

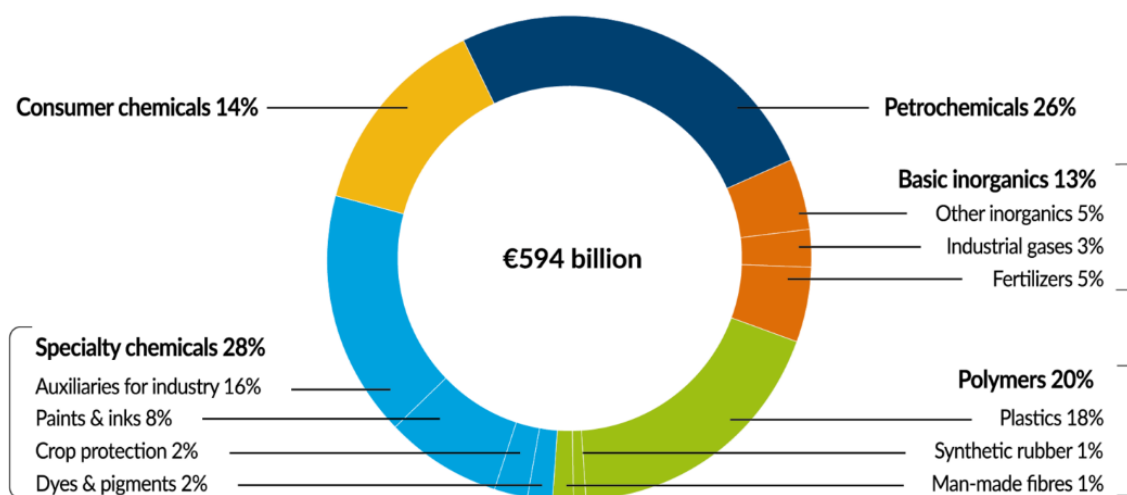
Paving the road towards bio-based specialty chemicals

Article written by Konstantinos Drousiotis, October 2023

A prominent segment of the chemicals industry are the specialty chemicals. These types of solutions are either comprised of a single chemical or formulations which modify and uniquely tailor the properties of the end-product. They are often sold based on their performance capabilities rather than their price and are difficult to replicate by competitors^{1,2}. Some examples of specialty chemicals include adhesives, catalysts, coatings, flavors, lubricants, fragrances, surfactants, water treatment chemicals, construction chemicals, elastomers etc. Therefore, it is evident that the specialty chemicals industry is present in many major sectors across the global economy including automotive, aeronautics, electronics, agriculture, cleaning etc.

This segment occupied almost 30% of the total chemical sales within the EU in 2021³ (Figure 1). Hence, it is important that their production methodologies consider the use of bio-based feedstocks, take into account circularity, and preferably have low carbon footprints.

EU27 chemical sales 2021 (€594 billion)



Source: Cefic Chemdata International

Figure 1. Breakdown of chemical sales in the EU27, based on type (2021).

— Source: *Facts & figures 2022 - the profile of the industry (2023a)* cefic.org. Available at: <https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/profile/>

¹ Specialty Chemicals Market Size, share & trends report, 2030 (no date) Specialty Chemicals Market Size, Share & Trends Report, 2030. Available at: <https://www.grandviewresearch.com/industry-analysis/specialty-chemicals-market>

² *Specialty Chemicals Market - size, Forecast Report & Industry Overview* (no date) *Specialty Chemicals Market - Size, Forecast Report & Industry Overview*. Available at: <https://www.mordorintelligence.com/industry-reports/specialty-chemicals-market>

³ *Facts & figures 2022 - the profile of the industry (2023)* cefic.org. Available at: <https://cefic.org/a-pillar-of-the-european-economy/facts-and-figures-of-the-european-chemical-industry/profile/>

The potential for a transition into bio-based manufacturing

There is enormous potential for companies to switch to bio-based manufacturing as evidenced by the low percentage of bio-based production in different sub-segments of specialty chemicals, within the EU (Figure 2).

