



Using a state-of-the-art extruder donated by ENTEK, Professor Kaichang Li is developing a strong, lightweight, nontoxic wood-plastic composite — just one of several lines of investigation in Li's lab, including soy-based adhesives and wood-based tire components. (Photo: Karl Maasdam)

# Nature's Glue

**Kaichang Li teaches soybeans to act like shellfish**

by Lee Sherman

Soy may help prevent cancer not only on your kitchen table but also in your kitchen table.

Across campus from OSU's Linus Pauling Institute, where nutrition scientists have been studying soybeans' place in a healthful diet (see "The Zinc Link," page 22), another OSU scientist has found a way to use those same protein-rich beans in everyday wood products — paneling, cabinets, desks and, yes, the table where you eat your meals. These soy-based wood composites are free of the cancer-causing chemical formaldehyde, which for decades has been a mainstay of adhesives used in plywood, particleboard and furniture.

The wood adhesive breakthrough of Kaichang Li, an associate professor in OSU's College of Forestry, is just one of many bio-based products and processes under investigation in labs across the university. While Oregon Governor Ted Kulongoski, the Oregon Innovation Council and others work to secure Oregon's prominence in the new "carbohydrate economy" — drafting bills to boost bio-fuels development and considering a new bio-products research initiative — OSU scientists are at work on the technical challenges. Among them: wood-plastic composites made from recycled carpets, botanical sources of natural rubber, wastewater-generated electricity, cellulose as a source of ethanol and edible coatings for fresh foods (see Growing Technology sidebar.)

Although Li made his bio-based discovery just a few years ago, his interest in nontoxic composites dates back to his post-doctoral studies at the University of Georgia, where he was researching ways of making wood pulp with fungi.

His Scandinavian colleagues told Li about seeing the "reddish skin" of woodworkers using formaldehyde-based glues in their native Sweden. "They all said those glues are nasty materials to work with," says Li.

But it wasn't until a weekend at the Oregon Coast several years later that true inspiration hit. Equipped with a plastic bucket and rubber boots, Li was scouring the craggy outcroppings for mussels in anticipation of a savory seafood dinner. Suddenly, he was struck by the tenacity with which the blue-shelled mollusks clung to the rocks, even as waves pummeled mercilessly and tides tugged relentlessly. Taking some of these tough little shellfish back to his lab, he began investigating their natural super-glue. Prior studies of the proteins forming the mussels' stringy, clingy tentacles showed a unique combination of amino acids, clearly an evolutionary adaptation to the mussels' ecological niche. Such a powerful, waterproof bond was just what the wood-products industry needed to replace the formaldehyde-based formulas, Li concluded.

The trouble was, mussel protein is rare. It wouldn't be practical or, more to the point, cost-effective, to use it directly. Still, the idea had formed and, just like those stubborn mussels, Li wasn't about to let go. The *scientific* question he began to investigate with funding from the U.S. Department of Agriculture was, Can you convert an abundant protein — such as soy — into a strong and water-resistant adhesive like the mussel protein? The *commercial* question was, Can you make the new adhesive at a price competitive with the traditional resin, which costs only about 30 cents a pound?

## Growing Technology

From microbes to plants, OSU researchers are leveraging biological materials to develop a variety of new products. Here are some highlights:

### Cellulose Power

Professor Michael Penner in the Department of Food Science and Technology is studying one of the holy grails of the bio-based fuel industry: the economical conversion of woody plant materials into ethanol and other value-added products. In the Pacific

Northwest, where woody biomass is an abundant source of potential energy, the search for enzymes that can break down the tough-walled cellulose holds huge promise. Unlike the starches found in agricultural crops like corn, which can be easily converted to sugar and then to liquid fuel, woody materials are, in Penner's words, "recalcitrant" to conversion — that is, they require extra chemical intervention before they reach the simple-sugar stage. Penner's lab is working on cost-effective ways to attain this critical "sugar platform."



### Bleaching Agent

Fungi that commonly colonize old tree stumps may benefit the paper industry and the environment. In the Department of Chemical Engineering, Christine Kelly is using white-rot fungi and yeast to create a nontoxic alternative for bleaching paper. She has transferred a gene from the fungi, which produce an enzyme that degrades lignin, into yeast that can be cultivated under industrial conditions.

