BioAmber’s commercial-scale facility in Sarnia guarantees sustainable material for a wealth of downstream options.
Bio-succinic acid makes the big time

BioAmber has successfully started up its first commercial-scale plant for bio-succinic acid, bringing a reliable source of the versatile bio-based material to the market.

JOHN BAKER LONDON

Production of commercial-scale quantities of bio-succinic acid at Sarnia in Canada represents a significant landmark in the development of BioAmber, as well as in the market for the bio-based material in general.

The 30,000 tonne/year plant, built in just two years and with an investment of $142m, offers chemical producers a consistent and reliable source of succinic acid, a versatile building-block chemical with an established and now rapidly growing range of applications. The project has been developed as a joint venture with Japan’s Mitsui & Co.

New uses being opened up include plastics, coatings, textiles, artificial leather, food and flavours, and personal care products (see page 5). The chemically derived version of the product already has an established market of around 50,000 tonnes/year, especially in China and other parts of Asia, where it is used in food ingredient and agrochemical applications.

Succinic acid was identified back in 2004 by the US Department of Energy (DOE) as one of 12 leading candidates for commercial development using bio-based or syngas routes as alternatives to petrochemical-based production.

So, in 2008 BioAmber spun off from Diversified Natural Products (DNP) and set out to scale up a process to make succinic acid from sugars, leveraging the technology it had licensed from the DOE in the late 1990s, based on the fermentation of sugars using Escherichia coli.

CRITICAL SCALE-UP PHASE

The newly created spinoff inherited a joint venture in France with Agro-industrie Recherches & Developpements (ARD) and used this to scale up the technology at ARD's multipurpose demonstration-scale facility in Pomacle.

This was a critical phase, notes BioAmber CEO Jean-Francois Huc. The fermentation reactors at Pomacle, at 350,000 litres, were some of the largest in the world at that time and enabled large-scale development and trials to be carried out from January 2010.

“We used the demo plant to significantly improve and simplify the technology and were able to run the process on a continuous basis”, he said. This allowed BioAmber to address the important issues of waste streams and recycling, and to manage the inevitable build-up of impurities in the process “which you don’t see at the lab and pilot scales.”

Five years of learning at the Pomacle facility has been transferred to the Sarnia plant, Huc notes. But the transfer to the new, commercial-scale plant was not to be that straightforward, he adds. It became clear to BioAmber that use of E. coli was not the best way forward, as the bacterium is sensitive to pH in the fermentation process, and this falls as the succinic acid is produced, effectively poisoning the reaction.

The answer was to make a big leap and use yeast to carry out the fermentation, says Fabrice Orecchioni, chief operations officer at BioAmber. Cargill had already developed a yeast that could produce lactic acid, and so BioAmber exclusively licensed the yeast from Cargill and then collaborated with Cargill to re-engineer the process.

“We strive to be a leading bio-based materials producer and have always seen the benefits of owning and operating plants”

JEAN-FRANCOIS HUC
CEO, BioAmber

The first commercial-scale product came off the plant in the fourth quarter of last year.
yeast, together with the BioAmber R&D team, so that it would optimise the production of succinic acid at a much lower pH than *E. coli*.

This left BioAmber with something of a dilemma, explains Orecchioni, as it had already designed the Sarnia commercial facility based on the *E. coli* technology. “The decision was taken in 2012 to switch technologies and delay the Sarnia project by a year,” he says.

The rest is, as they say, history – if indeed only very recent history. Construction on the now simpler and more economical plant was begun in autumn 2013 and completed in spring 2015. The official opening took place in August last year, with the first commercial product being shipped to customers in the fourth quarter of 2015.

**MOVE TO FULL-SCALE PRODUCTION**

The ramp-up to full operating capacity is expected to proceed smoothly and be completed in 2017. It is, as it stands, the largest succinic acid plant in the world, and production costs are lower than at petroleum-based facilities.

Early experience with the plant has confirmed the superior performance of the proprietary yeast used in the fermentation process and shown it to be above the initial targets set for 2015. Product quality is also better than product previously made in the Pomacle demonstration unit.

Huc and Orecchioni are both keen to extol the performance achieved during plant construction, especially for a new technology delivered by a bio start-up company. “We were very schedule-driven”, notes Orecchioni, “and were heavily prepared for the commissioning and start-up phase. We invested early in this – recruiting two years in advance and training operators. We also made sure our business processes worked so we would be ready for an effective start-up”.