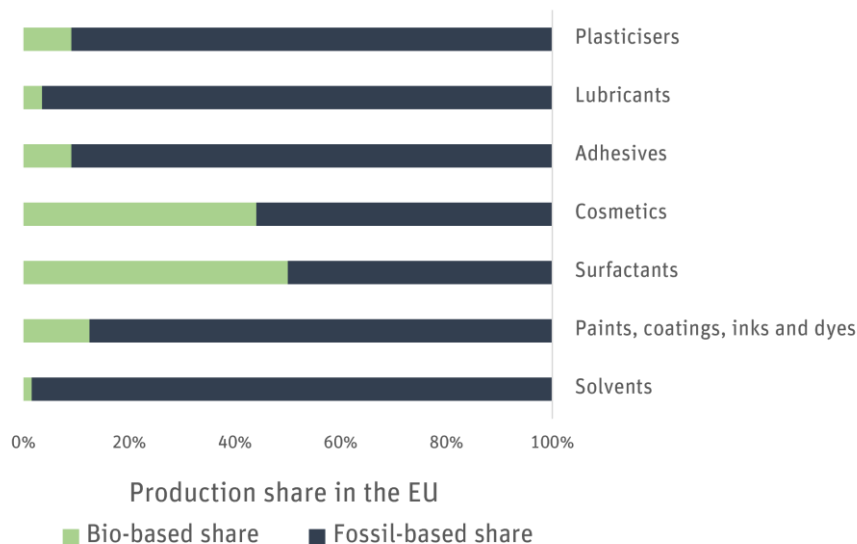


Figure 2. Bio-based share of production for different categories of specialty chemicals in the EU (2019).

— Data collected from: SPEKREIJSE, J. et al. (2019) Insights into the European market for bio-based chemicals, JRC Publications Repository.

The current research shows that there is ample potential and interest towards manufacturing bio-based specialty chemicals. Even though, on a global scale, only 24% of the surfactants are produced from renewable resources⁴, emerging literature is a strong impetus that demonstrates alternative methodologies in manufacturing bio-based surfactants. A notable example of progress are academic applied research projects. Yue and Queneau (2022), review published methodologies for utilizing microbial fermentation inhibitors derived from hemicellulose and cellulose feedstock, ie. HMF, furfural and furan, as substrates for manufacturing surfactants⁵. Such methodologies can assist in decreasing the concentration of fermentation inhibitors in liquor, therefore rendering such media, a dual-purpose solution. The same substrates have also been shown to be suitable to produce diamines and diepoxy monomers for the synthesis of epoxy resins⁶. The thermal and mechanical properties of the attained bio-sourced resins were compared to their fossil fuel analogues, highlighting the high potential of bio-based monomers as substituents for non-renewable ones⁶.

Another promising avenue is the genetic engineering of microorganisms to produce specialty chemicals. The use of synthetic biology is a near term opportunity for specialty chemicals as

⁴ Hayes, D.G., Y., S.D.K. and Ashby, R.D. (2019) *Biobased Surfactants: Synthesis, properties, and applications*. London: Academic Press, an imprint of Elsevier.

⁵ Yue, X. and Queneau, Y. (2022) '5-hydroxymethylfurfural and furfural chemistry toward biobased surfactants', *ChemSusChem*, 15(13). doi:10.1002/cssc.202201009.

⁶ Eid, N., Ameduri, B. and Boutevin, B. (2021) 'Synthesis and properties of furan derivatives for epoxy resins', *ACS Sustainable Chemistry & Engineering*, 9(24), pp. 8018–8031. doi:10.1021/acssuschemeng.0c09313.

the technology is suited to producing novel and niche products faces fewer smaller challenges with regards to scaling and market development compared to large scale commodities. Whether the manufacturers choose to replace their existing methodologies with synthetic biology or renewable feedstocks, or a combination of both, there is a marketing advantage around the perceived environmental benefits⁷. Germany-based Evonik are pursuing syn-bio production strategies and are actively contributing towards increasing the percentage of biosurfactants via low-energy fermentation, by predominantly using municipal waste⁸. Adding to this effort, the Manchester-based Holiferm are also producing biosurfactants from renewable feedstocks via a natural fermentation process using yeast, rapeseed oil and sugar⁹. Biosurfactants are considered less harmful and can replace fossil-based surfactants in many uses including in herbicide formulations¹⁰.

The push...

