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Biotech breakthroughs

Biotechnology is now delivering for cosmetics, surfactants, fragrances and more, says Steve Weiss of Genomatica

FOR MANY OF the thousands of applications in which speciality chemicals are used, end users are demanding greater sustainability and/or natural sourcing. In a survey of 1,000 consumers in the US, 95% said sustainability is a good goal, 55% were surprised by the fossil-derived origins of ingredients in everyday products like some baby sunscreen lotions and 71% felt 'bothered' or 'disgusted' when they learned of these origins. About 70% would prefer more sustainable choices, depending on product category.

Increasingly, biotechnology provides an advantageous approach to producing chemicals with substantial existing markets. The pressures facing speciality chemical producers and users – including sustainability, costs, purity, and customer acquisition and retention – can be addressed through the benefits of biotechnology, including:

- A better environmental profile during production, often due largely to the use of renewable feedstocks and generally less energy-intensive production
- Product differentiation and market advantages for companies using renewably sourced biobased chemicals in their formulations
- Lower capex/tonne of production capacity and/or contract manufacturing options for producers

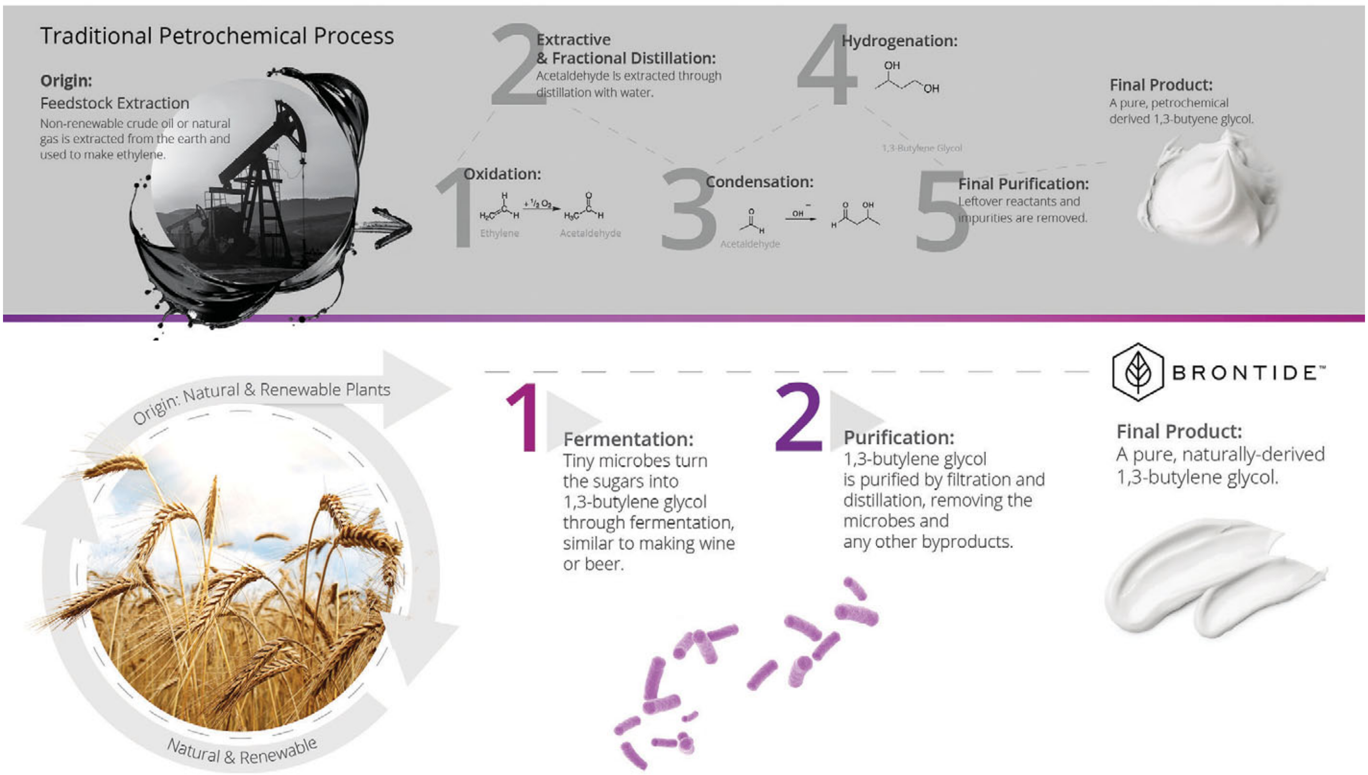
Biotechnology has particular advantages over conventional chemistry in terms of:

- Specificity, for instance making specific enantiomers or isomers, and avoiding by-products
- Production of molecules with oxygen or nitrogen atoms using fewer unit operations and/or milder reaction conditions
- Facilitating a new set of feedstocks, such as plant-derived sugars or agricultural residues

Biotechnology can also be used to produce novel chemicals not readily produced with conventional chemistry, with the potential to make new, higher-performance products. This article discusses the implications for both speciality chemical users and producers, while providing an introduction to how biotechnology is applied.

