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Biofuels from waste

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biofuel
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At present, fossil fuels are used to provide most of our global energy requirements. In this article, Claire Goncet and Sandra Messenger describe new efforts to replace fossil fuels with biofuels.

Fossil fuels – such as crude oil, coal and natural gas – power cars and generate heat and electricity. Fossil fuels are a finite resource as they take millions of years to form and the remaining supplies are being used at a greater rate than can be sustained.

When burnt, fossil fuels release carbon dioxide (CO_2) into the atmosphere. This stored form of carbon is released, increasing atmospheric CO_2, adding to greenhouse gases and contributing to climate change. It is therefore essential that alternative energy sources are developed. Biofuels may have a big part to play.

Why are biofuels different from fossil fuels?

Biofuels are different from fossil fuels because they come from recently formed biological material, such as plant biomass, which is renewable. Plants use CO_2 to grow. The CO_2 that is released on burning a biofuel is that used in a plant's life cycle as illustrated in Figure 1, so that there is no net increase in atmospheric CO_2.

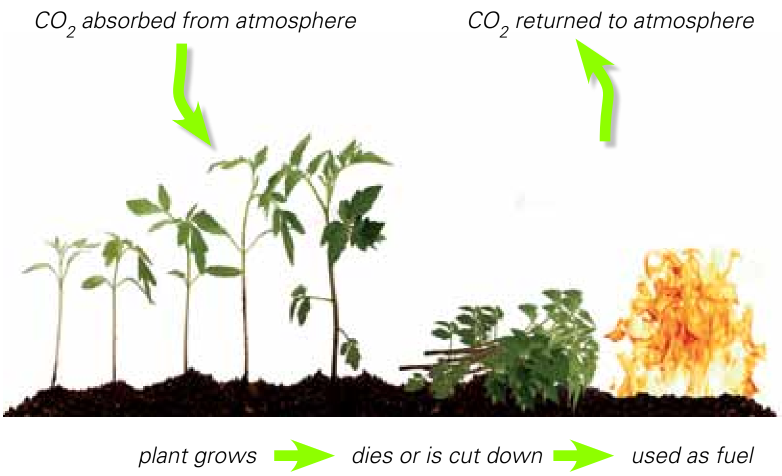


Figure 1 A plant stores carbon from the atmosphere as it grows, and releases it when it dies or is burned.

The 'first generation' biofuels focused largely on energy rich crops such as wheat and rape seed oil, and vegetable oils which were processed to create biofuels. The use of these biofuels created a lot of debate and controversy across the world due to issues such as increased food prices as food crops were diverted from the human food chain, increased demand for land, and potential loss of vital habitats.

Microbial bofuels

Interest has now turned to creating biofuels from more sustainable means including the use of industrial biomass waste or by-products, for example the stalks of wheat, corn, and other inedible waste products. This has a number of benefits, both environmental and commercial, including the reduction in waste being sent to landfill. Biofuels can be made from a number of resources. There are many different biofuels including bio-diesel, bioethanol and biobutanol (see Figure 2). Biofuels do not negatively impact on global warming, can reduce waste to landfill, and are often carbon neutral (they do not increase the amount of CO_2 in the atmosphere.)

Current research, including at the Biofuel Research Centre at Edinburgh Napier University, aims to help companies currently sending waste to landfill, and looks at the potential for this waste to be converted into biofuel, and in particular biobutanol, instead.

