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Research Report: Sector update

Bioplastics update

Pace of development accelerates; NatureWorks (Cargill) stiffens its challenge to CSM

Bioplastics moves to the spotlight

- Bioplastics, judging by the increasing incidence of corporate events, is suddenly the place to be. Pioneers in the sector such as Cargill and CSM (each has a distinct model) are now being joined by a host of new names.
- The race is on to be market leader in the various biopolymers being developed. These pioneers are leapfrogging each other with technology claims.

Cargill and CSM at the forefront of bioplastics technology

- Technology matters but, as Clayton Christensen points out in his masterful *The Innovator's Dilemma*, "disruptive technology should be framed as a marketing challenge, not a technological one".
- Based on comparative news releases, Cargill has strong customer links for its version of polylactic acid (PLA). Its latest release (July 6th) tells that it will have samples of a new improved lactide (a PLA ingredient) available by 2012 with capacity for thousands of tonnes available in 2013. Cargill claims superior functional and cost benefits for its new development. Lactide is CSM's core bioplastic technology.
- We cannot assess which is the superior technology, but we subscribe to Christensen's viewpoint. For this reason, we believe that CSM may have to become as revelatory about its customer links (that will consume its 2012 lactide output) as it is as forthright about Purac's technical superiority.
- In this report, our specialist consultant, Dr Kevin O' Connor, provides an update on succinic acid and lactic acid-based polymers.

Please refer to important disclosures at the end of this report.

Activity levels picking up – food and beverage early adopters

Activity levels in the bioplastic supply chain are beginning to accelerate. Supply-side companies such as CSM, BioAmber and Cereplast are starting to commit capital to pilot projects in this burgeoning sector. Increased levels of capital spend are coinciding with a greater willingness of the part of large corporations such as Danone, Nestlé and Heinz to include bioplastics in their future procurement strategies.

Supply-side activity picking up

Over the past 12 months, we have seen numerous press releases from supply-side participants announcing planned capital investments in the sector. Examples of these include the following:

- On July 6th 2011, NatureWorks LLC (the Cargill subsidiary) announced a major capital investment at its Blair, Nebraska, facility. According to its statement, it will be the world's first to offer a high-purity, polymer-grade lactide rich in the stereoisomer meso-lactide in commercial quantities. By early 2013, NatureWorks said that it will offer thousands of tonnes of Ingeo M700 lactide.
- US based BioAmber raised $45m in Series B financing from investors in May 2011. The proceeds will be used to accelerate the commercialisation of BioAmber's product set (biosuccinic) and fund the construction of a large-scale plant in North America.
- Cereplast (NASDAQ: CERP) announced in May that it is establishing a bioplastics manufacturing plant in Assisi (Cannara), Italy. The plans for the plant include a total capacity of approximately 100,000 tonnes. This is likely to occur in several phases: the first phase of 50,000 tonnes is expected to start manufacturing in late-2012, and the second phase of 50,000 tonnes is planned to begin manufacturing in mid-2013, based on market demand. This venture will be funded through local and regional financing with Italian institutions and is expected to receive subsidies from various state and local agencies. The initial investment is estimated to be €10-12m.
- In April, the CJ Group of South Korea and Arkema agreed a Memorandum of Understanding to build a bio-methionine and thiochemicals platform in South East Asia. The 80,000-tonne bio-methionine production plant and the thiochemicals platform would come on-stream at the end of 2013. The project represents overall investments of $400m split equally between both partners.
- In May 2011, Myriant (biotech developer and manufacturer of renewable bio-based chemicals) filed for IPO. Earlier in the year, Myriant raised $60m in strategic equity from PTT Chemical Group (PTT Chemical), Thailand’s largest petrochemical producer. In late December, Myriant announced that it will begin construction on a $30m bio-based succinic acid production plant in Louisiana. The total cost to complete the plant will be approximately $103m.

To us, this looks like the classic early adoption phase of a cycle, with participants in the supply chain starting to commission pilot projects to test the concept.