We highlight three examples of bio-based chemicals spanning cosmetics, surfactants and fragrances, which are all in early or full commercial status. For users of chemicals, we discuss issues like application qualification, the impact on production and marketing. For producers, we see the possibility of rapid adoption of these new biobased production technologies, starting in sectors that most value sustainability.

Figure 1 – Petrochemical & bio-based processes for butylene glycol



Unlike much higher-volume monomers, like caprolactam and 1,4-butanediol, where markets are served by dozens of production plants worldwide and a few competing technologies, the smaller markets for a given speciality chemical mean that each one is produced at one or a few plants. Thus, opening a single commercial-scale biobased plant can reshape downstream markets, set a new standard for customers, and rapidly address substantial and growing opportunities.

Better BG

Butylene glycol (BG) has a worldwide market of about 50,000 tonnes/year or over $200 million. It is widely used in cosmetics and personal care for moisture retention and as a carrier for plant extracts.

Conventional fossil-based BG production presents increasingly serious problems. Firstly, it relies on fossil-derived acetaldehyde, which is a toxin, an irritant and a Group 1 carcinogen. Secondly, suppliers are leaving the acetaldehyde business.

Moreover, the customers for BG's primary applications represent one of the segments demanding naturally sourced ingredients and sustainable processes most vocally. Not many conventional producers would want to be transparent about their current fossil-based origins; many consumers would probably be aghast at the idea of a skincare product that started with a toxic carcinogen.

In contrast, bio-based processes can be simpler, cleaner and friendlier, encouraging supply chain transparency by chemical producers and product formulators. For example, Genomatica's Brontide* natural BG (Figure 1) converts sugars to 1,3-BG entirely within a microorganism, avoiding the capital intensity and yield losses of multiple corresponding conventional steps.

The environmental impact is cut by half: a detailed, independent lifecycle analysis (LCA) shows a 51% lower global warming potential, as measured in greenhouse gas equivalents.[1] Formulators incorporating Brontide can highlight its natural origins and smaller environmental footprint as marketable advantages, which they can support with real data in the form of the LCA and conformity to the ISO 16128 definition of a natural ingredient with a natural index of 1.

Conventional chemistry results in a 50:50 racemic mix of BG's two isomers. Genomatica has designed its process with the ability to produce only the R isomer, taking advantage of the specificity possible in biological reactions. This isomer has the potential for high-value nutraceutical applications and new polymers, but is very difficult and prohibitively expensive to produce through conventional chemistry.

As of late 2019, in its first year of commercial production, Genomatica has made well over 1,000 tonnes of bio-BG to support market introduction. It plans to further scale up production to supply a substantial part of the world market.

PKO-free surfactants

The surfactants used in many cleaning products and personal care items are mostly molecules with a backbone of eight, ten or more carbon atoms (C_8s, C_{10}s, etc). These have a huge range of applications, depending on the family of chemicals (such as fatty acids, alcohols, esters and oleochemicals), branching, additional groups and saturation.

The starting point today for most C_8 and C_{10} production is palm kernel oil (PKO) and coconut oil. While these are technically renewable feedstocks, many sources are not grown and harvested sustainably, resulting in deforestation, displacement of endangered animals, water management issues and consequences for local economies.

Additionally, these are inefficient sources, as C_8s and C_{10}s are essentially by-products of the production of C_{12} and C_{14} fatty acids and alcohols, leading to availability issues and price fluctuations. For example, the processing of palm fruits result in a broad set of molecules with different chain lengths.

Only 10% of the oils from a palm fruit are PKO and of that, only 5-11% are C_8s and C_{10}s. The more of these products we need, the worse the environmental impact. These molecules are also used in many food ingredients in the form of oleochemicals.

Biotechnology can now be used for the targeted production of specific C_8 and C_{10} molecules, starting from plant-based sugars rather than palm fruits. These include fatty esters, fatty alcohols and fatty acids useful for personal care, dishwashing and laundry detergents.

For example, in 2019, Genomatica acquired technology from the REG Life Sciences division (REG LS) suitable for developing a wide range of medium- and longer-chain products that can be tailored for specific applications (Figure 2). REG LS had already shipped multiple tonnes of specific C_8 and C_{10} products.

Genomatica now plans to scale these offerings rapidly over the next few years. Internal LCA estimates suggest an 80% reduction in greenhouse gas emissions compared to conventional processes.

Making fragrances

Most fragrances are relatively complex molecules. They require potentially inefficient, land-intensive cultivation, gathering and extraction and/or multiple steps to synthesise them.

