The Good Oil

Stephanie Williams and Peter Gresshoff explain why legumes promise to improve the efficiency of biodiesel production, making them an even better prospect as a green alternative to liquid fossil fuels.

It seems hard to imagine that tomorrow’s cars could be full of beans, but it’s a fact that geological reserves of petrol are dwindling.

The world uses 3.8 trillion litres of oil each year. Known reserves can provide 162 trillion litres per year, which means we have 43 years left.

There’s no choice but to find “sustainable” alternatives as petrol prices continue to soar. Enter biodiesel: a masked hero promising a renewable, cleaner and safer source of energy for the future.

Biodiesel is made predominantly from fresh or recycled vegetable oils and animal fats. It is non-toxic and biodegradable, and produces significantly lower emissions compared with petrol-based diesel.

Currently, Australia’s transport sector is responsible for approximately 15% of total carbon dioxide emissions, and this figure is on the rise. Notably, biodiesel is carbon dioxide-neutral, a concept that links greenhouse gas emissions with greenhouse gas absorption. This means biodiesel’s carbon footprint is minimal and does not contribute to increased atmospheric concentrations of carbon dioxide.

Plants convert solar energy into chemical energy using photosynthesis, and it is this chemical energy that biodiesel releases when burned. Unlike other emerging alternatives such as nuclear power, biodiesel is a storable form of energy.

Diesel blends containing up to 20% biodiesel (B20) can be used in most diesel-powered equipment. Higher level blends and pure biodiesel (B100) can be used in many diesel engines with minimal modifications to seals and piping.

Biofuels made from renewable organic sources are not a new concept. Rudolph Diesel’s first internal combustion engine was powered by peanut oil. However, in the 1920s diesel engine manufacturers altered their engines to use the fossil fuel petroleum because it was cheaper to produce. Along came the rise of the petroleum oil cartels.

In Australia, the main focus on biofuels has been on ethanol blends made from sugar and petrol. This is fuelled by an abundance of sugarcane and the associated low average price being paid for sugar.

While ethanol production has been heavily subsidised by the government, the jury is still out as to whether the subsidy money may be better spent elsewhere. Since ethanol will only replace a very small fraction of Australia’s petrol consumption, its impact on fuel security will be fairly small. Environmental benefits are at best marginal, as sugarcane requires nitrogen fertiliser, which is itself manufactured with the aid of fossil fuel.

Biodiesel’s revival began with farm cooperatives in Austria in the 1980s. Now more than 20 European Union (EU) countries are producing biodiesel on an industrial scale. Diesel engines, after all, are much more accepted in Europe than in Australia.

However, recent technical advances in engine design have eliminated the smell and the characteristic “gluck-gluck” noise, and heightened the performance component. Outstanding passenger vehicles marketed by Audi, Volkswagen, Mercedes, BMW and Peugeot, among others, use attractive diesel engines. Such engines develop great torque, have less moving parts and, more importantly provide excellent mileage: 800–900 km/tank is quite common.

The EU has slowly but surely become the production stronghold for biodiesel, producing nearly 3.2 million tonnes in 2005. Germany is by far the leading biodiesel producer with a production capacity of 2.35 million tonnes and, encouraged by tax breaks, used a reported 1.98 million tonnes last year.

While most European biodiesel is made from canola oil, the main source of biodiesel in the United States is soybean oil. The US is the world’s fourth largest biodiesel producer behind Germany, France and Italy, making 250,000 tonnes in 2005.

In Australia, commercial biodiesel production is in its infancy. Notably, all public transport trains and most public transport buses in Adelaide have been...
operating on a B5 blend (5% biodiesel) made from mustard seed and canola oil since March 2005.

While diesel in Australia attracts a federal government excise of 38 ¢/L, biodiesel is excise-exempt until July 2011. This creates a cost advantage in marketing and an attractive profit margin for the industry.

Unfortunately, an excise equivalent ramping to 19 ¢/L is legislated to phase in for 2011–16. It would appear to be logical for governments of all persuasions to continue to support the broader public acceptance of biodiesel through continued exemption status into the future.

Biodiesel is undoubtedly a good alternative to fossil fuels. The success of biodiesel sourced mainly from canola in Europe is a testimony to its numerous benefits.

However, biodiesel faces a number of drawbacks. Worldwide production of vegetable oil and animal fat is not sufficient to replace liquid fossil fuel use. With current yields, huge amounts of land and fresh water would be needed to completely replace fossil fuel usage. Thus, ongoing research is looking for more suitable crops with high oil content. Enter legumes.

Legumes are plants with a seed pod that splits in two. There are about 18,000 species worldwide. Some have edible seeds and include peas, beans, soybeans, lentils, peanuts and chickpeas.

It is the ability to fix nitrogen that makes this family of flowering plants remarkable, and good candidates for biodiesel production. “Fixing nitrogen” means that a plant can take an unlimited supply of nitrogen gas in the atmosphere to produce ammonia, which is the building block of proteins and other essential components of any organism.

Thus legumes can grow on rather poor soils and generate good crops and sources of biodiesel. Perhaps it is no coincidence that the first biofuel was indeed peanut oil.

Legumes can fix nitrogen due to a symbiotic relationship with soil bacteria known as rhizobia. These bacteria live harmoniously in tiny nodules on legume roots. In return for food and shelter, the soil bacteria convert atmospheric nitrogen to ammonia, which the plant can then use to make proteins and nucleic acids such as DNA. Consequently, legumes do not need nitrogen fertiliser, and in fact are used as a natural fertiliser during crop rotations.

Legumes are an important food source for both humans and animals since their seeds are high in protein and contain various nutriceuticals, such as phytoestrogens. The value of legume crop production worldwide and associated inputs in nitrogen fertiliser equivalents exceeds A$200 billion each year. In contrast canola, which requires nitrogen fertiliser, yields about 0.9 tonnes/ha/year.

Most importantly Pongamia is fast-growing, has no known diseases and is tolerant to salt and drought condi-
Research is now needed to optimise our potential legume crops to feed supplies into the expanding biodiesel production facilities in Australasia. We need to find technologies to detect superior plants (both in terms of yield and oil content), propagate them clonally *en masse* without major genetic instabilities, and then attempt to use modern genetics to optimise the oil product for its industrial applications. Such research capabilities exist within the ARC Centre of Excellence for Integrative Legume Research (see www.cilr.uq.edu.au).

The Australian biodiesel industry is poised for rapid expansion over the next 2 years. Three biodiesel manufacturing plants are in production in New South Wales and South Australia, several are under construction in Queensland and the Northern Territory, and a number of Australian companies are looking at constructing biodiesel plants overseas. Australian biodiesel production capacity is expected to increase more than sevenfold to 750 million litres by 2008; more than double the federal government’s target of 350 million litres of biofuel use by 2010.

It is estimated that Australian biodiesel will replace about 5% of our total diesel market in the next few years. The stage is thus set for a major cultural shift in transport fuel usage in Australia.

In the meantime, the research focus is on improving the efficiency of biodiesel production using legumes with high yields and oil content. This is a valuable opportunity to decrease national dependence on foreign petroleum, increase efficient and sustainable production of domestically grown crops and significantly boost agricultural revenue for Australia.

Dr Stephanie Williams and Prof Peter Gresshoff are members of the Australian Research Council Centre of Excellence for Integrative Legume Research at The University of Queensland.