All the major food and beverage companies have put sustainability high on their corporate agenda. A good example of a bio-initiative was announced in February when Coca-Cola and H.J. Heinz announced a strategic partnership that enables Heinz to produce its ketchup bottles using Coca-Cola's PlantBottle™ packaging. The PET plastic bottles are made partially from plants and have a lower reliance on non-renewable resources compared with traditional PET plastic bottles. While more expensive to produce, Heinz will not increase its ketchup price to cover higher bottle costs.

On June 3rd, NatureWorks announced that Danone had switched to Ingeo, the former's plant-derived biopolymer, for packaging of its flagship Activia yoghurt in Germany. In a comment on the switch from oil-derived polystyrene packaging, Danone's CEO for Germany and Switzerland said the following: "going forward, it is increasingly important for companies and brands to realise that the path ahead is one of technological investment, sustainable development and high quality in all aspects of production – packaging included…with our partners we have taken a first significant step in the packaging development of the future".

Danone plainly sees sustainability as a key competitive advantage. This is understandably so as regards the German market, prospectively the largest market for sustainable product and processes in Europe (for its part, Europe is the leading world market for products that are sustainable and are speedily biodegradable). But an interesting part of the relationship between NatureWorks and Danone is that they will continue to collaborate to "create a new option for recovery of the package after use". Danone states that Ingeo will be used in some 80% of the total volume of all Activia yoghurt products in Germany and that it plans to expand its use to include the other products in the Activia line (drinks, yoghurt, fruit purée and larger consumer formats that account for the remaining 20% of its German volume).

The European Bioplastics Association released new forecasts suggesting that global output from bioplastics will exceed 1m tonnes this year. It expects production to double between 2010 and 2015.

CSM bioplastics – early stages but well positioned

CSM recognised the bioplastics opportunity early and cleverly leveraged its in-house fermentation skills and experience. CSM's lactide plant in Thailand is near completion – the capital cost of the facility is approximately $45m, and it will have 75,000 tonnes of capacity. Management believes that commercial quantities of Purac lactides are expected to be available by end-2011.

In September 2009, CSM and BASF announced a joint production initiative for bio-based succinic acid – sample material from the first production campaign, which was carried out in June 2010, has been made available to selected customers and partners. In the next section of this note, Dr Kevin O'Connor, UCD School of Biomolecular and Biomedical Science, provides an overview of succinic acid and lactic acid-based polymers.

Since 2005, CSM has spent €243m on PPE (Property, Plant and Equipment) related capex and a further €16m on capex relating to intangible fixed assets. Capex/sales have averaged 14% over the period. In a group context, approximately 50% of capex has been allocated to the Purac division. Over the medium term, we expect capex to remain elevated in this division as CSM positions itself for the opportunity in bioplastics. We assume group-wide capex of €137m in the current financial year and €93m in 2012.

Table 1: Purac summary of divisional performance 2005-2010

	2005	*2006*	*2007*	*2008*	*2009*	*2010*	
Sales (€'000)	281.0	295.4	310.1	325.6	355.2	400.4	
EBITDA (€'000)	47.1	53.8	44.7	44.9	59.2	81.0	
Depreciation (€'000)	24.3	26.3	22.4	22.1	21.3	24.4	
EBITA (€'000)	22.8	27.5	22.3	22.8	37.9	56.6	
							Total
Capex on PPE (€'000)	45.4	61.2	60.9	21.4	16.3	37.9	*243.1*
Capex on intangible fixed assets (€'000)	1.2	1.1	1.8	0.8	0.9	10.3	*16.1*
							Average
EBITDA margin	17%	18%	14%	14%	17%	20%	*17%*
EBITA margin	8%	9%	7%	7%	11%	14%	*9%*
Capex/sales	17%	21%	20%	7%	5%	12%	*14%*
Capex (PPE)/depreciation	187%	233%	272%	97%	77%	155%	*170%*
ROCE including goodwill	7.8%	8.7%	6.7%	7.6%	12.7%	18.8%	*10%*

