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Evonik's portfolio of biosurfactants

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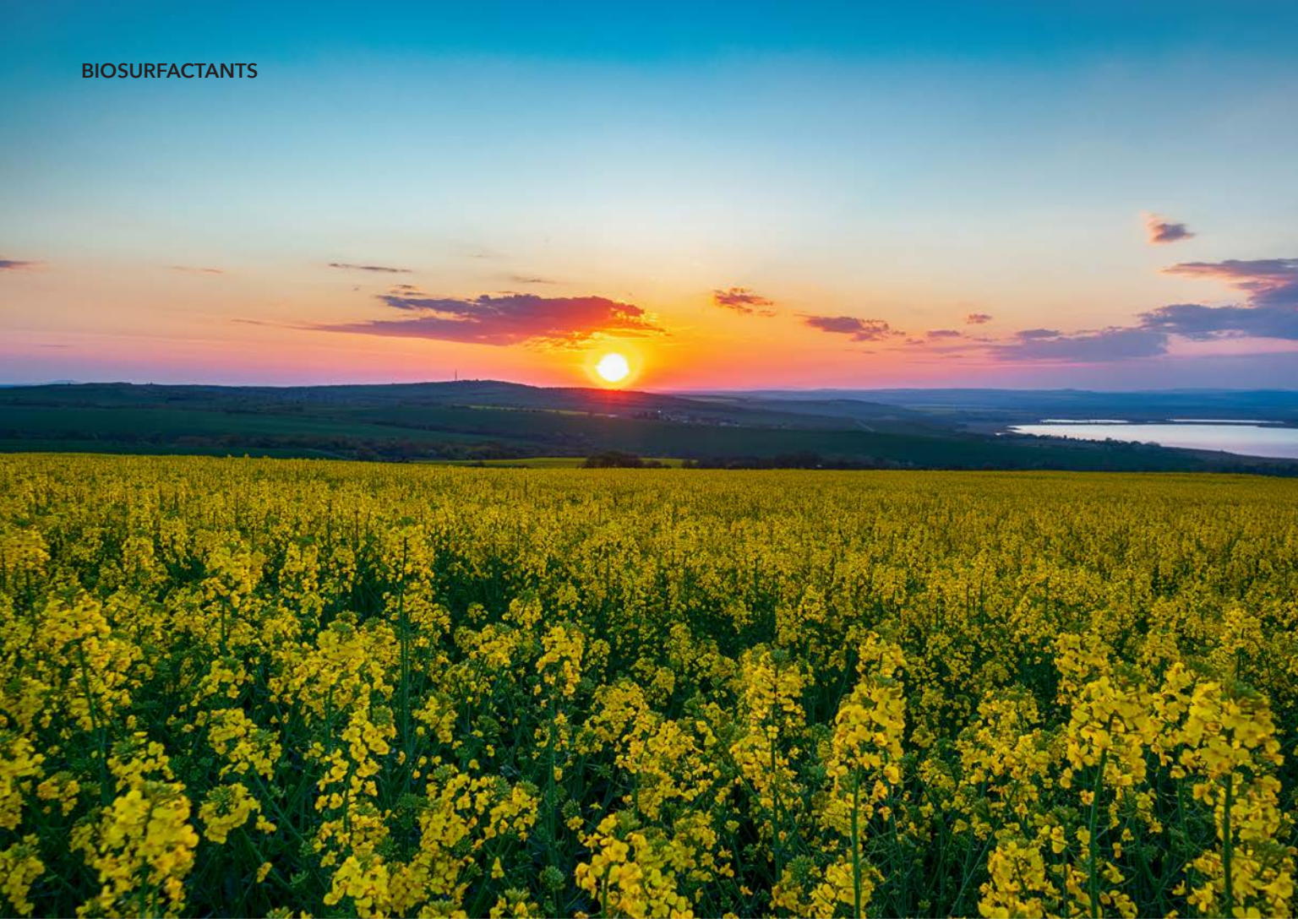

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EVONIK HAS A NEW PORTFOLIO OF BIOSURFACTANTS THAT MEET THE HIGHEST STANDARDS IN SUSTAINABILITY AND FUNCTIONALITY.