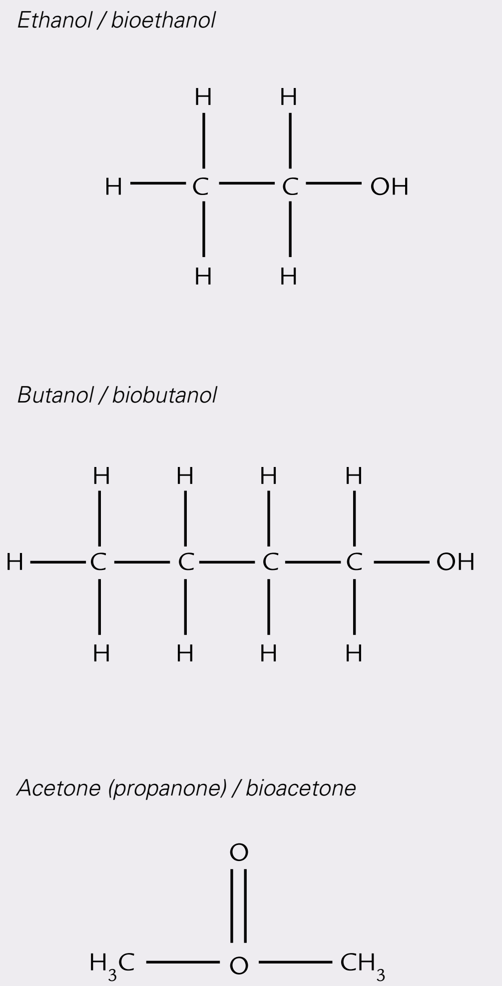


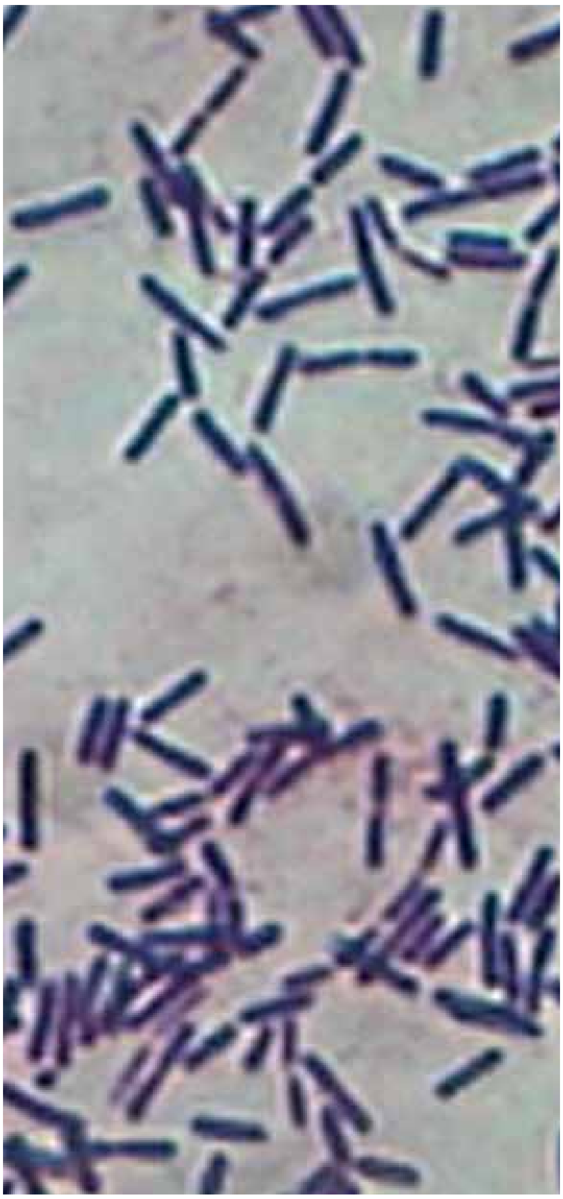
Figure 2 Molecular structures of three biofuels

Discovery of biobutanol

In 1915 Chaim Weizmann isolated the bacterium *Clostridium acetobutylicum*. It produced high levels of bioacetone, biobutanol and bioethanol under anaerobic (oxygen-free) conditions. When it was grown on maize mash and potato it was found that these valuable chemicals were produced through fermentation. This fermentation process was exploited on an industrial scale during the First World War to supply chemicals needed for explosives. The availability of cheap petrochemicals led to the decline of this process on an industrial scale. Today fermentation is once again being developed for industrial scale biofuel production.