“It has been an incredible achievement,” adds Huc. “Not only have we got the plant up and running quickly, but we have already obtained essential safety, environmental and quality management system certifications so that customers can rely on the product coming out of the plant. This differentiates us from some other biochemical companies.”

**GOOD SAFETY RECORD**

He also points out the plant was built without a single lost-time injury and that the construction project won a safety award from IHSA (Infrastructure Health and Safety Association) last year. “What our operations team has been able to do as a small company has been absolutely remarkable.”

Says Orecchioni, “The plant started up relatively smoothly and on time, and we have begun doing some early optimisations of the process and control. We are moving ahead quickly with getting product qualified by customers, with roughly 100 companies having already qualified our bio-succinic acid.”

As well as making succinic acid globally competitive, the new production process will make the chemical available more sustainably. The starting materials are sugars from renewable crops, and the production process overall allows a 100% reduction in emission of greenhouse gases when compared with the equivalent conventional process using oil as a feedstock.

The focus in the short term for the new plant, says Orecchioni, “is to make sure operation is consistent and that we are delivering volumes to our customers. The key to our success in the market is to prove we can be seen as a reliable player and operating company and can supply quality material on a reliable basis.”

BioAmber has a strong commitment to operational excellence both in manufacturing and supply chain, he adds, using LEAN principles, for instance, in both areas. “Everything is driven by value to the customer,” he declares.

**PRODUCTION STRATEGY**

The Sarnia plant and the move to full commercial production of succinic acid is an affirmation of BioAmber’s strategy to concentrate on production rather than licensing of the technology it develops, often in partnerships. The decision to be a manufacturer was made very early on, says Huc.

“BioAmber is different to many other bio-based manufacturers. We did not begin as a biofuels company, and we decided not to go down the route of producing branded specialty ingredients. We want to be a bio-based materials producer and have always seen the benefits of owning and operating our own plants.”

As well as succinic acid, BioAmber has licensed technology to produce 1,4-butanediol (BDO) and tetrahydrofuran (THF) using its succinic acid as a feedstock. It has plans for a second large-scale facility that will produce all three (see page 7), but for the moment, concludes Huc: “It’s all about ramping up Sarnia – in terms of production, sales, expanding the customer base. This is the foundation of our next phase of growth.”

“The plant started up relatively smoothly and on time... We are moving ahead quickly with getting product qualified by customers”

**FABRICE ORECCHIONI**

Chief operations officer, BioAmber
BioAmber has taken a deliberate partnership approach both to financing and building the Sarnia plant and ensuring it has committed customers to take the output.

JOHN BAKER LONDON

BioAmber’s journey to commercial production of bio-succinic acid in just seven years has been achieved with a number of significant partnerships in terms of open innovation, financing and investment, and long-term supply offtakes.

When it spun out of DNP in 2008, BioAmber was essentially just a five-person operation, says CEO Jean-François Huc. To speed up development and commercialisation of succinic acid, the company has not only built up its own capability and expertise, but also developed and licensed technology with the likes of ARD in France for scale-up, US-based Cargill for yeast (see page 2), and Johnson Matthey Davy Technologies for the production of BDO and THF from bio-based succinic acid (see page 7).

To ensure product from the new plant and subsequent ones is sold in volume, BioAmber has also put in place offtake agreements with two major partners: trader Vinmar International and PTTMCC BioChem, a joint venture between Japan’s Mitsubishi Chemical and Thailand’s energy major PTT.

BioAmber decided to buy out its joint venture in France with ARD in 2010 when it became increasingly probable that the first large-scale plant would be built in North America. “It was clear at this time that we would need a partner to build the plant, someone with financial strength, an understanding of chemical markets and a long-term commitment to bio-products,” Huc says.

That partner was Japan’s Mitsui & Co, which made its first small investment in BioAmber through its venture capital arm. “We talked to them in Tokyo and found they had all these things: they were very integrated and had access to feedstock, markets and technology and a long-term view of commitment.” As the world’s largest trader of ethanol, it also had a global infrastructure.

When it came to financing the first plant, Mitsui & Co increased its commitment to BioAmber and signed up to take a 30% stake in the project. “The venture got stronger and Mitsui was getting more and more bullish and was looking to play a stronger role in commercialisation,” Huc says.

Other finances were raised through a successful initial public offering in July 2013 that raised $80m and a second share offering in 2014 that added another $35m. BioAmber also received significant financial support for the plant from the governments of Canada and Ontario.