Boston consulting group reports that funding events for synthetic biology materials increased by almost 10% every year between 2018 and 2022. Specifically, specialty-chemicals and enzyme manufacturers accounted for 42% of the investment events. Solugen, a Houston-based specialty-chemical company which redesigns production methodologies utilizing industrial biotechnology and green chemistry, has raised more than \$200 million during their Series D funding round in November 2022. This, in turn, elevated its market cap to more than \$2 billion¹¹. Biosyntia, a Danish pioneer in producing vitamins and other nutraceutical ingredients by fermentation, has raised \$18.55 million during their follow-on investment phase for their Series B funding round. Citrine Informatics, one of the prominent AI providers involved in designing and developing smart drop-in specialty chemicals or formulations thereof, has announced the successful close of a \$16 million Series C funding round in January 2023^{12,13}. P2 Science, a company that designs chemical process technologies for converting renewable feedstocks into specialty chemicals, has announced the close of a successful additional funding round (ie. Series D) in February 2023¹⁴. The proceeds from this round will primarily be spent to promote sales and expand production of Citropol®. The latter chemical is a low molecular-

⁷ IChemE (2017) Synthetic biology touted for Specialty Chemicals production, The Chemical Engineer. Available at: <https://www.thechemicalengineer.com/news/synthetic-biology-touted-for-specialty-chemicals-production/>

⁸ Ögmundarson, Ó. et al. (2019) 'Environmental hotspots of lactic acid production systems', GCB Bioenergy, 12(1), pp. 19–38. doi:10.1111/gcbb.12652.

⁹ Explore.azelis.com. Available at: https://explore.azelis.com/en_GB/uk_pc/holiferm-biosurfactants-sustainable-surfactant-technology#:~:text=Holiferm%20produce%20biosurfactants%20from%20renewable,petrochemical%20derived%20surfactants%20traditionally%20used.

¹⁰ Song, H.-Y. et al. (2012) Cellular toxicity of surfactants used as herbicide additives, Journal of Korean medical science. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3247771/#:~:text=The%20severely%20toxic%20category%20included,in%20a%20dose%2Ddependent%20manner.>

¹¹ Rothman, A. et al. (2023) How synthetic biology can make a materials difference, BCG Global. Available at: <https://www.bcg.com/publications/2023/how-synthetic-biology-materials-can-make-a-difference>

¹² Citrine informatics raises \$16M in series C financing (2023) Business Wire. Available at: <https://www.businesswire.com/news/home/20230104005839/en/Citrine-Informatics-Raises-16M-in-Series-C-Financing>

¹³ Cheung, J. (2023) Specialty Chemicals, Citrine Informatics. Available at: <https://citrine.io/specialty-chemicals/>

¹⁴ Agrifood, L.& C. (2023) P2 science raises funding round led by Lewis & Clark Agrifood, PR Newswire: press release distribution, targeting, monitoring and marketing. Available at: <https://www.prnewswire.com/news-releases/p2-science-raises-funding-round-led-by-lewis--clark-agrifood-301754023.html>

weight liquid polymer consisted primarily of terpenes obtained from forestry biomass¹⁵. Furthermore, the Belgian-based AmphiStar attempts to 'make biosurfactants mainstream' by utilizing municipal waste as a feedstock for chassis microbes. Their partnership with the Belgian manufacturer Ecover has proved especially fruitful as they have released their initial batch of cleaning products during May 2023¹⁶. In November 2023, they have announced their success in securing an injection investment from 'The Federal Agency for Disruptive Innovation', ie. SPRIN-D¹⁷.

In terms of partnerships, Solugen has announced in October 2023 that they are working with a global chemicals and energy company, Sasol Chemicals to explore commercialization of fully fledged home and personal care products¹⁸. During this month, Solugen have also announced a partnership with ADM to utilize their dextrose feedstocks and construct a production facility adjacent to their corn complex in Minnesota¹⁹. During the last quarter of 2022, California-based Lygos Inc., a vertically integrated designer of solutions for producing sustainable specialty ingredients, and Ginkgo Bioworks, the leading horizontal platform for cell programming, announced their collaboration. Eric Steen, PhD, CEO at Lygos has mentioned that the partnership will "augment our development timelines, allocate more research and development, and accelerate our product commercialization programs."²⁰ A few months later, Ginkgo Bioworks announced another collaboration with a specialty-chemicals company ie. Copenhagen-based Octarine Bio. Their multi-phase partnership will attempt to engineer the tryptophan biosynthetic pathway of their proprietary microbial strains to optimize the yield of violacein²¹. The latter substance has multiple bioactive properties including anti-microbial, antioxidant, and UV shielding properties; but most importantly it can be used to dye fabrics due to its purple colour. A research group has already studied the capacity of such production methodology to allow for textile dyeing to occur simultaneously with bacterial fermentation²². Octarine Bio hopes to expand their palate through this collaboration by giving rise to new