Source: CSM

The recent setback in CSM's bakery division places greater pressure on CSM to deliver on its bioplastics business plan. Even if we struggle with the economic model around bioplastics, we are comfortable with CSM's strategy, the business model (including the inter-relationships with Sulzter, Synbra and Indorama) and the scale from a production cost perspective. As we said in an earlier research note, the more CSM can inform us about lactide off-take, the more comfortable we can become. Customers make businesses. In Purac's case, a couple of commitments from large multinational players will increase the probability of success and investor confidence.

Succinic acid and lactic acid-based polymers

Dr Kevin O Connor, UCD School of Biomolecular and Biomedical Science

Introduction

The purpose of this overview is to describe the biopolymer and biodegradable polymer landscape, with particular emphasis on lactic acid and succinate as building blocks for polymer synthesis and the current uses of these chemicals. A brief introduction to petrochemical-based polymers provides an understanding of the current and likely developments for biopolymers and biodegradable polymers. The terms polymer and plastic are often interchanged. In the strictest terms, a polymer is a chain of repeating units while plastic refers to an end-product (a plastic therefore contains a polymer).

Petrochemical-based polymers and plastics

Fossil oil and natural gas are the sources of the key building blocks for the manufacture of polymers and plastics. In the process of refining crude oil, a number of by-products are generated that can be converted to the polymer building block 'ethane' (also called ethylene), which is used to make polyethylene (PE). There are a wide variety of petrochemical-based plastics on the world market. PE is the single biggest plastic product on the market with polypropylene (PP) and polyethylene terephthalate (PET) the other most common or recognisable types. The following table outlines the most common polymers on the market and their uses.

Table 2: Common petrochemical polymer characteristics and uses

Name	*Major characteristics*	*Example of uses*
Polyethylene (PE)		
- High density (HDPE)	Stiff and strong chemical and water resistant	Water pipes, automobile parts, toys, shampoo bottles
- Low density (LDPE)	Flexible and strong chemical and water resistant	Bags, squeezable bottles, container lids
Polypropylene (PP)	Strong, tough, heat resistant	Microwaveable dishes, yoghurt/butter containers, disposable water drinking cups
Polyethylene terephthalate (PET)	Clarity, strength, toughness, barrier to gas and moisture	Soft drink bottles, food containers
Polyvinyl chloride (PVC)	Strong and tough, easy to blend	Electrical cable insulation, rigid piping, window frames, vinyl records, blister packaging
Polystyrene (PS)	Versatility, clarity, easily formed	Disposable (styrofoam) cups, cutlery and furniture

No one polymer has all of the properties required for all products. There is no silver bullet in the petrochemical plastic treasure chest that will address all of the market’s needs. To enhance the performance of polymers and to address the growing needs of polymer and plastic end-users, the petrochemical polymer industry has developed additives and combinations of polymers.

Composite materials

A large number of petrochemical polymer end-products are made up of more than one polymer or contain a polymer with inorganic additives. These are referred to as composite materials. The blending of polymers can result in a product with additional or combined properties, offering new applications, or enhanced properties for existing applications. For example, modern aircraft are made up of composite polymer materials that make them lighter and therefore more fuel-efficient. The use of composite materials provides these same aircraft with both strong and flexible wings, thus enhancing their flying performance. The use of composite materials has allowed the petrochemical plastics industry to expand and to diversify applications for its polymer resins.

Bio-based and biodegradable polymers

Bio-based polymers are polymers made from natural resources (e.g. PE, a common petrochemical-based polymer, can also be bio-based). The ethylene used by PE manufacturers can be sourced from corn. How? Corn contains starch which can be extracted and converted to glucose, and glucose can be fermented by yeast to produce alcohol (ethanol). The latter can be chemically converted to ethylene and then polymerised by the polymer industry. The bio-based PE is the same as the petrochemical-based PE apart from that fact that the ethylene has come from a renewable bio-based resource (corn). Brazilian petrochemical company Braskem, which makes ethanol from sugar cane, is about to commercialise a similar technology to the one described here (Table 3).

