◁11...LOBBY FOR AG RESEARCH

narrowing agriculture R&D in Australia while in many parts of the world expenditure has been going up – sometimes dramatically.

"Australia's urbanised politicians are frightened by small but vocal, well organised and well funded radical environmental and other groups. Some of these oppose research into issues such as genetically modified crops and animal welfare, and want significant government research money diverted to unrelated areas.

How to supply enough food

"Australian governments should not assume that we will always automatically have a plentiful supply of good quality fresh locally grown food as our population increases, climate changes and energy becomes more expensive. It has been estimated that in the next 50 years the world must produce more food than has been produced in the whole of recorded history.

"Quite dramatic changes are likely in the foreseeable future – and some have already occurred. For example, Singapore imported all its rice needs from Thailand – but in 2008 Thailand, for many reasons, without warning embargoed all exports.

"India was recently a major sugar exporter but in 2009 it was an importer. Brazil is using sugarcane to produce ethanol because it pays better.

"And our government and urban population should not overlook the fact that Australian agriculture is still, and should remain, one of our most important export income earners – which helps to support the urban lifestyle.

"What this highlights for the rural community is the need to get onto the playing field. For farmers it is absolutely vital that they have a well funded, very professional, very focused and unified lobby group working consistently at all level of the political system."

The George Wilson Oration is named in honour of Nuffield Australia's founding chairman George Wilson, CMG.

Ian Macintosh AM is Pro-Chancellor of Charles Sturt University, acting as an ambassador for the University in the Bathurst and central western communities. Ian is a former Mayor of Bathurst Regional Council and Deputy Chancellor of CSU. He served as a member of the University Council for eight years, including four years as Deputy Chancellor. He was also chairman of Nuffield Australia for six years, following George Wilson in the position.

For more information contact Ian Macintosh
Ph: 02 6331 8747; Mobile: 0429 326 473
E: imacintosh@ix.net.au ■

Niches and glitches in ethanol production

By Ann Perry, USDA – Agricultural Research Service

All plant matter – from small piles of lawn clippings to overgrown masses of lantana enveloping entire hillsides – contains sugars that could be fermented to make cellulosic ethanol.

That's why USDA scientists at the National Center for Agricultural Utilization Research (NCAUR) in Peoria, Illinois, are working to optimise cellulosic ethanol production and yield from the field to the fuel pump.

Since commercial cellulosic ethanol production will probably be fueled by a diverse collection of plant feedstocks, it won't be a one-size-fits-all process. Bringing commercial production online will depend on finding feedstocks that have suitable carbohydrate levels, finding cost-effective ways to free the sugars stored in those carbohydrates, and finding microorganisms that ferment all sugars.

ARS chemist Badal Saha has just wrapped up a five-year study and concluded that wheat stubble could have commercial potential for cellulosic ethanol production. Badal works in NCAUR's Bioenergy Research Unit.

A key step in cellulose conversion is finding effective ways to pretreat different feedstocks and break down the cell walls, where most of the sugar is stored. There is a long list of pretreatment options that use a range of chemical and physical processes, and each one has its drawbacks and benefits.

Badal found that he could access and ferment almost all the sugars in wheat straw when he pretreated it with alkaline peroxide and then used enzymes to break down the cellulose into sugars for fermentation – a process called 'enzymatic saccharification'.

The ethanol yield was about 102 US gallons per metric tonne of wheat straw (386 litres per tonne). Plus this approach did not produce substances called 'fermentation inhibitors' which sometimes develop as a result of pretreatment dynamics and reduce ethanol yield.

Pretreating wheat straw with lime also resulted in a good ethanol yield – around 91 US gallons per tonne of straw (344 litres per tonne). As with the alkaline peroxide pretreatment, lime pretreatment didn't prompt the development of fermentation inhibitors, and it produced sugars that were easily fermented.

It is also a much cheaper alternative to alkaline peroxide pretreatment.

Badal was also pleased that he obtained good ethanol yields when he combined barley straw with wheat straw. Rice hulls also showed promise as a biofuel feedstock, even though their high silica content lessened the final ethanol yield to only around 59 US gallons per tonne of feedstock (246 litres per tonne).

Although cellulosic ethanol conversion processes often use yeast for fermentation, conventional yeast is not capable of

Microbiologist Ken Bischoff, who developed the shake-flask model for simulating bacterial infection during ethanol fermentation, places flasks in an incubator.
(PHOTO: Stephen Ausmus)

fermenting all the sugars released from cellulosic feedstocks. So Badal worked with bacteria instead, and used a strain of *E. coli* bacterium that had been genetically enhanced to bolster its fermentation abilities. He wanted to see if this strain could sustain good fermentation rates at industrial production levels.

"We tested the *E. coli* continuously for four months to ferment wheat straw," Badal says. "When we looked at the results, we didn't see any loss of bacterial productivity. The ethanol yield remained consistent throughout the study, which is a good sign that the *E. coli* can maintain good fermentation rates in prolonged production cycles."

Badal is ready to move to the next stage. "In four trials, we successfully demonstrated the conversion of wheat straw into ethanol at a 10-litre scale," he says. "Now we want to scale up to 100 litres and conduct a cost analysis of the production process."

The sick ward

An ethanol plant is not a pristine place. The brew of liquids, chemicals, and plant matter used to produce ethanol also gives rise to organisms that can infect the system and disrupt production until the bad guys – which are usually bacterial species that produce lactic acid – are under control.

