Biobased chemicals at **industrial scale**

Joachim Merziger and **Sebastian Anton** of **Afyren** introduce a new approach to producing biobased acids with a significantly improved carbon footprint

To improve their carbon footprint, manufacturers of chemicals and ingredients can now consider products that use sustainable feedstocks to replace conventional crude-derived raw materials. For example, whereas in the past petro-based derivatives were needed to produce carboxylic acids at industrial scale, renewable and sustainable alternatives are now within reach in commercial quantities.

Over the past ten years, many attempts have been made to find a way to replace petroleum in the production of carboxylic acids. While solutions have been found at a research stage, none of these efforts have found the right equilibrium between efficiency, ecology and a viable business model.

Afyren, a French biotechnology firm, is set to prove its process and business model. Its first commercial plant in north-eastern France is expected to start producing commercial quantities (16,000 tonnes/year) of seven 100% biobased carboxylic acids early in 2022: acetic (C_2), propionic (C_3), butyric (C_4), isobutyric (iC_4), valeric (C_5), isovaleric (iC_5) and caproic (C_6).

These will be marketed as drop-in replacements for all the applications of existing, crude-derived acids. These include chemicals used in flavours and fragrances, mould inhibitors for bread, feedstocks for ester formulations lubrication, building blocks for pharmaceuticals and additives in animal feed that promote gut health. The objective is not to compete with petroleum-based industries, but to respond to the emerging demand for more sustainable products.

Biomimetic fermentation, upcycled waste

Carboxylic acids are components that can be found in natural products or plants, such as butyric acid in Parmesan cheese, valeric acid in the valerian plant, propionic acid in Emmental cheese, acetic acid in vinegar and caproic acid in vanilla. The initial inspiration was to master biomechanical routes in order to control the level of production, the efficiency of the process and scalability.

The technology is biomimetic. The company's zero-waste process does not need any complex chemical pretreatments to produce ➢

The sugar beet fields of northern France will be a key supplier of raw materials

a reaction, because it is based on natural anaerobic fermentation and uses microorganisms that are not genetically modified.

In the first step, microbial communities convert agricultural co-products into biobased platform intermediates of all the above-mentioned acids, without pre-treatment. The second step consists of the separation through purification and distillation of the organic acids that have market-known technical specifications.

The only leftover from the fermentation process is a solid co-product that is rich in potassium. This offers an alternative to synthetic or extraction-based potassium production and can be returned to the agricultural sector as an organic fertiliser, completing the circular, zero-waste approach.

Terrial, a subsidiary of Avril Group and Suez which is the French leader in organic fertilisation, has an exclusive deal to use this co-product as an environmentally friendly supply of certified organic potassium that will be used in its premium products. As this co-product will be returned into the soil, it represents the start of the forming of new biomass.

Potassium strengthens cell walls (preventing lodging), improves resistance to abiotic stresses (drought, frost) and promotes the migration of glucides to reserve organs. The potassium produced by Afyren will add to Terrial's range with formulations for crops requiring it (beet, potatoes, canola and corn) and crops that cannot receive it in chloride form (vineyards, vegetable crops, etc.).

As simple fermentation processes usually yield high amounts of short-chain acids, it took Afyren years of R&D to design the process, in terms of volume ratio between the different acids, so as to provide commercially relevant quantities. The most difficult issues faced in scale-up included maintaining the robustness of the fermentation process and the consistency of purity and quality, and more generally managing the delicate balance between ecology and economy.

Sustainable, local feedstock

The fermentation technology works with a very large variety of complex substrates. Technically, the process works with numerous feedstocks that can be fermented, such as plants or agro-industrial co-products. Some of the challenges are to find the right volume of acids for each category of feedstock and what is relevant from a commercial standpoint.

From the beginning, Afyren's model was to align ecology and economy and to favour local and circular economy approaches. Therefore, the goal is to make use of the biomass surrounding production sites. After several years of research and experimentation, we decided that sugar beet co-products would be the perfect feedstock for the first plant in Carling Saint-Avold.

Among other practical reasons, this feedstock is widely available within a 250 km radius and the proximity of sourcing with the production site reduces carbon footprint from transportation. In March, we announced a deal, under which

