Engineers develop higher-energy liquid-transportation fuel from sugar

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Plants absorb carbon dioxide from the air and combine it with water molecules and sunshine to make carbohydrate or sugar. Variations on this process provide fuel for all of life on Earth.

Reporting in the June 21 issue of the journal *Nature*, University of Wisconsin-Madison chemical and biological engineering Professor James Dumesic and his research team describe a two-stage process for turning biomass-derived sugar into 2,5-dimethylfuran (DMF), a liquid transportation fuel with 40 percent greater energy density than ethanol.

The prospects of diminishing oil reserves and the threat of global warming caused by releasing otherwise trapped carbon into the atmosphere have researchers searching for a sustainable, carbon-neutral fuel to reduce global reliance on fossil fuels. By chemically engineering sugar through a series of steps involving acid and copper catalysts, salt and butanol as a solvent, UW-Madison researchers created a path to just such a fuel.

Currently, ethanol is the only renewable liquid fuel produced on a large scale," says Dumesic. "But ethanol suffers from several limitations. It has relatively low energy density, evaporates readily, and can become contaminated by absorption of water from the atmosphere. It also requires an energy-intensive distillation process to separate the fuel from water."

Not only does dimethylfuran have higher energy content, it also addresses other ethanol shortcomings. DMF is not soluble in water and therefore cannot become contaminated by absorbing water from the atmosphere. DMF is stable in storage and, in the evaporation stage of its production, consumes one-third of the energy required to evaporate a solution of ethanol produced by fermentation for biofuel applications.

Dumesic and graduate students Yuriy Román-Leshkov, Christopher J. Barrett and Zhen Y. Liu developed their new catalytic process for creating DMF by expanding upon earlier work. As reported in the June 30, 2006, issue of the journal *Science*, Dumesic's team improved the process for making an important chemical intermediate, hydroxymethylfurfural (HMF), from sugar.

Industry uses millions of tons of chemical intermediates, largely sourced from petroleum or natural gas, as the raw material for many modern plastics, drugs and fuels.

The team's method for making HMF and converting it to DMF is a balancing act of chemistry, pressure, temperature and reactor design. Fructose is initially converted to HMF in water using an acid catalyst in the presence of a low-boiling-point solvent. The solvent extracts HMF from water and carries it to a separate location. Although other researchers had previously converted fructose to HMF, Dumesic's research group made a series of improvements that raised the HMF output and made the HMF easier to extract. For example, the team found that adding salt (NaCl) dramatically improves the extraction of HMF from the reactive water phase and helps suppress the formation of impurities.

In the June 21, 2007, issue of *Nature*, Dumesic's team describes its process for converting HMF to DMF over a copper-based catalyst. The conversion removes two oxygen atoms from the compound lowering the boiling point, the temperature at which a liquid turns to gas, and making it suitable for use as transportation fuel. Salt, while improving the production of HMF, presented an obstacle in the production of DMF. It contributed chloride ions that poisoned the conventional copper chromite catalyst. The team instead developed a copper-ruthenium catalyst providing chlorine resistance and superior performance.

Dumesic says more research is required before the technology can be commercialized. For example, while its environmental health impact has not been thoroughly tested, the limited information available suggests DMF is similar to other current fuel components.

"There are some challenges that we need to address," says Dumesic, "but this work shows that we can produce a liquid transportation fuel from biomass that has energy density comparable to petrol."

Source: University of Wisconsin-Madison

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