¹⁵ Citropol - P2 Science Inc.: The New Green Chemistry Company (2023) P2 Science Inc. | The New Green Chemistry Company. Available at: <https://p2science.com/citropol/>

¹⁶ Siteadmn and Siteadmn (2023) News, AmphiStar. Available at: <https://amphistar.com/blog/>

¹⁷ Roelants, S. (2023) Sophie Roelants on linkedin: #biosurfactants #syntheticbiology #startuplife #funding #circular...: 18 comments, sophie roelants on LinkedIn: #biosurfactants #syntheticbiology #startuplife #funding #circular... | 18 comments. Available at: <https://www.linkedin.com/feed/update/urn:li:activity:7128317595409080320/>

¹⁸ Harms, N. (2023) Sustainability startup based in Houston scores major corporate partnership, InnovationMap. Available at: <https://houston.innovationmap.com/solugen-sasol-strategic-partnership-2666097645.html>

¹⁹ Solugen and ADM announce strategic partnership to meet increasing demand for sustainable products with new biomanufacturing facility in the U.S. Midwest (2023) Business Wire. Available at: <https://www.businesswire.com/news/home/20231030550926/en/Solugen-and-ADM-Announce-Strategic-Partnership-to-Meet-Increasing-Demand-for-Sustainable-Products-with-New-Biomanufacturing-Facility-in-the-U.S.-Midwest>

²⁰ Bioworks, G. (2022) Lygos and Ginkgo Bioworks announce partnership to optimize production of Biobased Specialty Chemicals, PR Newswire: press release distribution, targeting, monitoring and marketing. Available at: <https://www.prnewswire.com/news-releases/lygos-and-ginkgo-bioworks-announce-partnership-to-optimize-production-of-biobased-specialty-chemicals-301675172.html>

²¹ Bioworks, G. (2023) Octarine Bio and Ginkgo Bioworks announce partnership to produce natural colors, PR Newswire: press release distribution, targeting, monitoring and marketing. Available at: <https://www.prnewswire.com/news-releases/octarine-bio-and-ginkgo-bioworks-announce-partnership-to-produce-natural-colors-301818803.html>

²² Kanelli, M. *et al.* (2018) 'Microbial production of Violacein and process optimization for dyeing polyamide fabrics with acquired antimicrobial properties', *Frontiers in Microbiology*, 9. doi:10.3389/fmicb.2018.01495.

bioactive dyes that address the consumer desires through safer, healthier, and more sustainable alternatives¹⁴.

A path with hurdles: is it worth the investment?

Despite scaling constituting a minor challenge for specialty chemicals compared to commodity chemicals, manufacturers of the first are still faced with multiple hurdles. Using new ingredients as drop-in solutions are often unsuccessful because manufacturers are focused on optimizing their efforts the performance of the end-application as changing one ingredient can affect the formation to the detriment of the final product. The costs for replacing their existing processing equipment and ensuring the quality of the specialty chemical is retained throughout its transportation to businesses and customers are frequently underestimated. Furthermore, synthetic biology companies might become tempted to profit by charging unrealistic green premiums, with research by Boston consulting showing that while 80% of buyers are well-informed about sustainability, only 1 to 7% are willing to pay premium for such products⁸.

