

EMERGENCE OF THE CLEAN ENERGY BIOTECH INDUSTRY

The race to develop new, more efficient methods of biofuel production is transforming a once sleepy corner of the biotech industry.

- By Stephan Nielsen

The recent boom in ethanol production has dramatically increased demand for corn – a staple food crop – with the result that US corn prices have soared. Farmers who once planted soya, wheat or cotton are now switching to corn in their droves. More acres of corn were planted this year than at any time since 1944 and it is thought that even more will be planted next year. The story is the same wherever there is a thriving biofuels industry: biofuels crops are displacing food crops and driving prices higher.

With corn as high as USD 4 per bushel farmers are prepared to pay a premium to seed companies for high-yield varieties. The market is dominated by a few big players such as Monsanto, Pioneer Hi-Bred International and Syngenta that have the resources to fund the intricate and often lengthy research programmes necessary to generate winning seeds. However, a few venture-backed companies such as Seattle-based Targeted Growth, have managed to establish a presence.

The seeds are being developed using a combination of artificial selection and genetic engineering to increase yield, among other desirable characteristics. In the former, plants that yield more corn or are pest-resistant are selected and cross-pollinated. The latter entails inserting genes directly into the crop genome either by blasting DNA directly into the cell using a 'gene gun' or using a tumour-inducing microbe. In both methods the genetically modified organism will express the selected characteristics and pass them on to its progeny.

Paul Winters of the Biotechnology Industry Organization says that investment in agricultural biotech is concentrated in North America and not Europe because of an aversion to genetic engineering

and less demand owing to the prevalence of biodiesel for which there are fewer applications.

Further up the value chain, bio-refiners are focused on improving the efficiency of ethanol production. Work is centred on enzymes called amylases that breakdown the starch into sugar monomers and microbes that subsequently ferment these into ethanol. Producers of ethanol from sugar cane and sugar beet are at an advantage as they can derive sugar monomers straight from the feedstock.

The key players in this market are Genencor, a California-based diversified biotechnology company, Canadian cellulosic ethanol producer Iogen and Danish biotechnology research group Novozymes.

Two US firms Mascoma and Amyris are currently engineering microbes that perform the dual function of breaking up the long cellulose sugar chains and converting the resultant sugars into ethanol. Meanwhile, researchers at Rice University are working on a bacterium that ferments glycerin into ethanol which they say could reduce operational costs by 40% at corn-ethanol plants.

Most biotech research, however, is focused on solving the biofuels industry's fundamental problem: that the use of food crops is both expensive and grossly inefficient. Production of ethanol using lingo-cellulosic material opens up a vast range of feedstocks at a fraction of the price of corn or sugar cane. Refiners could use all plant waste, including maize stover, cereal straw, food-processing wastes as well as dedicated fast-growing crops such as switch grass and poplar trees. Moreover, feedstock could be grown on land unsuitable for crops, thereby increasing

land availability.

This potentially lucrative solution has sent scientists to scorching sulphur vents at the bottom of seas and into the bellies of pigs in search of enzymes stable enough to withstand the hot and acidic conditions necessary to loosen the long sugar chains from their lignin anchor.

Not surprisingly there are a number of university research programmes. Cornell University is working on a new enzyme discovered in tomato plants that could assist with lignin degradation, while Purdue University is looking at how to alter lignin and test whether the genetic changes affect the quality of plants used to produce biofuels. The University of Tennessee together with Oak Ridge National Laboratory is building a pilot project in which farmers are growing about 100 acres of switchgrass to be transformed into cellulosic ethanol.

Research in this area has also prompted the formation of a number of partnerships between ethanol producers and enzyme developers. Last year, dry-mill ethanol producer POET joined forces with Novozymes. Similarly, US biotech firm Dyadic struck a deal with Spanish bioethanol producer Abengoa Bioenergy to develop enzyme technology designed to process Abengoa's proprietary biomass substrates.

Oil companies are also queuing up to gain exposure to the sector. Shell and Petrol-Canada have both taken stakes in Iogen, which produces enzymes and is building a full-scale plant. BP has formed partnerships and taken stakes in US firms Mendel Biotechnology and Synthetic Genomes. Chevron and ConocoPhillips, hoping to cash in on cellulose-to-ethanol technology at the early stage, have founded research programmes with various universities.

In the US, a river of government grants has helped galvanise private sector involvement. In the

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first five months of this year, the Department of Energy awarded more than USD 600m to the cellulosic cause including, in February, USD 385m spread across six companies to set up small biorefineries. Three of these - BlueFire Ethanol, Broin and Iogen - are using biotechnology.