These bacteria can grow rapidly and thrive in environments with low pH levels and relatively high alcohol levels, conditions that are both commonly found in ethanol production. The organisms fuel their growth with the plant sugars that would otherwise be fermented into alcohol. And when the bacteria usurp the sugars for their own growth, they produce lactic and acetic acids, which harm the fermenting yeast.

The result: a 'stuck' fermentation. Sometimes antibiotics can take care of it, but other times, infected facilities need to be completely shut down for a thorough cleanup.

Microbiologist Ken Bischoff and geneticist Tim Leathers, who work in NCAUR's Renewable Product Technology Research Unit, have now become unofficial ethanol epidemiologists as well.

"Chronic infections can reduce ethanol yields two to four per cent, which is a lot at a plant that produces 100 million US gallons (378 million litres) of ethanol a year," Ken notes.

Tim decided to do an identity check of the microbes that were derailing ethanol

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Technician Greg Kennedy (left) and chemist Badal Saha sample cellulosic ethanol from wheat straw produced in a 100-litre fermenter to assess its ethanol content and to monitor how quickly the sugars in the wheat straw are being fermented into ethanol. Using the 100-litre fermenter allows the scientists to scale up the process so that they can finetune it and identify technical problems that might develop during large-scale ethanol production.
(PHOTO: Stephen Ausmus)

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production. He collected bacteria samples from a wet-mill commercial grain-ethanol facility that had never been treated with antibiotics and from a dry-grind facility that had been dosed with antibiotics after bacterial outbreaks and was not actively infected at the time of the study. He found that most of the bacterial isolates he collected from both facilities were different types of lactic acid bacteria.

After investigating the antibiotic susceptibility of these samples, Ken developed a shake-flask model for simulating bacterial contamination and infection. He found that when test cultures were inoculated with *Lactobacillus fermentum* – one of the most common sources of bacterial infections in ethanol plants – ethanol yield decreased by 27 per cent.

The infections could sometimes be cured by treating them with virginiamycin, an antibiotic commonly used in the ethanol industry. But one strain of *L. fermentum* was already resistant to treatment.

Ken hopes his model can help the ethanol industry develop alternative methods to control bacterial outbreaks and improve the production process.

"Bacterial contamination is a unique niche in ethanol research," Ken says. "It's new, and it's an area where we can support the industry and really make a difference."

To reach scientists mentioned in this article, contact Ann Perry, USDA-ARS Information Staff, 5601 Sunnyside Ave., Beltsville, MD 20705-5129; (301) 504-1628. ■

Chemist Badal Saha and technician Greg Kennedy collect a sample of a fungal culture to determine whether fermentation inhibitors are present after the pretreatment of wheat straw feedstock. Inhibitors can stop or reduce the rate of ethanol fermentation. (PHOTO: Stephen Ausmus)

Boosting barley for bioenergy

By Ann Perry, Agricultural Research Service – USDA

Agricultural Research Service scientists Kevin Hicks and David Marshall want winter barley to become a prime-time player in bioenergy production.

"The 2007 US Energy Independence and Security Act requires production and use of 136 billion litres of renewable transportation fuels by 2022. Today we only make 34 billion," says Kevin. "We see winter barley as the perfect biofeedstock for making biofuels on the US East Coast."

So Kevin and others in the ARS Crop Conversion Science and Engineering Research Unit in Wyndmoor, Pennsylvania, are developing new sustainable technologies to convert varieties of hulled and hull-less winter 'energy' barley into fuel ethanol.

This initiative also includes Virginia Polytechnic Institute and State University scientists Carl Griffey, Wynse Brooks, and Mark Vaughn, who are supervising ongoing research efforts to develop improved varieties of hulled and hull-less barley.

Their combined efforts could help farmers develop a profitable two-year rotation of winter barley, corn, and soybeans. Winter barley is grown on seasonally fallow land. It acts as a cover crop by protecting soil and nutrients and preventing migration of fertilisers from crop fields to the Chesapeake Bay – which is why the Chesapeake Bay Commission supports the development of winter barley as an energy crop.

And since the field would otherwise be left fallow, producing biofuels from winter barley would not interfere with food production.

Marketing opportunity

Now, too, there is a major marketing opportunity for growers of winter barley. Osage Bio Energy, headquartered in Glen Allen, Virginia, is well under way in constructing the first major barley-to-ethanol production facility in the US.

Meanwhile, in Raleigh, North Carolina, David coordinates the regional winter barley testing nursery, which has the best experimental lines from both public and private winter barley breeding programs in the US. He and other scientists in the ARS Plant Science Research Unit are just a few years into making crosses between hull-less barley and barley with resistance to Ug99 – a stem rust that can inflict crop losses of up to 100 per cent.

Once the researchers have developed robust lines that contain both traits, they'll begin breeding for traits to enhance ethanol production, such as starch content. "In several years, we hope to release barley varieties with traits for enhanced agronomic performance, good grain-to-ethanol qualities, and good resistance to stem rust," David says.

Kevin B. Hicks is with the USDA-ARS Crop Conversion Science and Engineering Research Unit, Eastern Regional Research Center, 600 E. Mermaid Lane, Wyndmoor, PA 19038; (215) 233-6579.

David S. Marshall is in the USDA-ARS Plant Science Research Unit, North Carolina State University, 3411 Gardner Hall, Raleigh, NC 27695; (919) 515-6819. ■

Hulled winter barley ready for harvest. (PHOTO: by Bill Scruggs)