While the enzyme — manganese peroxidase — has shown promise as a bleaching agent in the laboratory, Kelly and Curtis Lajoie, a research professor in Civil, Construction, and Environmental Engineering, are refining the production process. Their goal is to coax the yeast to create an active, stable and highly concentrated enzyme that can replace currently used chemicals.

### Microbe Energy

Turning sewage into voltage is the aim of Assistant Professor Hong Liu's research in OSU's Department of Biological and Ecological Engineering. Some bacteria living in wastewater can kick off electrons from pollutants. So Liu is developing microbial fuel

Li was pretty sure the answer to both questions was yes. "Protein is protein," he points out, "and all proteins consist of different combinations of amino acids."

In comparing mussel and soy proteins, Li discovered that the amino acid compositions of the two proteins are quite distinct. Mussels contain high levels of certain amino acids that are lacking in soy. At the same time, mussels lack certain amino acids that are abundant in soy. So, using mussels as a model, Li and his research group experimented with chemically modifying the soy protein. They blocked some of the soy amino acids, those that the mussels lack. Simultaneously, they transferred mussel amino acids into the soy. "We turned soy proteins into mussel adhesive proteins," Li says.

Manufacturing the mussel-mimicking adhesive via the chemical-modification route, however, would be too costly. So, to make the new adhesives competitive with traditional adhesive technologies, Li developed a "curing agent" that could readily modify soy under heat during the production of wood-composite panels.

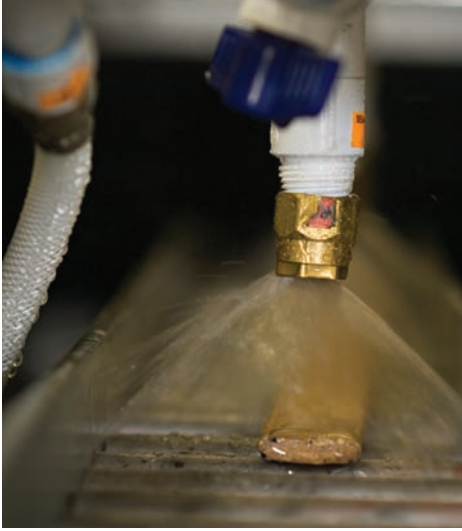
Finally, with funding support from Columbia Forest Products and Hercules Inc., Li's group honed the process for commercial use, running scaled-up experiments and mill trials.

"For 50 years," Li says, "the wood products industry has been arguing about what levels of formaldehyde emissions are safe for humans. But now some companies are taking a different approach — instead of explaining how much formaldehyde is wafting out of their wood products, they're saying, 'Our products are essentially formaldehyde-free.'"

Li's bio-based breakthrough — which he calls a "whole new concept" in wood composites — is revolutionizing the nation's \$4.4 billion wood adhesives industry. The Portland-based behemoth Columbia Forest Products — North America's largest manufacturer of hardwood plywood and hardwood veneer — is carving out a significant niche in the fast-growing "green" housing and construction fields. It took less than three years after OSU patented three adhesive formulas and licensed them to Delaware-based chemical giant Hercules Inc., for Columbia

*Strips of an experimental wood-plastic composite roll off an extruder as Kaichang Li (left) works alongside Kirk Hanawalt, ENTEK Extruders vice president and chief operating officer, and postdoctoral research associate John Lu. ENTEK, a Lebanon, Oregon, firm, donated the \$180,000 machine to OSU last fall. (Photo: Karl Maasdam)*





The hot composites get doused with a cooling spray of water, causing them to solidify, as they come out of the extruder.  
(Photo: Karl Maasdam)

to convert its seven hardwood plywood plants to the nontoxic soy-based adhesives. The company, which produces more than half of U.S. interior wood composites, estimates that it replaced 47 million pounds of formaldehyde-based resins with soy-based adhesives in 2006.

This year, Columbia is beginning production of formaldehyde-free particleboard. Plywood and particleboard have distinct adhesive requirements, Li notes. Plywood uses the glue to bind thin layers of wood. Particleboard, on the other hand, is formed from sawdust-like bits of wood bonded together. One particleboard plant can consume as much adhesive as five plywood plants, according to Li.