Biofuels produced by microbial action

Biofuels can be made by combining a waste by-product with a microbe such as Clostridium acetobuylicum. Figure 3 shows an overview of the different types of biofuels that are being developed with the use of microbes.



Clostridium bacteria – each is about 10 μm in length.

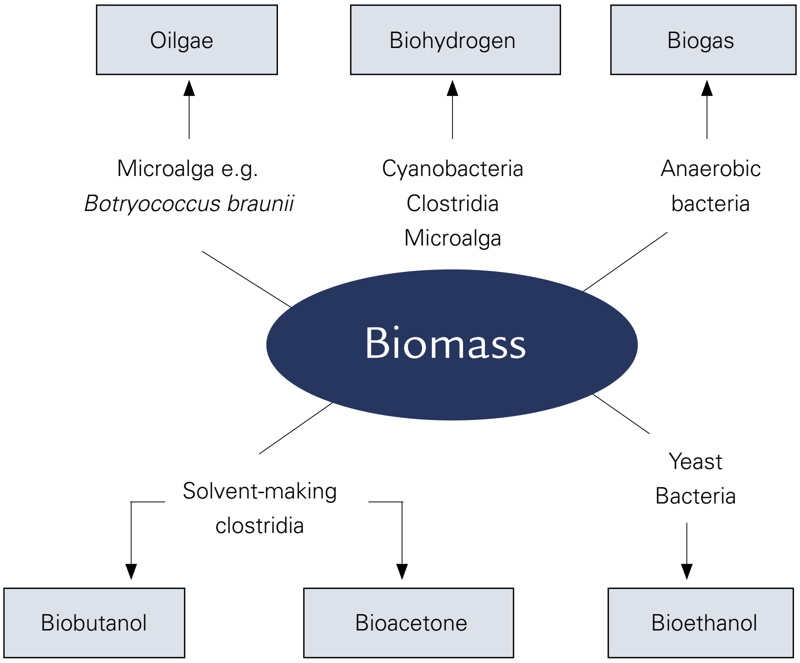


Figure 3 *Many different biofuels can be made using the action of bacteria on organic matter.*

Biobutanol is emerging as an important biofuel for the transport industry as it has more advantageous chemical properties than bioethanol (see Table). Biobutanol, unlike bioethanol, does not need to be blended with petrol, and can also be transported in existing pipelines.

Biobutanol can be used immediately as a substitute for petrol in the transport industry with no costly modifications or changes to the infrastructure of fuel transportation.

	Fuel type		
	Bioethanol	Biobutanol	Petrol
Energy content (megajoule / litre MJ/l)	21	29	33
Use as transport fuel	Engine modification required for higher than 15 – 20% blends with petrol.	Can be used in existing engines. Can be blended at any ratio with petrol or diesel.	Currently the predominant fuel used in vehicles.
Transportation	Rail, barge, truck	Existing pipelines	Pipelines

Table *Comparison of petrol, biobutanol and bioethanol*

Future research in microbial biobutanol production

Although current research has demonstrated that biobutanol from industrial biomass can feasibly produce biofuel, there is a need for continuing and future research.

Current research is focusing on identifying a wide range of waste products which can be converted to biofuel and developing ideal fermentation methods. There are many areas of research aimed at increasing the yields of bioethanol, biobutanol and bioacetone. Improved processes will lead to cheaper products. BP and DuPont plan to have a commercial plant by 2013.