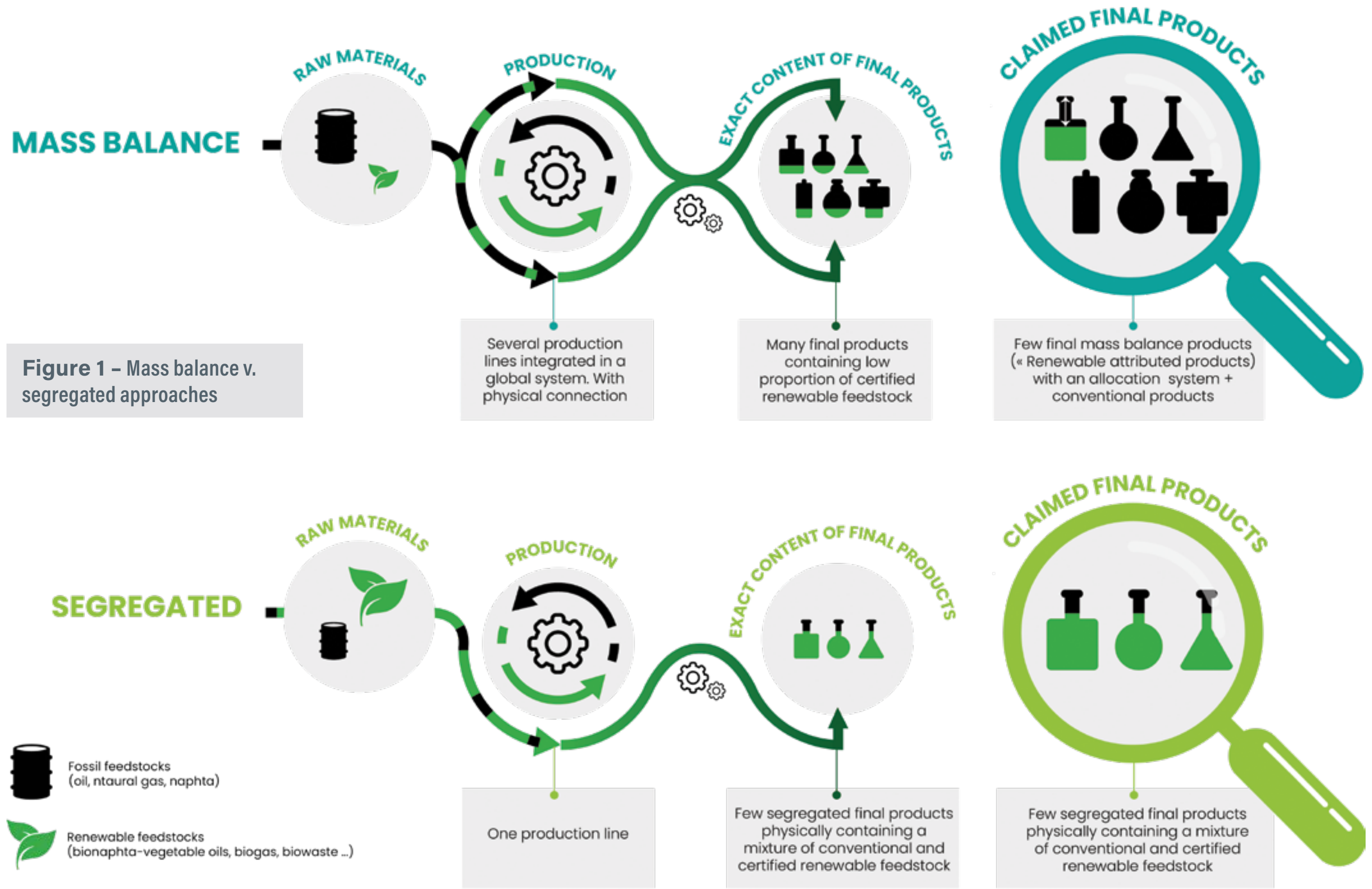

Figure 1 – Mass balance v. segregated approaches

Figure 2 – Afyren approach

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Südzucker, Europe's largest sugar producer, will provide the biorefinery's supply of sugar beet co-products.

The Afyren process is able to adapt to other sustainable feedstocks, but the microorganism mix and other parameters would have to be adjusted.

Lifecycle analysis

Afyren is working to make its process even more efficient and environmentally sound. Three years ago, we partnered with sustainability consulting firm Sphera, who conducted the first environmental study of our products through 'cradle-to-gate' lifecycle analysis (LCA) for the 2018-2019 period, based on pre-industrial data.

The latest LCA update, using data from 2020, gives a more complete environmental assessment of the future biorefinery under construction in Carling Saint-Avold. It shows that Afyren's biobased acids have on average a carbon footprint 81% lower than equivalent petroleum-based products. This means that Afyren's production will allow savings of more than 30,000 'tonnes/year of greenhouse gas emissions.

One of the key elements to reducing the environmental impact was the location of the factory. Afyren's first plant is being constructed within the Chemesis platform, an association of chemical companies located at the same site in order to develop synergies and to share infrastructure. Hooking up to available utilities, such as water, power and steam, was easy, brought additional competitiveness and avoided building new facilities from scratch.

Afyren and Sphera will carry out a critical review of the LCA analysis and plan further iterations to create other sustainability assessments in an effort to continually minimise the environmental impact of its products.

Different approaches, different measures

Moving from 100% petro-based to fully biobased production is too big a leap for many players in the chemical industry. However, other new products and solutions have been emerging as options for more sustainable chemistry. It is important, though, to distinguish the different ways of measuring sustainability.

The most common approach is mass balance, which describes a model where conventional and more sustainable raw materials get commingled in an integrated production system. The sustainable part of the production is allocated to a selection of final certified products, which may not necessarily contain the actual sustainable raw material.

While this approach encourages industry players to buy and use more sustainably produced ingredients, customers need to be sensitive when it comes to the correct labelling of products produced using the mass balance approach.

The final certified products benefit from a claim that reflects the sustainable approach but not necessarily its exact physical content. When applied to bioeconomy, the mass balance approach involves the gradual substitution of fossil feedstocks by renewable feedstocks, with attribution along the value chain.

These products should be considered as renewable-attributed products and should not be called 'bio-based products' in order to avoid any confusion for the consumer. Further claims are derived from exchanging fossil feedstock for renewable feedstock through the mass balance process. The ISO 140212 standard helps specify self-declared environmental claims regarding industrial products.

By contrast a segregated approach consists of materials or molecules produced with a mixture of fossil and renewable raw materials (Figure 1). Fossil resources and renewable feedstocks are mixed in the same production system and flows are merged. The final product physically contains exactly what is claimed and what has been integrated at the beginning of the process.

Afyren is pursuing a segregated, 100% biobased chemistry approach, which allows the customer to buy a product that is entirely made from biomass without any petro-based component all. That means all the molecules' carbon atoms originate from biomass.

As opposed to other approaches where the actual content of biomass can only be calculated theoretically, the biogenic carbon content (or biocontent) in Afyren products can be determined precisely and checked by the C_{14} radiocarbon dating method required by the norms ISO 16620-25 and EN 16785-16 (Figure 2). The result is a significantly reduced carbon footprint that contributes to a zero greenhouse gas emissions target while at the same time respecting nature with a circular process. ●