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SCIENTISTS HAVE FOUND A FUNGUS IN HORSE MANURE THAT HELPS SPEED UP THE CONVERSION OF PLANT MATTER TO SUGAR

Freak feedstocks

In a bid to secure renewable sources of energy, scientists are investigating ever stranger biofuel feedstocks. Fungus, human fat, rabbit corpses – these are just some of the ideas of recent years. Charlotte Niemiec looks at the viability and commercialisation of these unexpected feedstocks

While the vast majority of biofuels are derived from agricultural sources such as rapeseed or soyabeans, over the past decade, some slightly more unorthodox ideas for biofuel feedstocks have crawled out of the woodwork. As weird as they sound, many work extremely well; some are more renewable than traditional biofuels, make better use of waste products and many make more commercial sense.

Smelly, rotten feedstocks

One potential feedstock is a particularly smelly crop called field pennycress, nicknamed 'stinkweed'. A weed of Eurasian origin that is now naturalised throughout North America, it is occasionally used in salads or sandwich spreads, as it has a distinctive taste. However, researchers have looked into its potential as a biofuel due to its high oil content.

According to Advanced Biofuels USA, scientists extracted oil from wild stinkweed, pre-treated it with acid and used methanol to react with the oil to produce both biodiesel and glycerol. After some additional refining, the biodiesel met the US biodiesel fuel standard. Previously considered a problematic, malodorous weed, attitudes towards stinkweed are changing as its low cloud and pour point make it a promising biofuel. Furthermore, the plant can be grown in the winter and harvested in the spring, making solid commercial sense as a good rotation crop.

Another plant-based idea is the use of the fungus *Gliocladium rose* (Glio), discovered to be responsible for rotting canvas during World War Two. According to *Biofuels Digest*, Glio produces diesel, synthesises ethanol and produces cellulase. It is significant because of its ability to convert plant material directly into hydrocarbons that are identical to those found in petroleum.

Biofuels Digest explains that the traditional method of producing biofuels involves using yeast and proceeds in two steps. First, enzymes are used to degrade plant material into sugar. Then, yeast converts the sugar into ethanol that is then mixed with other fuels or used directly in engines that can handle its corrosive properties. With Glio, however, the plant matter is converted directly to hydrocarbons in a single step and they can be used in a standard engine without the worry of conversion.

Re-purposing waste products

If fat is fuel, Beverly Hills plastic surgeon Dr Craig Alan Bittner epitomised this in 2008. Bittner re-purposed the fat he removed from his patients' bodies and turned it into biofuel to power two Ford SUVs. Human fat contains triglycerides in the same way as vegetable oil. *Scientific American* reported in 2008 that a 1996 report to the National Biodiesel Board (NBB) by University of Idaho researcher Jon Van Gerpen concluded that biodiesel fats produced from vegetable oils and animal fats were very similar, containing the same chemical compounds but in different amounts.

"There does not appear to be any basis for making a distinction between the two fuels in terms of their impact on engine performance and emissions", he wrote. Environmentally-friendly but deemed illegal in California to use human medical waste to power vehicles, it is nevertheless a process similar to using rendered animal fat.

Others have turned to more conventional waste products of the human body as a source of biofuel. In 2009, Applied Clean Tech (ACT) and Qteros announced that 'Recyllose' – a recycled solid-based material produced from municipal wastewater could be turned into fuel from cars. In other words – the companies were turning human excrement into biofuel. It was surprisingly effective; the researchers found that one tonne of human excrement produced 120-130 gallons of ethanol. ACT president, Dr Refael Aharan, said a wastewater plant that handled 150M gallons/day of waste would have to produce 20-30M gallons/year of ethanol in order to make the process profitable.

Horse manure may also provide the key to a better biofuel. In 2013, *Western Farm Press* reported that scientists had discovered candidate enzymes in fungi living in the faeces and intestinal tracts of horses. Michelle O'Malley, PhD, explained that the fungus "thrives on lignin-rich plants and converts these materials into sugars for the animal." The scientists' goal, the report said, is to take the genes that produce such enzymes from gut fungi and genetically engineer them into yeast.