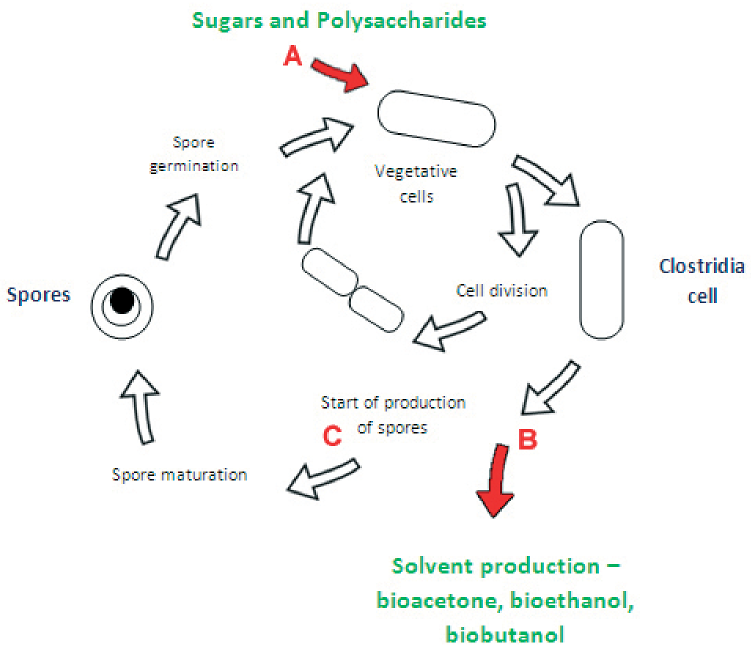


Figure 4 The lifecycle of Clostridia bacteria.

Figure 4 shows the lifecycle of Clostridia. Scientists are targeting the points shown as A, B and C in their efforts to increase yields.

Point A Biomass utilisation

Clostridia rely on the uptake of nutrients from their immediate environment to complete their life cycle. Clostridia typically exist in areas of plant decay and have the natural ability to use a wide range of sugars from a range of biomass resources. Research is required into the full spectrum of waste, sugars and polysaccharides that *Clostridia* can use to assess which biomass streams the microbes can break down naturally with their own enzymes. There is also potential to genetically modify the microbes to enable them to break down and use alternative energy sources. At present, additional enzymes need to be added to produce biobutanol. If this were not the case, the industrial costs of biobutanol production would decrease.

A continuous process is one which runs without interruption. A batch process is stopped and started again frequently, to extract the product.

Point B Solvent tolerance and specific solvent production

An additional approach to maintaining continuous solvent output is to increase the levels of bioacetone, biobutanol and bioethanol which *Clostridia* can tolerate. By understanding the solvent biochemical pathways it may be possible to encourage the production of biobutanol rather than bioacetone and bioethanol. This could increase the level of this desirable solvent.

Point C Solvent-producing strains that do not form spores

When the environment becomes too harsh for the *Clostridia* cells to handle they produce spores. There is a point where solvent production (biobutanol, bioethanol and bioacetone) makes the environment unfavourable for cells to live, and this induces spores to form. When this happens, biobutanol production stops. In order to prevent this, industrial biobutanol fermentations in the past have been done in batches. By modifying the ability to produce spores without reducing solvent production, a continuous process could be achieved. This would increase production and therefore increase income. A continuous process is usually more profitable than a batch process.

A laboratory fermenter for experiments using bacteria.

Oxygen tolerant strains

Clostridia are not able to tolerate oxygen; currently fermentations must be oxygen free making the process more difficult to handle. Research into the development of oxygen tolerant species is needed.

Dr Sandra Messenger and Claire Goncet work in the Biofuel Research Centre at Edinburgh Napier University. Sandra is a research fellow and has a PhD in plant carbohydrate biochemistry. Claire is the Marketing Officer and has a degree in English and experience in marketing both in the UK and internationally.

Look here!

For a previous Catalyst article about biofuels, see: *http://www.sep.org.uk/catalyst/articles/catalyst_17_1_297.pdf*

Researchers at Edinburgh Napier University have developed a biofuel from the waste produced in whisky production. Watch this video: *http://www.napier.ac.uk/randkt/Pages/BiofuelsVideo.aspx*