Dr. Hans Henning Wenk, Evonik

For the past century, the cleansing properties of virtually all household cleaning and cosmetic products have been obtained from surfactants derived from petrochemical sources. In response to shifting consumer demand toward sustainable products, this fast-growing $40 billion global market for surfactants is now undergoing a rapid transition toward green surfactants that are fully biodegradable, minimize CO2 emissions and are not harmful to aquatic or other natural organisms.

However early generations of bio-based surfactants developed since 2000 have faced several challenges relating to raw material sourcing and manufacturing that constrict their green credentials. Most of all, there have been few, if any, bio-based surfactants that have been able to generate the cleaning and foam-generating functional properties of traditional raw materials. To address these unmet market needs, Evonik, one of the world leaders in specialty chemicals and a market innovator for green biosurfactants used with household cleaning products, has developed a new portfolio of biosurfactants that meet the highest standards in sustainability and functionality.

AN OVERVIEW OF SURFACTANTS

Surfactants are amphiphilic molecules with surface tension properties that enable the efficient breakdown of the interface between water and other particles. The molecules feature hydrophobic (water-repelling) and hydrophilic (water-loving) parts that naturally bond with each other to form spherical micelles. Each of these parts work in unison, with the hydrophobic tail being attracted to substances such as oil or dirt while the hydrophilic head then draws these particles toward the micelle's core.

This physico-chemical reaction, followed by the rapid dissolution of such particles in water, makes surfactants an attractive active ingredient for use with a range of personal care and cleaning applications. In prod-

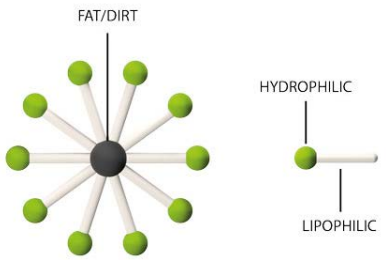

Figure 1: A surfactant molecule highlighting its hydrophilic and hydrophobic (lipophilic) elements

ucts such as dishwashing detergents, surfactants can account for up to around 30% of total content volume. Their functional effectiveness plays a major role in determining rates of brand preference among consumers. Accordingly, the global market for surfactants is highly competitive. The market was valued at $40 billion in 2020 and is expected to increase to $52 billion by 2025 for a CAGR of 4.5%.[1]

The first generation of synthetic surfactants were known as branched alkylbenzene sulfonates (BAS), which were used from the 1930s until they were phased out across most international markets in the 1960s. Within most global regions and for most applications, BAS was replaced by another anionic class of surfactants known as linear alkylbenzene sulfonates (LAS) which has superior biodegradability properties.

Extracted from benzene (crude oil), LAS surfactants are legally required in most nations to be degradable within four weeks. While the overwhelming majority of LAS can be removed from the water supply during initial processing at sewage treatment plants, studies indicate that higher concentrations of LAS can be toxic to certain aquatic and soil-based organisms such as bacteria, algae, fish and crustaceans.[2] Furthermore, petrochemical-derived LAS can contribute greenhouse gas emissions of 2.36 kg CO2 eq / kg LAS until its End-of-Life (EoL).[3]

THE MARKET SHIFT TO GREEN SURFACTANTS

Increasingly, global demand for surfactants used in household and personal care products is being determined not only by the functional performance of the active ingredient, but also by its sustainability as consumers and regulatory agencies seek more environmentally-friendly solutions. This demand for sustainable cleaning products has given rise to a new era of bio-based surfactants that are based on biological raw materials. The annual worldwide market for bio-based surfactants (partially bio-based surfactants, fully bio-based surfactants and biosurfactants, which will be detailed here) was estimated to be $5.52 billion in 2022, with a CAGR of 5.6% from 2017 to 2022.[4]

There are three separate classes of bio-based surfactants. First are partially bio-based surfactants, where fatty alcohols and acids are derived from the natural fats and oils from natural sources including soya, palm and palm kernel, rapeseed, sunflower, tallow and coconut. Examples of partially bio-based surfactants include alkyl ether sulfates and coconut-oil-derived cocamidopropyl betaine (CAPB). However, most of the oils used to create these surfactants are sourced from tropical regions, where it can be challenging to obtain certifications that confirm the use of sustainable practices for harvesting, or the use of non-exploitive hiring practices for local workers and communities. In addition to the use of hazardous raw materials during harvesting, further processing is typically required to obtain the necessary functionality for their use with most personal and home care applications. These additional processing steps can involve the use of petrochemical-based substances or moieties that are also less sustainable.