“Particleboard creates a dramatic new demand for soy-based adhesives,” he notes.

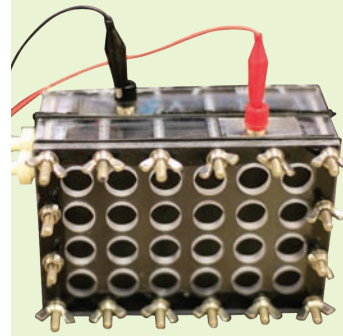
For Oregon, whose forest industry employs more than 85,000 workers statewide, novel wood products like Li’s adhesive help fuel demand and bolster communities, particularly in rural counties hit hard by recent downturns in logging and manufacturing. Wood-plastic composites offer another potential boost. Li’s research team is developing a nontoxic alternative for outdoor construction: decks, cabins and children’s play structures. The new material, besides being strong and lightweight, would be free of such hazardous chemicals as arsenic and chromate, found in some treated wood.

The research focuses on the adhesion between the water-absorbing wood and the water-resisting plastic. Better adhesion translates to stronger materials. A novel wood-plastic composite using recycled carpets and wood is the team’s latest breakthrough.

Wood can also be a competitive source of liquid fuel in Oregon. A recent analysis by OSU economists found that ethanol made from wood cellulose yields the highest “net energy” return (84 percent), compared with canola (69 percent) and corn (20 percent) after subtracting production and transportation costs.

Just as fuels made from these sources can reduce U.S. dependence on foreign petroleum, soy-based adhesives can lessen the nation’s need for foreign sources of natural gas, from which formaldehyde is derived. “I get lots of phone calls about this new adhesive,” says Li. “One person said, ‘This is one of the greatest inventions I’ve seen in the past 50 years in terms of affecting peoples’ lives.’” **terra**

To learn more about Kaichang Li’s research on adhesives and composite materials, see [woodscience.oregonstate.edu/faculty/Li/](http://woodscience.oregonstate.edu/faculty/Li/)



cells to capture the energy stored in wastewater, while simultaneously treating the water. She envisions a day when developing nations, such as her native China, will have waste-treatment facilities powered by the very waste they process, making them energy

self-sufficient and thus more widely affordable.

Liu is also working with Kaichang Li in Wood Science and Engineering to generate electricity from wood. A mixture of the hundreds of small, organic compounds in hydrolyzed wood, the researchers have recently discovered, can be converted directly into electricity with microbial fuel cells. “Liu and I are seeking funding to build the world’s first integrated, portable, compact system for generating electricity directly from wood,” says Li.

### Natural Rubber

OSU agronomist Daryl Ehrensing is part of a private-sector initiative to develop a domestic source of natural rubber. With support from Akron, Ohio-based start-up Delta Plant Technologies, Ehrensing is principal investigator for the Department of Crop and Soil Science breeding program to grow a high-yield variety of the Russian dandelion. The plant, native to Kazakhstan, produces a high-quality latex that can be used in auto and aircraft tires. Other universities working on the project are Ohio State, Washington State and Montana State. In another rubber-related project at OSU, this one funded by a German rubber chemical company, Kaichang Li in Wood Science and Engineering is investigating ways to use cellulose crystals instead of silica and carbon black in tire manufacturing.



### Food Coatings

Yanyun Zhao, an associate professor in the Department of Food Science and Technology, is focusing on the freshness, health benefits and market value of foods. She is developing biodegradable and edible films and coatings to prolong the shelf-life of perishable delicacies such as strawberries and other small fruits. Other projects include vacuum impregnation and infusion techniques for value-added fruit and vegetable products.



## Researcher Profile

**Kaichang Li** is an associate professor in the Department of Wood Science and Engineering in the College of Forestry. He specializes in organic chemistry, wood chemistry, materials science and biotechnology, applying his expertise to a wide range of problem-oriented projects of interest to manufacturers. His research interests range from the development of green wood adhesives to stronger wood-plastic composite materials and applications of biotechnology in the pulp and paper industry. He holds four patents related to the development of formaldehyde-free adhesives. He has received funding support from the U.S. Department of Agriculture, the U.S. Department of Energy, Hercules Incorporated, Columbia Forest Products, and many other sources. He collaborates with researchers at Novozymes and the Pacific Northwest National Laboratory.

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