Biodegradable polymers are degraded by micro-organisms as the bonds that make up the polymer chain are recognised by the micro-organisms and subsequently broken down. Biodegradable polymers can be made from natural resources or from petrochemical resources (e.g. polylactic acid (PLA), a rapidly emerging biodegradable polymer, can be made from corn as with the example of PE above (Table 3)). Glucose derived from corn starch can be fermented by bacteria to produce lactic acid. This lactic acid can be polymerised to form PLA. The PLA is biodegradable and bio-based. Polymers such as polycaprolactone are fully biodegradable but are derived from petrochemical oil and not biomass (Table 3).

Biopolymer and biodegradable polymer composites

No single bio-based or biodegradable polymer will satisfy all the needs of the plastics market and thus composite biomaterials and composite biodegradable materials will emerge to meet end-user needs. The development of composite biomaterials and composite biodegradable materials is an area of intense activity as plastic compounders seek to make composite materials with properties that will allow their use in existing products and emerging/new products. Compounders are already working to produce composites of PLA, PBAT, PCL, PBS, PHB and others. For example, the BioBag®, a compostable plastic bag for use with kitchen/food waste, is a composite material made predominantly of starch-based Mater-Bi (Novamont proprietary biopolymer) but with other materials (e.g. vegetable oil-derived polyester) added to improve performance as the thermoplastic starch alone does not have the inherent properties needed for such an application.

Table 3: Biodegradable and bio-based polymers

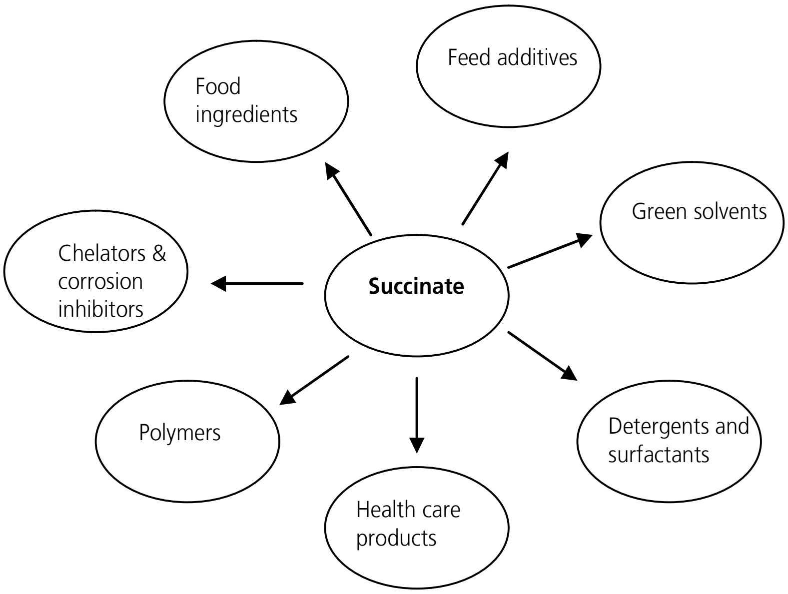
Polymer name	*Characteristic*	*Example of use/comment*
Polylactic acid (PLA)	Biodegradable biopolymer	Plastic bottles
Starch	Biodegradable biopolymer	Plastic bags
Poly(butylene succinate) (PBS)	Biodegradable petrochemical polymer	Cups and cutlery, fibres. Production of bio-succinate will make this part bio-based and part petrochemical-based polymer. Eventually it will be fully bio-based.
Poly butylene adipate-co-terephthalate (PBAT)	Biodegradable petrochemical polymer	Plastic bags, film
Polycaprolactone (PCL)	Biodegradable petrochemical polymer	Biomedical, additive for other polymers
Polyhydroxyalkanoate (PHA)	Biodegradable biopolymer	Plastic film, bottles, biomedical
Cellulose	Biodegradable biopolymer	Paper, cardboard, textiles
Polyethylene	Non-biodegradable petrochemical based polymer (currently)	Agricultural film, food packaging, bottles
	Non-biodegradable bio-based polymer (near future)	Sugar cane to ethanol to ethylene to polyethylene. Brazil and China.

