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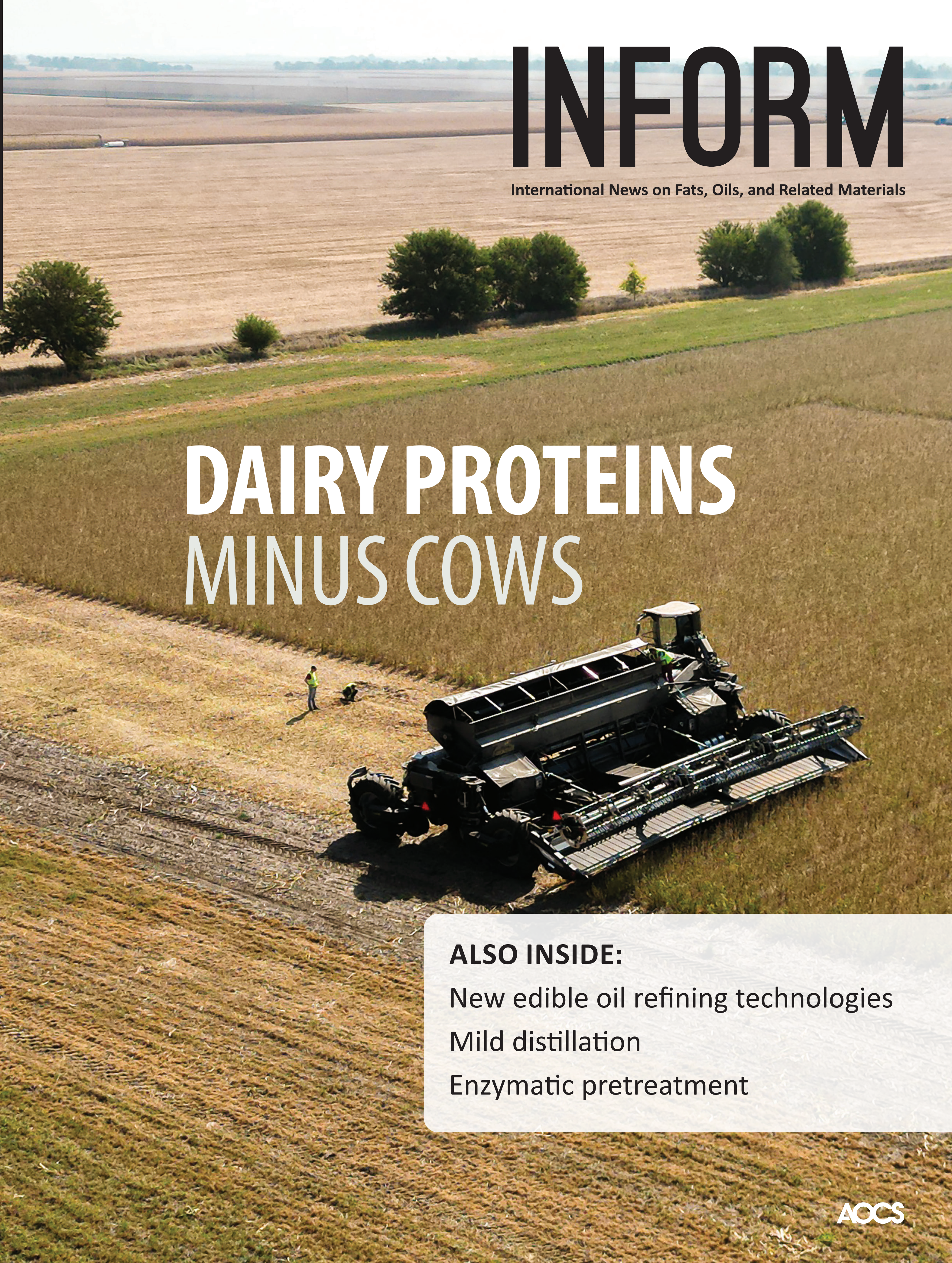
International News on Fats, Oils, and Related Materials



DAIRY PROTEINS MINUS COWS

ALSO INSIDE:

New edible oil refining technologies

Mild distillation

Enzymatic pretreatment

AOCS

Revolutionizing edible oil refining with microfluidic networks

Diana Gitig

- The unique mass transfer ability of microfluidic networks has led to multiple medical device applications.
- One company used the idea to develop technology to carry out separations at industrial scale.
- Now they have taken the concept a step further by adding enzymes to microfilament surfaces.
- Testing proved the simple system can be used for edible oil degumming.

Trees transport groundwater all the way up through their trunks and out to each of their leaves using a vast network of microscopic tubes. Our bodies disperse fluids through a similar kind of network of capillaries. These biological systems exploit the principles of microfluidics—the flow of liquids on a microscale, through small channels, to achieve the mass transfer of dissolved solutes. Transport phenomena at this scale moves materials in a way that does not occur in larger vessels.