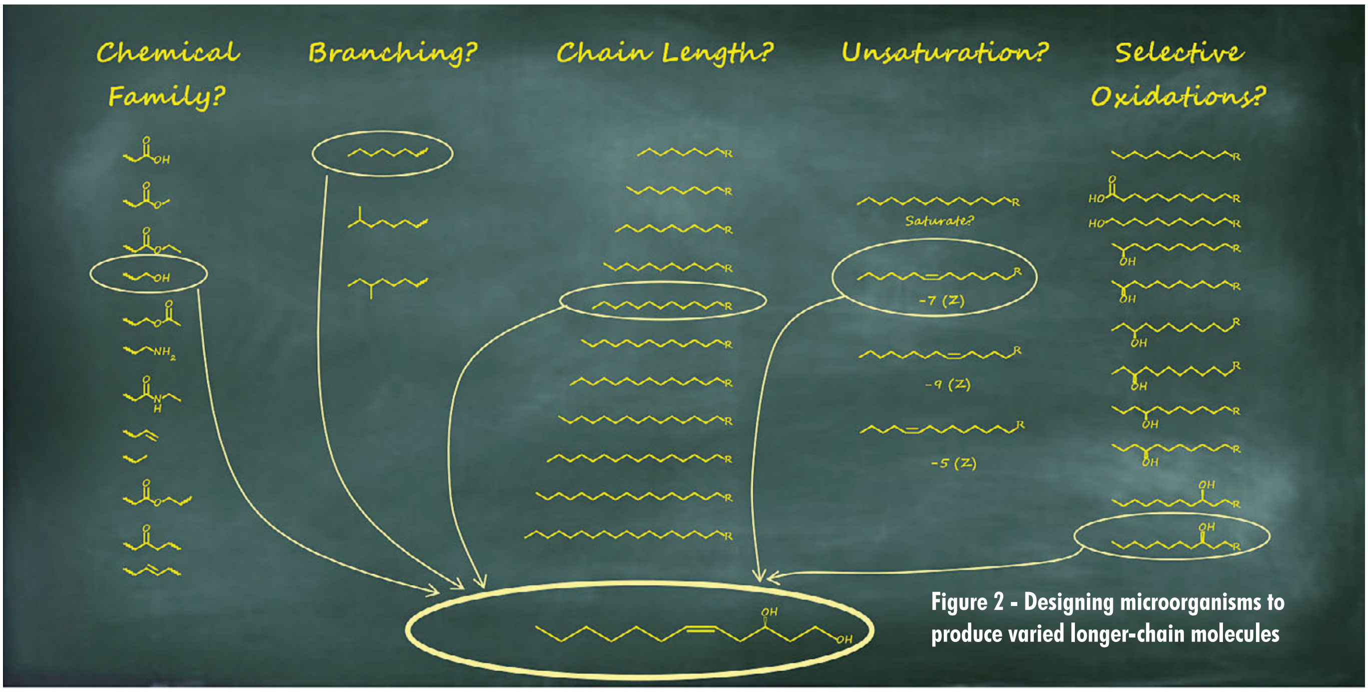


Figure 2 - Designing microorganisms to produce varied longer-chain molecules

In addition, particular extraction sources, like animals or insects, may prevent a fragrance from being marketed as vegan, while small changes in a target molecule, with respect to bond location or additional groups, can result in substantial changes in scent characteristics. Finding or developing variants can be challenging.

Biology is now able to produce commercially useful fragrances without the inefficiencies of traditional approaches, potentially removing supply constraints and stabilising market prices. An example is the technology developed by REG LS to make *cis*-iso-ambrettolide precursor (CIAP). REG LS has made tonnes of CIAP. A customer uses this to make *cis*-iso-ambrettolide, which it sells for use in consumer fragrances.

The specificity afforded by bio-production provides a particularly useful 'tailorability' for the fragrance industry. Microorganisms can be programmed to make molecules with very specific characteristics.

For example, the presence of a *cis* unsaturation generally lends a tenacity and noble character to a musk, placing its value above its saturated counterpart. This tailorability is one of the reasons that Genomatica acquired REG LS technology in 2019.

Outlook

Biotechnology is now something to get familiar with and to integrate into the short- and long-term plans of both chemical users and producers. Users of speciality and fine chemicals, including major consumer brands, should pay particular attention to the growing calls from their customers for more sustainable offerings and natural sourcing, while also noting the opportunity to distinguish themselves from their competitors.

Additionally, this is a good time to engage and expand your supply chain, both to understand what is available and to identify new potential sources. You can also make your interests known directly to biotechnology firms regarding particularly problematic chemicals with high environmental impacts, such as dyes and animal feed ingredients.

For chemical producers, this is a good time to consider the potential to implement new biobased production technologies, whether for adding capacity or to replace existing assets, with an eye toward gaining leading market share as demand for sustainability continues to increase.

We recommend discussions with biotechnology firms, especially those with a track record of successfully scaling up to commercial production levels. That can help you determine the practicality, economics, timelines and business models for evolving your product offerings. ●

References

1. R. Pacheco & K. Houston, *SOFW Journal*, 144, November **2018**

Shellac and flowers are used in traditional production of ambrettolide-based fragrances

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