Succinate and succinate-based polymers

Succinate is a versatile compound used in the manufacture of a variety of products[1] (Figure 1). Many production processes involve the transformation of succinate to other chemicals which are the active ingredient or major component of the end-product (e.g. succinate is converted to 1,4 butandiol, which can be used as a solvent or as a building block for polymerisation in PBS).

Succinate is made predominantly from fossil-based butane, but some is produced by fermentation. Between 15,000 and 20,000 tonnes of succinate are sold annually on the world market.[2,3] Petrochemical- based succinate costs €3 per kg; bio-based succinate is estimated to cost less than €1 per kg. A dramatic increase in succinate production is expected as the bio-based polymer and chemical markets expand. Bio-based 1,4 butanediol is a major target for the polymer industry. Over 400,000 tonnes of 1,4 butanediol are produced annually from fossil-based resources at a cost of €1.90 per kg.[3] Current research and development in the production of bio-based succinate is focused on maximising the yield of succinate so that the production costs of bio-based 1,4 butanediol can match or be cheaper than the cost of the petrochemical-based chemical.[2] Some 35,000 tonnes of PBS are currently produced annually at a cost of €4 per kg.[3] An expansion towards 300,000 tonnes of bio-based PBS is expected once the price of succinate production decreases. This is likely to happen as major chemical and agro industry players such as BASF (and Purac), DSM, Roquette, Bioamber and others scale up their bio-based succinate production technologies.

Figure 1: Products made from succinate as a starting material[1]



Lactic acid and lactic acid-based polymers

Lactic acid is produced by fermentation, usually using glucose derived from corn as the fermentation substrate. Other starting material feedstock such as sugar beet has been developed for lactic acid and PLA production.

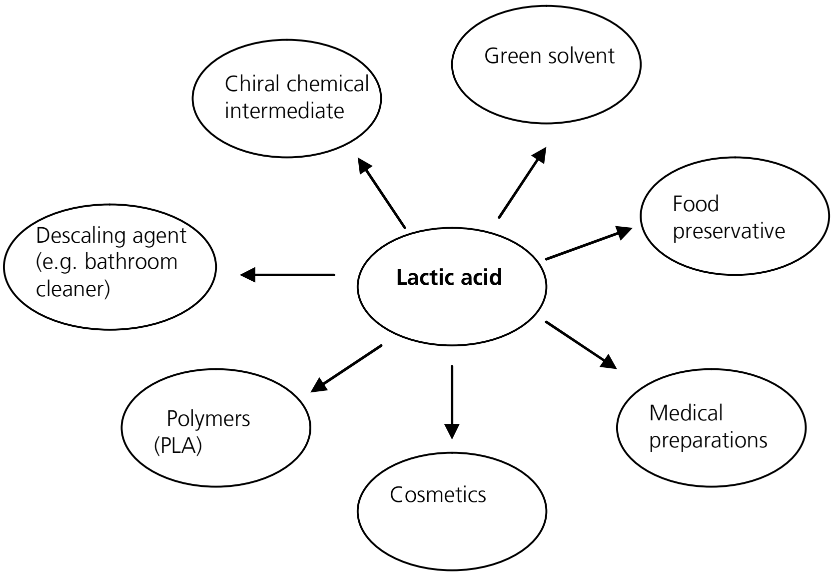
Lactic acid can be used in food, pharmaceutical preparations, animal feed, cosmetics and as a bulk industrial chemical (Figure 2).[4,5] The lactic acid market outside of PLA is over 200,000 tonnes per annum. The demand for PLA outstrips current supply capacity. PLA production will dramatically increase the demand for lactic acid. The current market demand for PLA is approximately 50,000-70,000 tonnes per annum. PLA market demand is predicted to grow to 300,000 tonnes by 2016. There are numerous players in the PLA manufacturing space, e.g. Natureworks (US), Synbra (Netherlands), Purac (Netherlands), Futerro (Total Petrochemicals and Galactic), Toyobo (Japan), Hisun Biosciences (China), Teijin (Japan), Pyramid Bioplastics (Germany).[2,3]