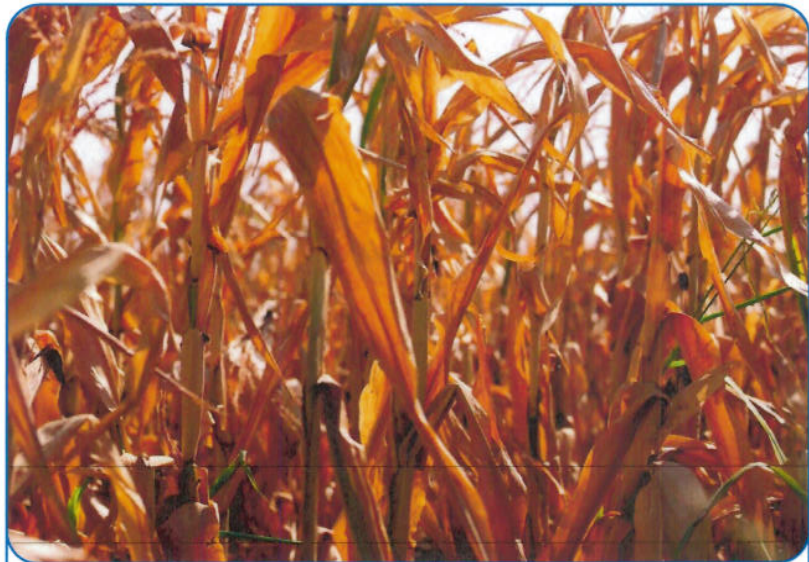
The grants will shoulder a significant proportion of the plant costs. It is estimated that the six plants will cost a total of USD 1.2bn to develop, meaning that the government will assume approximately one-third of the expense.

In March, the DOE announced a further five companies would share USD 23m for research into fermentation organisms. All five companies are pursuing the development of commercially viable, cost-competitive cellulosic ethanol.

At the start of May, the DOE announced a further USD 200m would be granted over five years to bio-refinery developers. Applicants will have to design, build and operate a demonstration plant which can produce biofuels, bio-based chemicals and other by-products. The DOE expects to divide the USD 200m between five to 10 successful applicants, granting up to 25% of the construction cost of each plant. The demonstration plants are intended to prove whether the technologies can be rolled out on a commercial scale.

The DOE has already had some success in improving the economics of cellulosic biofuel. In 2003, it granted large sums to two biotech companies - Genencore and Novozymes - to find a way of reducing costs. In 2005, Novozymes reported that it had slashed the cost of enzyme production from USD 1.47 per litre to between USD 0.30 and USD 0.59.

The availability of so much public money to companies developing cellulosic ethanol has meant that few have sought funding from VC investors this year. In Q2 2007, USD 38m was invested in early-stage biofuels technologies, down from USD 50m in Q1 2007. Although investments in cellulosic technology companies tend to dominate the press releases, analysis shows that the majority of



Advances in biotechnology will make corn bigger and stronger but it may also consign it to the history books as a biofuel feedstock.

investments are in synthetic biology platforms companies, for which the production of biofuels is primarily a means of bringing their technology to market.

It seems likely that these companies will continue to dominate as VC firms are naturally drawn to companies with a technology platform rather than single solution firms. However, the latter are more likely to gain traction among biofuels producers looking for proven affordable technology to reduce their production costs and extract maximum value from their by-products.

Another promising avenue of research has focused on developing strains of algae capable of producing bio-oil. Some start-ups doing interesting work in this area include two California-based companies Aurora Biofuels and LiveFuels. The latter announced it closed a USD 10m Series A funding round at the end of May, while Colorado-based Solix Biofuels recently landed USD 10m Series B financing and has signed a contract to supply algal oil to Imperium Renewables for processing into biodiesel.

One of the most interesting potentialities for biotechnology is its application in integrated biorefineries, says Ana Maria Bravo-Angel, director of communications and public affairs for Genencor. These high-capital plants could be geared to process biomass into a range of products including high-value chemicals

and bioplastics. DuPont, in partnership with sugar and ethanol producer Tate & Lyle, for instance, has developed an E.Coli with a tweaked metabolism that can convert sugars into molecules which can be strung together to generate a fibre called Serona used in clothing. The company has also, using technology licensed from Genencor, developed a micro-organism capable of fermenting sugars into biobutanol instead of the conventional ethanol.

Chemicals companies Huntsman, Dow Chemical, Senergy Chemical and a JV between Cargill and Ashland are also developing plants that convert glycerine, a co-product of biodiesel production, into propylene glycol, a chemical commodity used in anti-freeze and lubricants.

Looking ahead, the view from the laboratory is promising. Universities have mapped out the DNA sequences of a variety of different organisms' genomes providing considerable opportunities for scientists hoping to locate profitable genes. A plethora of patents has been issued ranging from innovative techniques of producing enzymes to genes themselves.

Assuming more countries continue to take up the biofuels mantle and the ethics of commoditizing genetic material does not hamper efforts in the sector, the market for industrial biotechnology products looks set to thrive.