-100 bar, 25°C respectively.

  - CS1: **High pressure separator** (First stage of separation) and
  - CS2: **Low pressure separator** (Second stage of separation).



4. Novel Extraction Methodologies (Cont.)

- Experimental conditions :—
  - Dry algal biomass powder (12% MC_{db}) used — **30g**
  - Reaction pressure & temperature — **200- 370 bar/ 40-80°C**
  - Reaction time — **60 min**
  - CO_2 flow-rate — **200 g/min** reduced to 100 g/min)
- As a result,
  - Researchers found that yields of algal liquid to be slightly higher on increasing pressure and temperature.
  - Maximum total algal lipid yield (31.37% based on dry basis) observed with
    a. pressure 340 bar,
    b. co-solvent (Hexane+ Ethanol; 1:1) to algae/solid ratio (SSR) of 12:1,
    c. Temperature 80 ˚C and
    d. reaction time of 60 min under controlled CO_2 flow-rate condition.
  - The percentage of highly valuable eico-sapentanoic acid, EPA (C20:5n3) extracted from algae were found in the range of 20- 32%.

4. Novel Extraction Methodologies (Cont.)

Proces / application	Process condition	Effect and results	References
Extraction of sunflower oil from sunflower seed (Fluid) (Temperature) (Pressure) (solvent flowrate)	Sunflower seed (0.5 mm to1.00 mm) – SC-CO_2 + ethanol – 333 K–373 K – 20 MPa–40 MPa – 0.83 -2.50 × 10^{-4} kg/s	Extraction yield increases with increasing pressure, solvent mass flow and co-solvent.	Rai et al., (2016)
Extraction of Jatropha oil (Fluid) (Temperature) (Pressure) (solvent flowrate)	Jatropha seed (0.90 mm) – SC-CO_2 – 50 °C – 30 Mpa – 3.23 × 10–3 kg/min	Max. 51.5% oil at optimum condition with 8 fatty acid (determined by GC-MS)	Mi´ci´c et al.2015
Extraction of sesame seed oil (Fluid) (Temperature) (Pressure) (solvent flowrate)	Sesame seed – SC-CO_2 – 50 °C to 70 °C – 250 bar–350 bar – 2 ml/min	Created user-friendly Excel interface to adjust the yields of an extraction column for SCF extraction	Cabeza et al., 2016

4. Novel Extraction Methodologies (Cont.)

Proces / application	Process condition	Effect and results	References
Guava seed oil from guava seeds (Fluid) (Temperature) (Pressure) (solvent flowrate)	Guava seed - $SC\text{-}CO_2$ - 313 K–333 K - 20 MPa–35 MPa - 30 g/min	Obtained max. 13.9 % w/w on the oil yield at 35.7 MPa and 325 K.	Ceron et al. (2016)
Fragrance from mangonalia Kobus	- 40°C and - 400 bar pressure.	Yield was 0.27%	Cho et al. (2015)
Extraction of cholesterol and some other fats without removing polar fats that is liable for sensory characteristics (Fluid) (Temperature) (Pressure) (solvent flowrate)	Sample: 115g dried egg yolk Extractor: Capacity 300mL Extraction (P-T-Density CO_2) Separator Capacity: 103mL - $SC\text{-}CO_2$ - 400-550 °C - 186 -713 bar - 5–10 L/min	Under extreme conditions (426 bar/55 _C), 36% of total fat and ~66% of whole cholesterol extracted	Ghosh et al., 2018

5. Challenges & Future Perspective

- Supercritical Fluid Extraction (SFE) offers numerous benefits, but

  1. **Optimization** of extraction conditions is a significant challenge, requiring extensive experimentation and expertise.

  2. **Scalability** is another significant challenge for SFE, requiring innovative engineering solutions and a thorough understanding of its principles to overcome issues with equipment design, process control, and cost-effectiveness.

  3. **Environmental sustainability** is major concern, as supercritical fluids like carbon dioxide require significant energy consumption, necessitating the development of energy-efficient processes and exploring alternative solvents with lower environmental impacts.

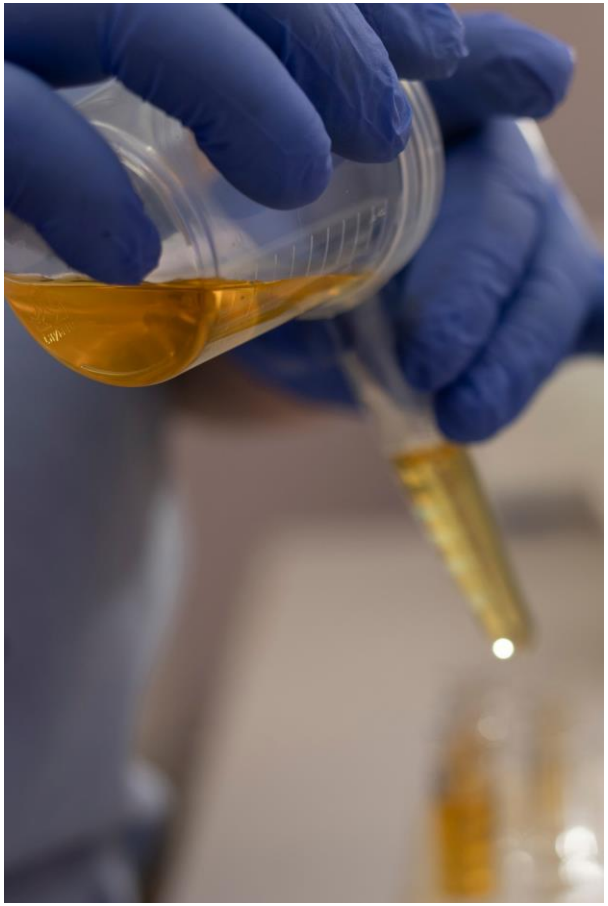
5. Challenges & Future Perspective (Cont.)

- On future aspect, there are exciting opportunities for SFE technology.

  1. Advances in **automation, data analytics,** and **artificial intelligence** offer the potential to optimize extraction processes and improve overall efficiency.

  2. Additionally, there is growing interest in expanding the application of SFE to new fields, such as pharmaceuticals, nutraceuticals, and renewable energy.

- Hence, Supercritical Fluid Extraction's future can holds promise due to ongoing research and innovation, enhancing **equipment design**, **process optimization**, and **sustainability**, thereby enhancing efficiency and versatility across various industries.



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