The second category are fully bio-based surfactants such as alkylpolyglycosides (APGs) which are plant-based but still manufactured by a chemical process. Like partially bio-based surfactants, they can be derived from tropical oils and involve the use of hazardous raw materials or processes. Certain functionality gaps, such as being less gentle to the skin, may also affect the performance and consumer preference of such surfactants.

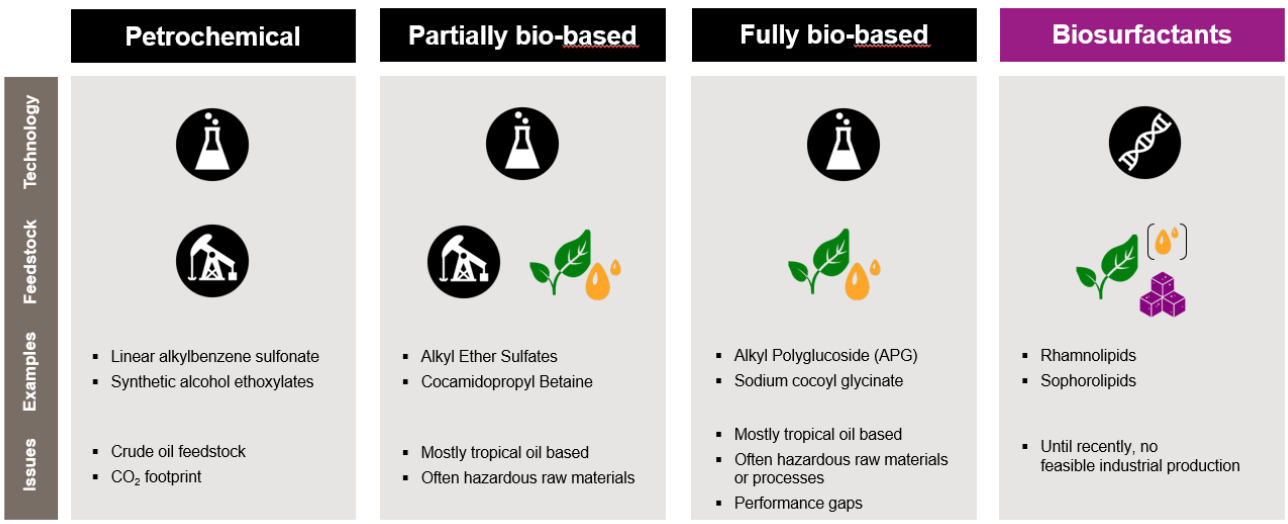

Figure 2: The market shift for surfactants derived from petrochemicals to green biosurfactants

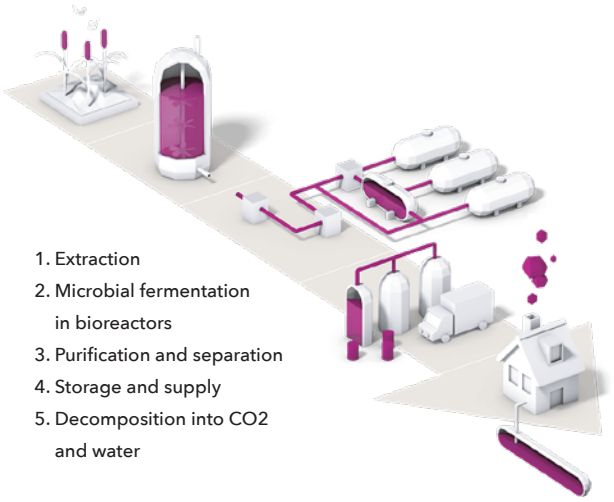

Figure 3: Evonik manufacturing and supply chain process for its biosurfactants

The third, and most recent category of surfactants are known as biosurfactants. These 100% natural surfactants are excreted by an organism during biological synthesis. Companies such as Evonik can utilize established fermentation-based processes to create biosurfactants from oils, sugars or a combination of the two.