In the run up to the plant coming on stream, BioAmber signed several supply and sales agreements, which in total exceeded the production capacity of the new plant.

The first take-or-pay deal was signed in May 2014 with PTTMCC BioChem. BioAmber will supply 80% of the succinic acid needed to feed the company’s 20,000 tonne/year polybutylene succinate (PBS) plant based in Rayong, Thailand, until the end of 2017.

The deal will involve some 5,000-plus tonnes/year of succinic acid, says Fabrice Orecchioni, chief operations officer at BioAmber. The PBS plant, which came onstream recently, is expected to require around 14,000 tonnes/year of succinic acid when operating at full capacity.

The second deal, with Vinmar, is a 15-year offtake agreement that commits the US-based trader to purchase 10,000 tonnes/year of the output from the Sarnia plant. The company will sell the material largely on a spot basis into areas where oil-based succinic acid is used today, in the food ingredients and agrochemical markets in China and other parts of Asia, and to customers wanting to substitute it for adipic acid.

Vinmar has since extended its offtake agreement to cover future output from BioAmber’s next two planned plants – amounting to 210,000 tonnes/year in all, including all of the BDO and THF production from the next plant, representing 100,000 tonnes/year.

Vinmar also plans to invest in the next plant, taking a minority equity stake of at least 10%. As part of the deal, Vinmar has a right of first refusal to invest in and secure 100% of the offtake from a second BDO/THF plant that BioAmber would build in the future.

These deals, says Huc, are accompanied by a number of other supply deals with chemical producers that specify price and volumes. These account for a potential 15,000 tonnes/year of the Sarnia plant’s output. BioAmber has also signed distribution agreements with Brenntag in North America and IMCD in Europe to sell to smaller users of succinic acid.
Building the customer base for bio-succinic acid started well before BioAmber’s Sarnia plant came onstream, to ensure demand creation was aligned with capacity build. While part of the 30,000 tonnes/year of bio-succinic acid is spoken for through offtake agreements, BioAmber has been focused on creating market demand through applications development.

By demonstrating the performance of bio-based succinic acid in the replacement of petrochemicals, in terms of improved sustainability and equivalent or improved performance, BioAmber has secured supply agreements with pricing that is not indexed to volatile oil prices.

VERSATILE PLATFORM
The applications development work with bio-succinic acid over the past five years has confirmed the versatility of this C4 dicarboxylic acid as a platform chemical with broad application potential, from large industrial markets such as polyurethanes and coatings to smaller, specialty markets such as personal care, flavours and food.

With the capacity now available from the Sarnia plant, market interest has been growing steadily and an increasing number of customers are commercialising new products containing BioAmber’s succinic acid. Customers are looking for enhanced performance, better economics or greener credentials, and more often than not, getting all three.

“Since we began commercialising bio-succinic acid in 2010 our focus has been to work with potential customers and demonstrate the ability of our products to substitute petrochemicals,” says Louise Batchelor, vice president of marketing for the company.

“We have targeted applications where succinic acid can be formulated into products without the need to change processing equipment, in order to minimise switching costs. By facilitating companies to innovate with new formulations, we have shown that our succinic acid can lead to better products – more ecologically responsible at competitive cost, without compromising on performance.”

Batchelor outlines the key advantages of using the new material. It is, she says, more sustainable, being based on renewable crop-derived feedstocks and having a much lower carbon footprint that petrochemical-based succinic and other commonly used acids, such as adipic acid.

COST-COMPETITIVE MATERIAL
Depending on how it is formulated, bio-based succinic acid offers equivalent or even improved or differentiated performance as compared with the petrochemical incumbents it is replacing in specific applications, and it is competitive on cost.

“We targeted applications where we could generate basic data and confirm the value proposition of succinic acid. We have good data supporting the use of bio-based succinic acid in polyurethanes and resins and coatings, where it mainly replaces adipic acid, as well as lubricants, personal care, flavours and food.”

In regard to applications development, Batchelor explains, BioAmber has built a network of external partners – customers, industry experts, independent laboratories, as well as universities. This has enabled speed and flexibility in developing new applications.

“By facilitating companies to innovate with new formulations, we have shown that our bio-succinic acid can lead to better products”

LOUISE BATCHELOR
Vice president marketing, BioAmber
SYNTHETIC FABRICS

One of the most exciting new products launched over the last two years has been renewable synthetic fabrics, such as leather analogue, where BioAmber’s succinic acid has been used to develop solvent-free, bio-based synthetic leathers for a broad range of applications, from home furnishing to fashion and accessories, footwear and more.

