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THE FUTURE OF FUEL

BIOREFINERY BREAKTHROUGH

No one has ever brewed biofuel from straw on a commercial scale. With Shell's backing, Iogen is likely to be the first.

A GUY DRIVING A FORKLIFT SPEARS A BALE OF straw the size of a stack of mattresses. Then he stuffs it into a whirring shredder that reduces the 1,000-pound rectangle of dry oat stems to a fluffy, fibrous state. These steps **(Nos. 1 and 2 in the illustration at right)** are the first in making ethanol motor fuel at Iogen's experimental plant in Ottawa. Built next to a former Air Canada hangar at the edge of the municipal airport, the factory is really a big science project aimed at learning how to make alcohol on a commercial scale from nonfood biomass like straw. If Iogen succeeds—and it is getting close—it will have the technology the world needs to kick its gasoline habit.

Each big bale will emerge after about a week as 35 to 40 gallons of ethanol. After shredding, the stuff goes through a "steam explosion" process **(3)** that breaks up its structure, like popcorn in a popper. The following step, enzymatic hydrolysis **(4)**, involves combining the biomass with water, heat, and enzymes in sealed, dumpster-sized, stainless-steel cylinders. The resulting mushroom-soup-looking slurry sits for a few days while the enzymes convert the cellulose portion of the straw fiber—which is about 75% of it—into sugars. (The leftover woody matter, lignin, is dried and pressed into burnable cakes; future ethanol factories may use them to fuel their processes.) Once you've got sugar, you can make ethanol—or booze, as it is known to most of us.

What happens next is like the process of making ordinary corn ethanol. A mash of sugars, water, and strains of yeast is pumped into towering five-story-tall stainless-steel vessels called fermenters **(5)**. There's a climb of 80 steps leading to the steel catwalk across the tops of the fermenters in Iogen's plant, and there's a cheerfully beery smell in the air. After brewing for a few days, the fluid in the fermenters reaches an alcohol content of about 4.5% (roughly what you'd get in, say, a bottle of Corona Light) as the hungry yeast organisms exude ethanol as a byproduct of their all-sugar diet. Next the stuff is pumped through distilling vessels and a desiccant process that removes all the water, leaving behind pure 200-proof ethanol **(6)**. As the very last step of its straw-to-fuel process, Iogen blends 1% gasoline into its ethanol to "denature" it **(7)**, so that nobody confuses the alcohol with that bracing, no-tax variety of booze upon which governments frown: moonshine. This brew **(8)** is meant strictly for imbibers equipped with pistons and tires.

Many eyes are watching the progress at this privately held $15-million-a-year Canadian biotech. Four years ago, Shell Global Solutions, the oil giant's technology arm, made a $45 million investment in Iogen to hasten development of a cost-effective way to make cellulosic ethanol. Iogen's plant has been cranking out test quantities for almost two years now. "We have made it work with straw from barley, wheat, oats, and rice; with cornstalks; with bagasse left over from sugar-cane processing; and with chips of hardwoods such as poplar and aspen," says president Brian Foody, whose father founded the company. "There's also research going on with energy crops like switchgrass."

YEAST FEAST Fuel brews in this Iogen fermentation tank.

Iogen's gold is those enzymes that convert cellulose into sugar. Produced by genetically modified microorganisms, they are a major focus of R&D. The best enzyme so far comes from a hopped-up version of *Trichoderma reesei*, the humble fungus that causes jungle rot, which devours canvas tents and other natural-fiber items in the tropics. (Rival enzyme developers like Genencor and BCI use *Trichoderma* and other organisms.)

For now, the plant consumes only about 30 tons of wheat, oat, and barley straw a week—just 10% of its capacity. Even running full tilt at one million gallons a year, the demonstration plant is small compared with a high-volume corn-ethanol plant, not to mention an oil refinery. Iogen calculates that an economically viable cellulosic-ethanol plant would consume 1,500 tons of biomass a day and produce about 45 million gallons of ethanol per year. The first such factory could end up being built in Germany: At the recent Detroit auto show, Volkswagen, Shell, and Iogen announced they are studying the possibility. Says Rob Routs, the senior officer at Royal Dutch Shell who oversees the company's ethanol bets: "We're going to get this thing to work on a larger scale." Zillions of yeast organisms in Ottawa will drink to that. — *Stuart F. Brown*