Biosurfactants are the first class of surfactant that are not only environmentally friendly, but capable of delivering rates of functionality that are equivalent, or even superior to, traditional petrochemical-based surfactants. In addition to coming from renewable, non-tropical raw materials, biosurfactants are gentle on the skin, impervious to hard water, possess excellent cleansing and foam cleaning characteristics, are 100% biodegradable and are well tolerated by aquatic organisms.

GREEN BIOSURFACTANTS FOR A RANGE OF APPLICATIONS

Evonik has developed two glycolipid-based platforms of biosurfactants known as sophorolipids and rhamnolipids. This portfolio gives the company significant flexibility to address the specific requirements of a range of personal care and household cleaning applications. Consisting of a carbohydrate moiety linked to fatty acids, Evonik's two glycolipid-based platforms are manufactured at commercial scale at efficiencies that make them attractive for use by companies seeking more sustainable brands that can still attain desired high levels of functionality.

SOPHOROLIPIDS

A select number of yeasts such as *Candida bombicola* can be utilized to produce sophorolipids through raw materials such as sugar and rapeseed oil. Their potential for use as surfactants was first identified in the 1980s; however, the original processes developed for their production were unfeasible for commercial use. During the past decade, however, Evonik's bio-based materials unit that is part of the nutrition & care division, together with other parties including Evonik's long-term innovation center Creavis, sought to develop a new commercially scalable biological production process.

In 2016, this R&D project culminated in the successful commercial launch of Evonik's platform of sophorolipids. Manufactured at the Evonik Fermas facility in Slovakia, an advanced and highly efficient process is utilized for extraction, synthesis and purification (Figure 3). Special yeasts are grown in a bioreactor feeding on plant-based sugars and oils, resulting in the production of the raw sophorolipid material during metabolism. A purification process then separates the microorganism from the sophorolipid material until it is ready for storage and supply.

One active ingredient developed by Evonik that is based upon its sophorolipid platform is REWOFERM® SL ONE. This composition features a mix comprising 40% sophorolipid lactones and sophorolipid acid combined with water and 1% free fatty acids and salt to create an amber-colored, low-viscosity aqueous solution.

In hard water, a mixture with REWOFERM® SL ONE performed significantly better in grease removal compared to a standard cocamidopropyl betaine (CAPB)-based alternative. Foam production in mixtures

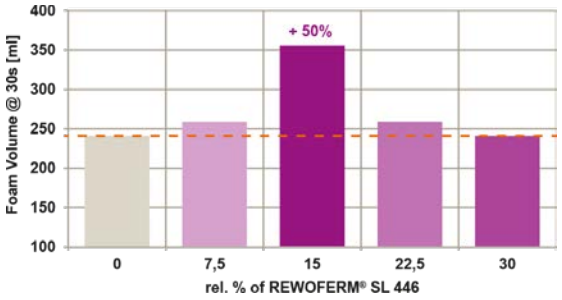

Figure 4. Grease removal by replacing 50% betaine with REWOFERM® SL ONE in hard water

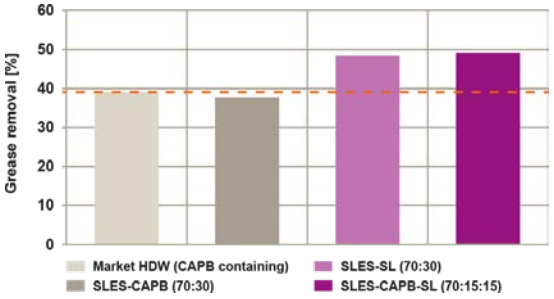

Figure 5.: Foam production under dirty conditions replacing part of CAPB with REWOFERM® SL ONE

containing REWOFERM® SL ONE was also up to 50% higher under dirty conditions compared to the CAPB-based alternative. Compared to CAPB and another common surfactant known as sulfosuccinates, REWOFERM® SL ONE was found to be the mildest option analyzed in red blood cell (RBC) tests with an L/D value of 1000, supporting its categorization as a non-irritant. In terms of sustainability, it easily met all

requirements including aerobic degradation, anaerobic biodegradation and low aquatic toxicity to earn the favored EU Ecolabel status.

