Thar Process: Historical development, successes, and challenges in scale-up and commercial scale processing

Dr. Lalit Chordia

Thar Process, Pittsburgh, PA 15238, USA

1. The path that lies behind

Thar Technologies Inc. was established in 1990 based on the pre-existence of Suprex Corp. and eventually was split into four entities. Thar Instruments Inc. was sold to Waters Corp. in 2009, while Thar Process Inc. spun off in 2012. Thar has always pioneered R&D and commercial applications in the supercritical fluid technologies. Nowadays, Thar Process has two major revenue streams, equipment manufacturing and R&D/Toll processing, always focused on supercritical fluid (SF)-based processes and technologies.

2. What we have mastered

Thar designs, manufactures and sells advanced supercritical CO2 extraction (SFE) and chromatography (SFC) systems ranging from pilot to commercial scale. These systems are optimally designed and fully compliant with food and pharma regulation (HACCP/cGMP). In this context, we are supplying state-of-the art extraction systems design with features like in-line winterization of extracts, separate terpene collection, very high-pressure large-scale systems (up to 1,000 bars). We are also the manufacturers of the largest and only actually industrial SFC systems equipped with DAC columns ranging from 10 to 60cm diameter and with co-solvent capabilities up to 30% for wide range of applications, also allowing for efficient CO_2 recycling, automated control and more. We also design and build custom-made systems for supercritical fluid countercurrent extraction, subcritical water extraction etc[1].

Figure 1. World's Largest SFC purification system (destined for cannabinoid purification)

Thar also operates a cGMP toll processing and contract R&D facility in the US. In the last ten years we have developed many new applications for food & pharma, in both extraction and purification. A few of the major application fields that we have focused at a large commercial scale were: 1) Polyunsaturated fatty acids and astaxanthin extraction from algae and microalgae through SFE, 2) Cannabinoid extraction and purification/remediation from hemp (*Cannabis sativa)* by utilizing both SFE and SFC, 3) Synthetic lipid purification for mRNA vaccine production through SFC, 4) Medicinal plants extraction for active ingredient recovery, 5) Chiral separations of active pharmaceutical ingredients (APIs) 6) Flax seed defatting and oil extraction through SFE and many more[2].

[1] https://www.tharprocess.com/equipment
[2] https://www.tharprocess.com/processing-services

3. The path that lies ahead

Today SFE/SFC technologies although they have become very recognizable, they remain niche for some major natural products, food and pharma applications, e.g. oleoresin extraction, seed oils recovery, API purification, tetrahydrocannabinol (THC) remediation etc. Moreover, these technologies -although very efficient- have poorly penetrated the biorefinery concept as this applies to medium/large crops by-products valorization for the recovery and purification of valuable ingredients, e.g. spent hops, tomato pulp, winemaking residues, olive oil refining by-products etc[3]. Additionally, SF-based technologies are still very much focused on apolar applications -naturally- while there is a potential for other classes of compounds deriving mainly from medicinal plants like polyphenols, flavonoids, saponins, chlorogenic acids, xanthines, alkaloids, fucoidans etc., as well as relatively polar compounds destined for pharmaceutical APIs. To be able to expand capabilities we need to master parameters like S/F ratio, high-pressure vs. co-solvent, static vs. dynamic extraction, subcritical water, stacked injections various stationary phases and online detectors for SFC etc.

4. What is challenging us

Albeit the well-known advantages that allow one to characterize the SF-based tehnologies as the most efficient and environmentally friendly processing technologies, these remain niche and under-valorized. The main reason is that these advantages are poorly evaluated qualitatively and merely measurable quantitatively. Our mission is to clearly demonstrate that Thar's Supercritical CO2 technologies are not just better than conventional technologies but essentially superior and among the few green chemistry tools for the new era of climate change and environmental, social and corporate governance (ESG). And thus, they must become mainstream in the production of ingredients in the fields of food, cosmetics, and pharmaceuticals.

To disseminate our technology and persuade the community and industry that this is what they should be utilizing, we need to better understand and/or demonstrate a couple of crucial aspects: 1) The global environmental impact of SF-based processes vs. conventional process flow paths should become measurable, through carbon footprint evaluation (CO2e) and *life cycle assessment (LCA)* approaches[4]. 2) The same applies for cost efficiency and return on investment through *total cost of ownership (TCO)* comparisons[5]. The key element is to consider all sources of environmental & financial impact for specific applications, which requires thorough understanding and optimization of both SF-based and conventional processes, CAPEX/OPEX for core and auxiliary equipment, solvent recycling capabilities, quality and compliance aspects that affect cost and environmental impact etc. To do this in a scientific manner we need to implement software tools for design and evaluation of processes, e.g., design of experiments (DoE), process design etc.

5. Thar's SF-based technologies & processes in the I4.0 era

An ultimate challenge for supercritical fluids becoming mainstream is their adaptation to the I4.0 era. In this sense Thar has already considered and aims to fully apply all I4.0 principles for its systems and process design: Interconnection, Information transparency, Technical assistance and Decentralized decision[6]. This, together with addressing the above-mentioned challenges will allow Thar's SF-based technologies & processes to penetrate the industries concerned and essentially contribute to sustainable chemistry and industrial production.

[3] https://extractionmagazine.com/2021/11/16/green-efficient-technologies-for-the-upcycled-recovery-of-bioactive-ingredients/
[4] https://www.sciencedirect.com/science/article/abs/pii/S0896844617306861
[5] https://extractionmagazine.com/2021/05/12/preparative-supercritical-fluid-chromatography-for-cannabinoid-refining-and-purification/
[6] https://en.wikipedia.org/wiki/Fourth_Industrial_Revolution