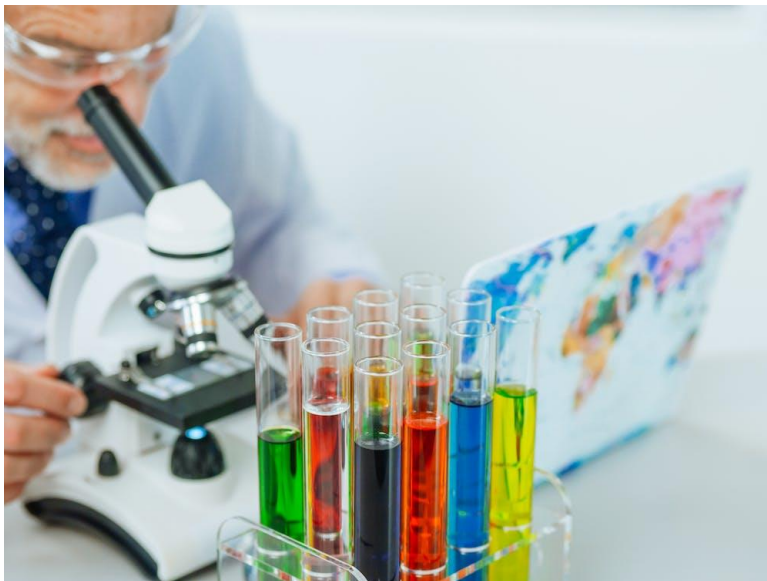


Figure 3. Octarine Bio aims to produce novel bio-based textile dyes that are non-toxic to aquatic life.

- Source: pexels.com

Despite their special qualities, numerous material discoveries including specialty polymers, composites, and nanomaterials have historically failed to penetrate or create new markets. In a lot of occasions, having a "syn-bio platform" or just being "bio-based" is insufficient. Large clients are becoming increasingly skeptical of their capacity for long-term success and therefore have introduced more stringent and time-consuming validation cycles than synthetic biology inventors can handle, especially when it comes to functional materials⁸.

It's all in the substance: coordinated efforts can lead to success.

The need for bio-based specialty chemicals with low carbon footprint production methodologies is evident. These chemicals have an obvious advantage over commodity chemicals since their scaling efforts are not required to reach excessive quantities, and they have specific business plans with defined product design and functionalities. However, there are a set of success factors advisable to all involved parties.

One should start with the market problem to be solved and assess the significance and scope of unmet demands. Carefully evaluate the anticipated timeframe for starting and completing a market transition from existing goods or procedures to novel solutions. Determine which legislative and regulatory adjustments have the potential to alter the rules or the playing field in the relevant region⁸.

Financially viable solutions are considerably more likely to take the shape of high-value goods or functional equivalents in high-value markets. In the case of flavour and aroma compounds, for instance, where existing molecules are costly or scarce, there have been several successful niche synthetic biology projects. For example, a new German start-up Insempra is successfully producing food flavors using a proprietary microbial fermentation chassis²³. Additionally, NY-based Osmo, a promising start-up funded by Google research, aims to produce the design molecules for the flavor and fragrance industry that are potent, allergen-free and biodegradable²⁴. Furthermore, a cosmetics manufacturer might be prepared to pay extra for biobased pigments or dyes due to the sustainability of the feedstocks²⁵, the low carbon footprint and the perceived benefits in marketing as well as budget flexibility due to the high cost of their goods. Nevertheless, while a textile company might still use them sparingly in more expensive niche products marketed to specific consumer segments it will think twice to include them in mass-market products⁸.

Another key factor to success is support and collaboration. Suppliers must be aware of the purchasing procedures used by their clients and, frequently, the manufacturing critical-to-quality requirements. It might be necessary for them to conduct in-use testing for possible clients. In this context, corporate partners with relevant sector knowledge and experience might be very beneficial⁸.

²³ Cumbers, J. (2023) A new raspberry flavor for your tastebuds: Brought to you by fermentation, Forbes. Available at: <https://www.forbes.com/sites/johncumbers/2023/04/04/a-new-raspberry-flavor-for-your-tastebuds-brought-to-you-by-fermentation/?sh=4c68b2e12285>

²⁴ Mullin, E. (2023) This startup is using AI to unearth new smells, Wired. Available at: <https://www.wired.com/story/this-startup-is-using-ai-to-unearth-new-smells/#:~:text=Google%20Research%20spinout%20Osmo%20wants,help%20combat%20mosquito%2Dborne%20diseases.>

²⁵ Synthetic Biology in cosmetics: Limitless perspectives (no date a) Croda Personal Care. Available at: <https://www.crodapersonalcare.com/en-gb/blog/synthetic-biology-in-cosmetics--limitless-perspectives>

Bio-based specialty-chemicals start-ups are here to stay

Such ambitious efforts require consistency and results-based progress. The LCA agencies and relevant regulatory bodies of governments, or unions, are expected to play a significant role, within the next decade, in assuring the share of bio-based specialty chemicals is increased.

Most importantly, new players need to fully comprehend their value proposition, one that has been validated through qualitative research, and stick to it religiously.

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