One of the first companies to sell products containing Evonik's sophorolipids was Ecover, a leading Belgian-based global supplier of organically produced washing and cleaning products.

Various detergents and cleaning products containing Evonik's sophorolipids are now available on supermarket shelves.

RHAMNOLIPIDS

Rhamnolipids consist of one or two rhamnose sugar groups that are attached to one or two hydroxy fatty acid chains. As a biosurfactant, the sugar groups fulfill the hydrophilic function of attracting water while the hydrophobic fatty acids latch onto oils and other substances. Scientists discovered in the 1960s that certain soil-dwelling bacterium from the Pseudomonas family could naturally produce rhamnolipids.

However, it was only following the decoding of the bacteria's genome in 2000 that Evonik was able to develop a fermentation-based manufacturing process that complemented its established commercial capabilities. Evonik's process converts sugars into rhamnolipids via the use of a well-researched bacteria known as *Pseudomonas putida*. Fermentation takes place in bioreactors at room temperature under energy-efficient conditions. No chemical processing or derivatization is required once the substance has been isolated in the fermentation broth. As with Evonik's manufacturing process used for sophorolipids highlighted earlier, further purification is then required to meet the high-quality requirements of use for home and personal care applications.

Evonik's rhamnolipids are completely biodegradable irrespective of the presence of oxygen, and require no tropical oils as feedstock. They are also able to remove oils or dirt as reliably as petrochemical-based synthetic surfactants even in hard water, have exceptional foam-forming properties, and provide a mild, gentle feeling on the skin.

RHEANCE® One is one rhamnolipid-based product now available from Evonik within its RHEANCE® glycolipid platform for use in rinse-off applications such as facial cleansers, oral care and baby wipes. Available as a low viscosity aqueous solution that is slightly yellow in appearance, it is easily processible and easy to handle in formulations between 1 and 8% in concentration. Foaming and viscosity properties can be easily tuned to address specific formulation requirements by adjusting the pH value.

RHEANCE® One is fully biodegradable under both aerobic and anaerobic conditions, with aquatic toxicity levels far lower than CAPB or other common surfactant alternatives. Furthermore, this multifunctional solution features excellent mildness to the skin and mucous membranes and is highly efficient in solubilizing various essential oils, fragrances and flavors. When tested with long-lasting facial and eye makeup, RHEANCE® One demonstrated significantly higher makeup removal than common alternatives.

Evonik and Unilever are in a long-term collaboration for the commercial manufacturing and supply of Evonik's rhamnolipids for use in a range of Unilever's green household cleaning products. In 2019,

Figure 6: A Unilever advertisement promoting the 100% biodegradability of Quix hand dishwashing liquids in Chile.

Unilever launched its first ever hand dishwashing liquid product utilizing Evonik's rhamnolipids in Chile under its Quix brand (Figure 6). This launch represented the first time a cleaning product utilizing a rhamnolipid-derived surfactant was commercially used in the world.

The partnership with Evonik was highlighted by Unilever earlier this year as one key pillar of its Clean Future initiative, which seeks to fundamentally change the way in which some of the world's best-known cleaning and laundry products are created, manufactured and packaged. Clean Future is unique in its intent to embed the principles of a circular economy into both packaging and product formulations at the commercial scale of global brands to eliminate or reduce their carbon footprint.

CONTINUED INNOVATION FOR A SUSTAINABLE FUTURE

Evonik will continue to expand its portfolio of biotechnology-derived ingredients to strengthen its position as a leading provider of sustainable solutions that are able to excite both suppliers and consumers of household cleaning and cosmetic products. In parallel, the leading global specialty chemical company remains committed to expanding its commercial manufacturing capabilities to support growing demand for glyocolipid-based surfactants including rhamnolipids and sophorolipids. ■

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Biosurfactants from Evonik

Evonik's biosurfactants make a clean sweep – literally. They not only remove grease and dirt but are also eco-friendly and gentle on the skin. Other performance advantages include exceptional foam-forming properties and hard water compatibility. They are 100 percent biodegradable and also impact the environment less than conventional surfactants. All our biosurfactants are produced from bio-based raw materials without the use of tropical oils.

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