Covestro, a global supplier of high-tech polymer materials, used BioAmber’s succinic acid to develop bio-based, waterborne polyurethane dispersions (PUDs) to transform fabrics into materials suitable for bags, shoes and other fashion garments under the Impranil eco brand.

The fabric is soft and durable and offers endless possibilities for design and colour not available with natural materials like leather; it also meets the growing need for improved sustainability in the textile industry. PUDs in the Impranil eco range have renewable content as high as 65%.

Turkish company Flokser Textile, which produces leather, suede and fabric for clothing, shoes, bags and other goods, has also worked with BioAmber to develop a PU-based synthetic leather using bio-succinic acid in combination with Susterra propanediol from DuPont Tate and Lyle BioProducts.

The result is a 70% bio-based synthetic leather that goes into the furniture, textiles and automotive sectors, offering improved touch and feel as well as better scratch and abrasion resistance, in addition to the high renewable content.

IMPROVED COATINGS

In coatings, bio-based succinic acid can be formulated to give improved gloss and gloss retention after UV exposure, good hardness while maintaining flexibility, less yellowing after UV exposure, and good solvent and abrasion resistance. Coatings with up to 95% bio-based carbon can be achieved when bio-based succinic acid is formulated with natural oil alkyds.

BioAmber’s succinic acid has demonstrated performance in a broad range of coatings technologies and applications: polyurethane dispersions (PUDs) for wood and metal coatings; polyester coatings for appliances, metal furniture and cabinetry; alkyd resins for DIY wood and general industrial coatings; and unsaturated polyester resins (UPRs) for fibre-reinforced plastics and composite structures.

Within this portfolio of applications, BioAmber’s succinic acid has been adopted by Stahl Polymers to produce solvent-free poly-urethanes for high-performance eco-wood coatings with equal performance compared with incumbent coatings based on petrochemicals. This creates value throughout the supply chain all the way to end consumers, who seek more sustainable solutions.

Stahl’s Relca urethane alkyd wood coatings are solvent-free aliphatic polyesters with up to 42% renewable content. These coatings demonstrate good adhesion to metal and plastic, good stain and solvent resistance, and good gloss and colour.

Scott Bader, a global manufacturer of polymers for composites, uses BioAmber’s succinic acid as a building block in its sustainable development programmes.

Steven Brown, polymer development manager, adhesives and advanced composites at Scott Bader, says: “When we first began to look at renewable monomers I accepted that we might have to compromise on performance to improve the sustainability content of our unsaturated resins.”

However, he explains, “we soon realised that this wasn’t necessarily true, as some of our recent development resins containing bio-succinic acid have properties that match, and in some cases exceed, those obtainable from more commonly used petrochemical feedstocks.”

“The drive for better products is a real opportunity for us, and with our Sarnia plant in operation, we can deliver”

LOUISE BATCHelor
Vice president marketing, BioAmber

LUBRICANTS AND PERSONAL CARE

In the lubricants area, BioAmber’s succinic acid is being used by Oleon to produce a new range of dibasic esters, which offer a number of advantages over conventional base stocks. They are more oxidative and thermally stable, making them less prone to deposit formation than mineral oils and polyalphaolefins.

Dibasic esters also have a wide operating temperature range – from -55°C to 300°C – with the superior low-temperature performance giving a substantial advantage to formulators. Oleon’s GREEN DITA brand is based on 100% renewable raw materials and has low ecotoxicity while preserving high performance for the formulation of hydraulic fluids, lubricants, greases, lubricant additives and waxes, as well as a co-base fluid for automotive engine oils.

In personal care, bio-succinic acid can be used to make 100% “natural” products, depending on how it is formulated. Inolex, an independent personal care ingredient company, uses the material in its LexFeel N series of natural emollients, which can be used in place of silicone fluids and offers excellent human and environmental toxicology as marketing advantages. The final product also gives outstanding sensory performance in skin and hair care.

“We are poised for rapid growth,” Batchelor says. “We see growing interest and demand for our renewable building blocks, not only from our customers but throughout the supply chain to brand owners. The drive for better products is a real opportunity for us, and with our Sarnia plant in operation, we can deliver.”
BDO and THF will expand the mix

BioAmber is already planning further succinic acid plants and will add BDO and THF capability to smooth the build-up of capacity

JOHN BAKER LONDON

With commercial production of succinic acid now established in Sarnia, what next for BioAmber? The company has several strands to its future development.