Engineered microfluidic systems have thus far been applied on a small scale. Inkjet printers have used similar techniques for fine fluid deposition for years. They are used in groundbreaking medical devices like organs-on-a-chip, cell sorters, and drug delivery systems that supplant IVs. They are small enough and fast enough to be used out in the field for diagnostic and environmental assays.

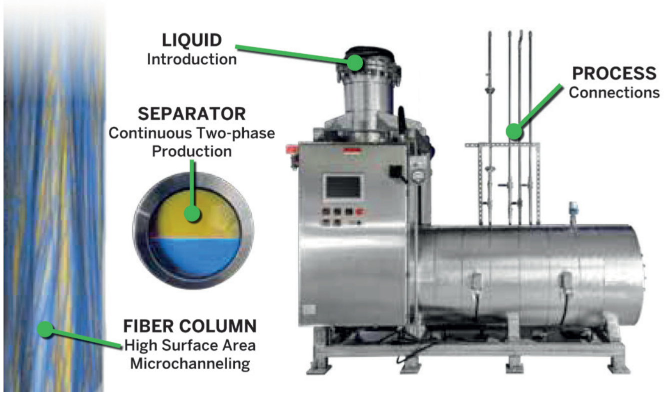
A company near Austin, Texas hopes to improve industrial processing by amplifying tiny, microfluidic systems to operate on a large scale. Visionary Fiber Technologies (VFT) took the concept of fluids flowing through channels etched on a surface and reimaged it to be suitable for multi-ton reactors (https://visionaryfiber.com). To accommodate the gallons of liquid that these applications require, VFT bundled thousands of monofilaments, 50 to 100 micron diameter wires, together and applied them in the unit operations of an oilseed processing plant.

HOW IT WORKS

The developers chose fibers with different textures or made of different materials, like polymers or carbon, based on their desired surface properties, an affinity for water, for example. Water *wants* to adhere to these wires. If the wires are intentionally kept at a specific distance from each other, they form a channel that an aqueous layer can then flow through. When these individual microfluidic channels are layered into stacks, they

create massive fiber reactor arrays containing a multitude of microchannels that can accommodate gallons of liquid flowing through per minute.

This fiber reactor technology allows mass transfer to proceed between micrometer thin ribbons of immiscible fluids without active churning and turbulence that forms emulsions, substantially increasing throughput while reducing both upfront and variable operating costs, as well as cleanup time. As the oil and aqueous phase flows through the channels and down the wires, contaminants dissolve into the water and clean oil is easily separated by centrifugation. The fiber reactor technology that VFT employs provides up to 60 times the available surface area used to mix immiscible liquids than other industrial two-phase column mixers, like static columns with packed media and agitated columns.