Animal energy

In October 2009, the UK's *BBC News* reported that Stockholm, Sweden, had solved the problem of the thousands of rabbits destroying the capital's parks in a rather unusual way. The rabbits were being culled by hunters employed by the city and the bodies were being used to fuel a heating plant in central Sweden.

Tommy Tuvunger, one of the hunters, told Germany's *Spiegel* website that 6,000 rabbits were culled in 2008 and a further 3,000 in 2009. "They are a very big problem", he said. "Once culled, the rabbits are frozen and, when we have enough, a contractor comes and takes them away." The frozen rabbits are taken to a heating plant in Kalskoga, which incinerates them to heat homes.

Leo Virta, the managing director of Konvex – the plant's suppliers – told the BBC that Konvex had developed a new way of processing animal waste with funding from the European Union (EU). He said that, with this new method, raw animal material was being crushed, ground and then pumped to a boiler where it was burned together with wood chips, peat or waste to produce renewable heat. "It is a good system as it solves the problem of dealing with animal waste and it provides heat," he said.

Nevertheless, some residents in Sweden were not too impressed with the city's out-of-the-box thinking and many animal rights groups voiced concern. However, Virta insisted the system was efficient and noted: "One hundred thousand tonnes of raw material can generate enough heat for 11,000 homes a year." The Stockholm facility also incinerates dead cats, cows, deer and horses.

Weirder and weirder

There are even stranger ideas out there. The *Biofuels Digest* report says that two projects have found research and development (R&D) funding to look at opportunities for growing biofuels in space. It notes that a group at NASA's Ames Research Centre is working to convert space-based plant residues from plants grown by astronauts to provide food and breathing air for long-period space travel into sources of fuel, chemicals and food. In March 2010, according to the article, jatropha seeds went into orbit on the space shuttle, where a research project looked at growth rates.

In 2011, researchers at Tulane University in Louisiana, USA, discovered a new bacterial strain, 'TU-130', that turns newspapers into butanol. Doctoral student, Harshad Velankar, who worked with the team, said: "Cellulose is found in all green plants and is the most abundant organic material on earth. Converting it into butanol is the dream of many. In the United States alone, at least 323M tonnes of cellulosic materials that could be used to produce butanol are thrown out each year."

The team first identified TU-103 in animal droppings, cultivated it and developed a method for using it to produce butanol. A news release from the university noted that butanol was superior to ethanol as a biofuel because it can readily fuel existing motor vehicles without any modifications to the engine. It can also be transported through existing fuel pipelines, is less corrosive and contains more energy than ethanol, theoretically resulting in improved mileage.

David Mullin, associate professor of cell and molecular biology at the university, said that TU-103 is the only known butanol-producing clostridial strain that can grow and produce butanol in the presence of oxygen, which kills other butanol-producing bacteria. Having to produce butanol in an oxygen-free space increases the costs of production.

Liquids produced for human consumption, such as wine or soda, are also candidates for biofuel. In the UK, the *Daily Mail* reported in July 2008 that the Prince of Wales was fuelling his Aston Martin D86 with ethanol made from waste wine not suitable for consumption.

At Oklahoma State University, USA, scientists reported that waste from soda pop production could be used as a feedstock for ethanol production by adding nitrogen and yeast, *Biofuels Digest* reported. The presence of sodium benzoate, a common food preservative, was the major indicator in whether a particular brand of soda would ferment well or not. Soda waste is typically disposed of by adjusting the pH level and sending it to a local wastewater treatment plant, a method that can be costly because it can be done only in limited quantities, the report said.