Naturally, the company is looking at further production capacity for succinic acid. But it is also planning to move into the manufacture of bio-based 1,4-butanediol (BDO) and tetrahydrofuran (THF), using its own succinic acid as feedstock. And third, it is looking at other bio-based building blocks, including adipic acid which can be used in polyamide production.

BioAmber has worked since 2010 with DuPont and Evonik and more recently with technology licensor Johnson Matthey Davy Technologies to develop a route from bio-succinic acid to BDO and THF.

LICENSING BDO TECHNOLOGY

In April 2015, BioAmber signed a catalyst technology licensing deal with JM Davy which will enable it to move to full-scale production in 2018, converting its bio-based succinic acid into 100,000 tonnes/year of BDO and THF capacity, split 70:30 between BDO and THF.

JM Davy has licensed its technology to a number of producers of BDO and THF, and adjusted its technology so that it can use bio-succinic acid as a starting material instead of maleic anhydride. JM Davy has validated the design in its UK pilot plant and is providing BioAmber with process and performance guarantees.

The licence also includes an option to build two further BDO/THF plants in the future. BioAmber has already signed a 15-year offtake agreement with Vinmar Interna-
tional for 100% of the BDO and THF output. Vinmar is also taking a 10% equity stake in the plant. Further debt and equity partnerships will be raised to fund the project, explains BioAmber CEO Jean-François Huc, who adds BioAmber is also looking for government loans for the project.

The strategy behind this approach, says Huc, is that by entering the $4bn global markets for BDO and THF with cost-competitive bio-based products, BioAmber can scale up its succinic acid production significantly in the second plant, achieving economies of scale without significant market risk.

Says Huc: “Our succinic acid is already a competitive feedstock. By building larger plants, we can further decrease the cost of succinic acid by benefitting from lower depreciation in terms of $/tonne of capex and lower operating fixed costs. This will allow us to price more aggressively and further expand the market.”

US OR CANADA LOCATION

Plans for the new investment are well advanced and location has been narrowed down to two locations: one in Louisiana in the US on the Mississippi river and one in Canada, close to the existing Sarnia unit. A decision is expected to be made by the end of this year.

“There is little risk in expanding the scale of the succinic acid unit for the second plant”, says chief operations officer Fabrice Orcioni. The fermenters in the second facility will be only slightly larger than those in the Sarnia facility.

After this second plant, BioAmber has its eyes set on a third succinic acid unit, possibly of 200,000 tonnes/year, and further BDO/THF capacity. But these are not priorities at the moment, says Huc. “We want to get the next plant running by 2018, and then 2019 and 2020 will be big ramp up years.

“There is little risk in expanding the scale of the succinic acid unit for the second plant”

FABRICE ORCIONI
Chief operations officer, BioAmber

BioAmber’s next facility will convert succinic acid into BDO and THF, large volume chemicals used to make stretch fabrics

In the longer term, BioAmber is looking to add bio-based C6 chemistry to its portfolio, notably through yeast that can express adipic acid rather than succinic acid. It has licensed worldwide, exclusive rights to a metabolic pathway that transforms sugars into a family of value-added products, including adipic acid, caprolactam, HMDA, caprolactone and hexanediol.

Patents covering this pathway have been issued in the US and Europe and are pending in a number of other jurisdictions. BioAmber believes this pathway has the advantage of offering a good yield on sugar, relative to alternative routes to these products, and having several products that can be derived from a common pathway.

It is currently focused on the development of adipic acid, which will allow it to leverage its experience in producing and scaling up succinic acid, including its experience with the low pH yeast licensed from Cargill. BioAmber has an exclusive, worldwide licence from Cargill to use its proprietary low-pH yeast platform to produce adipic acid.

Eventually the company sees itself as a $1bn turnover player in the building block chemical space, and who’s to say it can’t achieve this?
BioAmber uses industrial biotechnology to convert renewable feedstocks into sustainable chemicals. Our process has a lower carbon footprint and energy consumption than the equivalent petrochemical process, without compromising on performance and quality.

PLANT’S FACTS
- Commercial scale: 30,000 metric tons per year
- Significant reduction of greenhouse gas emissions compared to the equivalent petrochemical process
- Energy efficient compared to the equivalent petrochemical process

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