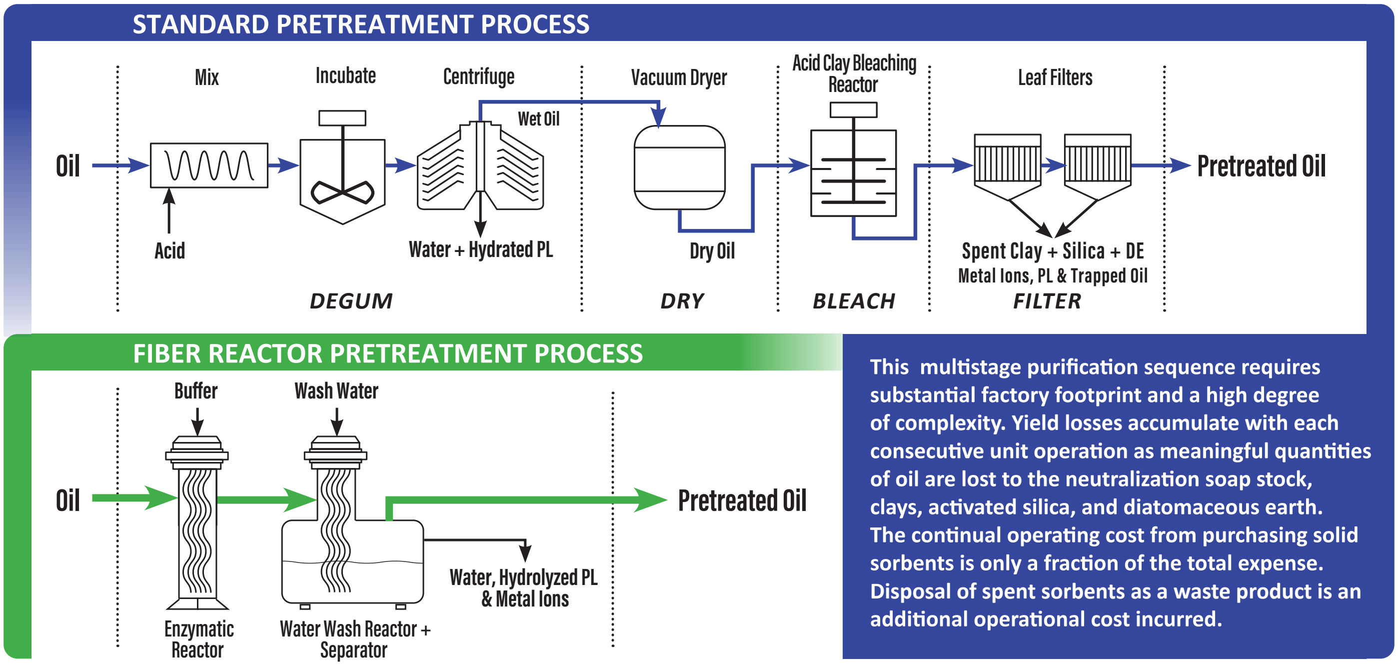


Left, microfibers being used to separate lipid (yellow) and aqueous (blue) phases. Right, commercial scale microfluidic array.
Source: VFT.

ORIGINS OF AN IDEA

According to Scott Kohl, VFT's Chief Technology Officer, this technology was pioneered by Merichem Technologies, in Houston, TX, in the 1950s (https://www.merichem.com). They used it to remove mercaptans from crude oil. They had flowing a NaOH solution adhered to the wires, and as the crude oil went through, the mercaptans within it would become ionized and dissolve into the NaOH solution.

John Massingill, at Texas State University, in San Marcos, TX, subsequently expanded and commercialized the concept of fiber reactors for other applications. VFT bought Massingill's patents and continued expanding on his work. The company has used their arrays primarily to purify crude soybean and corn oils in preparation for making biodiesel fuel. Recently they began refining edible oils with them, including palm, corn, and cottonseed oils.



A comparison between the major unit operations for a standard versus microfluidic array pretreatment of vegetable and animal lipids for renewable biodiesel applications. Source: VFT.

Producing a product for human consumption requires a higher quality standard than biodiesel applications. As a result, VFT has had to address several technical challenges associated with contaminant removal.

DISSOLVING GUMS

The sticky phospholipids (also known as gums or lecithins) present in all crude oils limit shelf life and impart off flavors. They make oils—those destined for fuel, but certainly those destined for cooking and eating—commercially undesirable and must be removed. Removing phosphorus is important for renewable fuels, as phosphorus damages catalyst beds. But they do not come out of soybean oil after a simple wash, the way they do for corn oil.

Leslie Wood is a senior scientist at VFT with a background in surface modifications and nanoparticle synthesis for a variety of applications. Before she joined the company the fiber reactors had only been used for their microfluidic properties in and of themselves, she said. Wood put her skills to work making steel wires catalytic. She attached phospholipase enzymes onto an array and tested it for soybean oil refining. To everyone's surprise the system worked well on the first try.

Kohl said of the simple design, it was "almost like a lead acid battery–it worked right out of the box without much tweaking."

The immobilized phospholipase breaks down phospholipids in soybean oil as it passes through the wires, solubilizing them in the aqueous phase. This is necessary because some of the phospholipid species, notably phosphatidic acid and its calcium salt, hydrate too slowly to come out of the oil otherwise.

The process uses phospholipase A (PLA_1 and PLA_2) and phospholipase C (PLC). PLA_1 and PLA_2 catalyze the hydrolysis of an ester bond which releases a free fatty acid moiety and creates a lysophospholipid. PLC liberates a diacylglycerol (DAG) and the phosphate head group; this creation of DAGs also serves to increase the oil yield. Both cleavages polarize the phospholipid molecules that then dissolve into the aqueous phase.

After just one pass through the reactor, Wood's technique reduced the phosphorus content of crude soybean oil to less than 10 parts per million, from approximately 600. In VFT's testing they were able to refine 535 gallons of oil over the course of a month; each drop of oil takes about three and a half minutes to pass through the column. They can currently run about half a gallon through the reactor a minute, which translates to about seven hundred gallons in twenty-four hours. Their ultimate goal is to be able to process over a hundred gallons per minute.

Next, VFT intends to start using other classes of lipases to make cocoa butter and breast milk replacements. The particular triglycerol composition of these fats makes them highly desirable, yet they are both difficult and expensive to attain. Lipases can be used to create these triglycerol profiles with cheaper, more abundant vegetable oils.

Diana Gitig earned her PhD in cell biology and genetics from Weill Cornell Graduate School of Medical Sciences in New York City. She writes about cell and molecular biology, immunology, neuroscience, and agriculture for arstechnica.com.