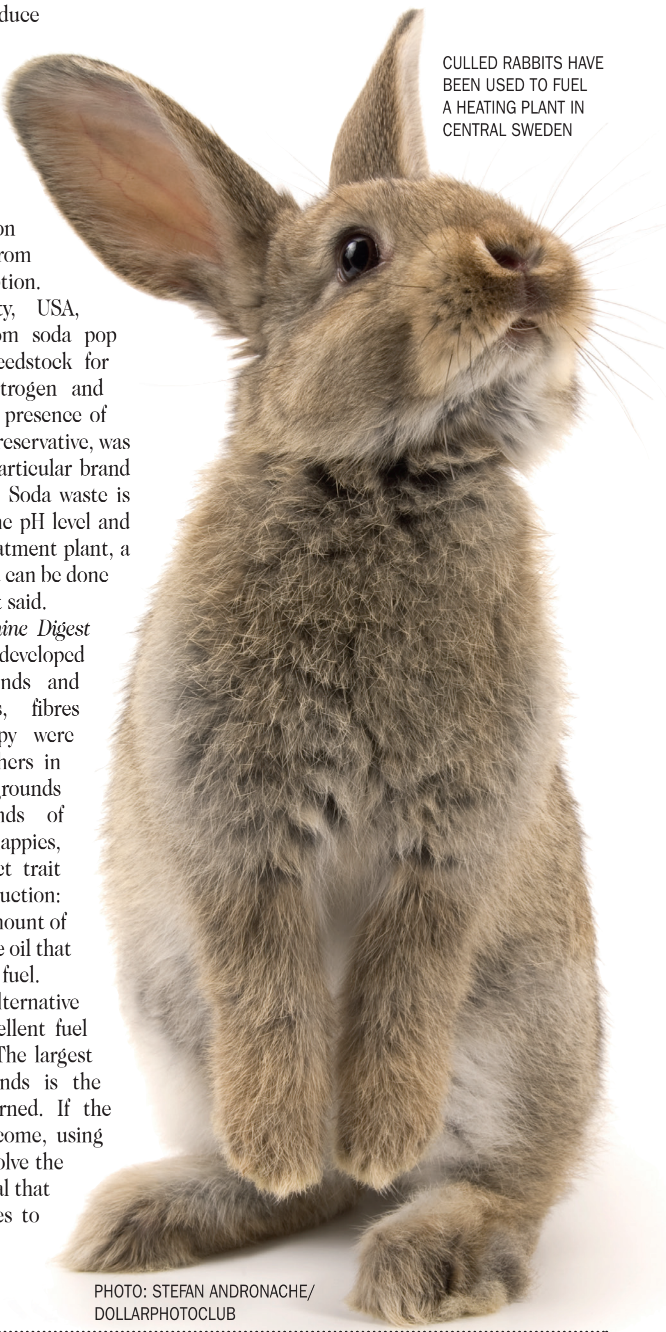
In November 2011, *Green Machine Digest* reported that biofuels were being developed from nappies, beer, coffee grounds and styrofoam. The plastics, resins, fibres and waste contained in a nappy were perfect fodder for biofuel, researchers in Canada discovered, while coffee grounds represented thousands of pounds of biological waste every year. Unlike nappies, however, coffee possesses a distinct trait that makes it ideal for biofuel production: coffee beans contain a significant amount of oil – 10-15% of a coffee bean is usable oil that can be processed into an alternative fuel.

Styrofoam, while not a potential alternative fuel source itself, could be an excellent fuel additive, the report said, adding: "The largest hurdle facing Styrofoam fuel blends is the emissions they produce when burned. If the environmental hazard can be overcome, using Styrofoam as a fuel additive could solve the problem of what to do with a material that can't be recycled and takes decades to biodegrade."

Finally, Joe Thompson, biodiesel lab manager at the University of Idaho, explained in 2011 that his lab had made biodiesel from a variety of feedstocks, including oil from candlenut and croton from Africa, avocado from Mexico, karanja from India, hemp from Canada, algae from California, peanuts from Georgia and coffee grounds from the lab's local Starbucks. But what had great potential was fat from black soldier fly larvae.

Thompson explains: "The larvae feed on manure and transform it into fertiliser. As they grow, they accumulate fat in their bodies. We received several pounds of larvae. First, we had to dry them in an oven and then we put them through our mechanical press to extract the fat. It was a gooey, smelly process. It was difficult to separate the oil from the rest of the larvae. Maybe hexane extraction would have been a better option." Nevertheless, he added, "We found that the fat was very high in free fatty acids – about 80%. The theory is that the larvae produce an enzyme in their bodies to break down the fat and use it for life support." ●

Charlotte Niemiec is OFI's assistant editor



CULLED RABBITS HAVE BEEN USED TO FUEL A HEATING PLANT IN CENTRAL SWEDEN

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