There are two forms of lactic acid: these are referred to as D (right handed) and L (left handed). PLA polymers can be made solely of the right or left handed form or be a mixture of the two.

Control monomer composition of PLA to control polymer properties

The ability to control the properties of a polymer allows a polymer producer the flexibility to address changing market needs. New or improved functionality can reduce costs, increase market share and even open new markets. The ratio of D and L lactic acid in PLA affects the properties of the polymer. For example, PLA with only the L lactic acid is hard and brittle while PLA containing 90% L and 10% D lactic is more flexible. The control of the L to D ratio is of paramount importance if one wishes to control the properties of PLA without having to add other polymers and additives. The ability of companies such as Purac to control the ratio of D and L-lactide combined with Sulzer's polymerisation technology would appear to offer Synbra the enviable ability to control the ratio of D and L lactic acid in PLA and thus adjust polymer properties.

Figure 2: Products made from succinate as a starting material[4,5]



PLA is a biodegradable bio-based substitute for non-degradable petrochemical-based plastics such as PET. PepsiCo announced in 2011 that it has developed a part bio-based PET bottle and is working towards a fully bio-based PET. Thus PET can compete with PLA as a bio-based polymer. However, PET made from either petrochemical or bio-based resources is not biodegradable and most PLA is compostable, which offers it an end-of-life advantage over PET. To complicate matters, some PLAs made up of the D and L lactic acid mixtures are not compostable. While this may be a disadvantage to that particular type of PLA, it may also open up opportunities for it as a durable bio-based polymer. In addition to packaging, PLA can be used in coatings, adhesives, fibres, fabrics, electronics and automotive parts. The price of PLA is currently around €2 per kg for bulk commodity applications and is predicted to fall below €1.30 per kg by 2016.[2,3] PLA is expected to gain a major share of the bulk biopolymer/biodegradable polymer market. While starch will reduce its share of the biopolymer market due to the growth of PLA sales, starch sales will also grow and starch is likely to retain its status as the major biopolymer on the market.[3]

Biobased monomers

A number of petrochemical-based chemicals are used as building blocks (monomers) for the production of petrochemical polymers. Intense investigations are underway to produce these building blocks from biomass (biobased). Such monomers include succinic acid, itaconic acid, isosorbide, 3-hydroxypropionic acid, 2,5 furan dicarboxylic acid and adipic acid. The production of polymers from biobased sources of these monomers will make their production more sustainable provided their production is from biomass that does not compete with food and does not negatively impact on land usage and CO_2 release. Several polymers are made up of more than one building block. The quest to make these fully biobased is gradual as the technology to make one monomer from biomass can be ahead of the technology to produce the other monomer (e.g. Coca Cola released a part biobased (30%) PET bottle in 2009 and Pepsi Co announced the launch of a fully biobased PET bottle in 2011 with pilot scale production predicted for 2012).

Conclusion

A number of biopolymers and bio-based biodegradable polymers are being (and will be) sold as single and composite polymers to satisfy current market demand and to provide new market opportunities. The success of one biopolymer does not automatically mean the demise of another as different polymers can satisfy different market segments. The emerging biopolymer/biodegradable polymer market will mirror the petrochemical market with some polymers gaining a greater share of the market. However, multiple opportunities exist for many bio/biodegradable polymers and will continue to grow for the foreseeable future.

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