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Growing fuel of the future, from benchtop to raceway

By Stephanie Hobby

Biofuels from algae are a promising option to help reduce the nation's dependence on foreign oil, but there is still a lot to learn about the tiny green organisms before we can start relying on them to fuel our cars.

A highly interdisciplinary team led by Jeri Timlin (8622) embarked on a three-year, multidisciplinary LDRD project to learn more about the fundamental biology of algae, what makes it productive, and how to sustain populations from the benchtop to the raceway.

The project took a three-tiered approach to better understand how to turn algal ponds into usable fuel. The first goal was to better understand the basic biology of algae, including the effects environmental stressors have on growth and lipid production. The team used input from those experiments to devise technology that could perform real-time monitoring of the health, growth and productivity of the algae. Having such knowledge in the field would help growers take actions that would result in more productive algal harvests. Finally, the third goal was to incorporate all of that knowledge to build a model for algae health and productivity at the large, open-channel raceway-style ponds.

“What many companies are focused on is the production goal – growing as many gallons of algal biofuels a year as possible – and they use empirical knowledge and prior experience to attempt to grow algae favorably, but key information linking environmental conditions to algal response is missing,” Jeri says. “So our underlying theme was to understand the fundamental relationships of algae and their environment.”

The systems at work in an algae pond are complex, and stressors, such as tweaks to heat, light, pH, and salinity, abound. It isn't well understood how an individual cell will respond to a given stressor, and even very similar algae can respond differently to the same environmental conditions. To make matters more complicated, several stressors are dynamic and often changing. What makes it even trickier is how fast those responses happen.

An unfavorable change in conditions can take a healthy pond to the verge of collapse in only a matter of hours to a day, as compared to traditional agriculture, which can take days and weeks to respond to changes in the environment. In such a fast-paced, high-stakes environment, algal growers would really benefit from automated ways to monitor their ponds in real time and have information to make decisions quickly. If a grower can't keep up with changing conditions, the consequences can be costly.

The Algal Biofuels Roadmap, produced by the Biomass Program of the DOE's Office of Energy Efficiency and Renewable Energy in 2010, suggests developing a toolkit to help growers make better decisions at the pond level. Ideally, this toolkit would provide sensitive, selective methods to predict and identify early fluctuations in algal health and productivity. Such capabilities would lead to increased productivity and an extended growing cycle, and ultimately reduce costs associated with producing algal biofuels.

One way to do that is by using spectroscopy and/or hyperspectral imaging to identify biomarkers, unique biological flags whose presence indicate something is amiss. Photosynthetic pigment molecules that harvest sunlight and convert it to chemical energy within the algal cells interact in a specific way with the different wavelengths of light. This forms the basis for its spectral signature, and like fingerprints, every signature is unique. Taking advantage of the many advanced bioanalytical imaging techniques and remote sensing technologies that Sandia is known for, Jeri and her colleagues, Thomas Reichardt (8128), Howland Jones (8622), and Aaron Collins (8622) identified hyperspectral reflectance and fluorescence biomarkers for algal growth and productivity at the subcellular, single cell and ensemble levels. By examining the spectral signatures, the team was able to assess algal health by measuring growth and productivity at the lab, greenhouse and raceway scales.

Specifically, these experiments provided information on areas such as the efficiency of carbon dioxide capture in collaboration with Professor David Hanson at University of New Mexico, a necessary step for photosynthesis, and how the gas gets converted into the fuel-rich lipids in algae. Additionally, Amy Powell (8635) and Kylea Parchert (8622) studied genetic regulation in high salt conditions, which are very important considerations when siting algal ponds in the desert southwest. Such understandings are important to engineer and operate an algal biofuel production plant.

Of the available algae growth options, outdoor open ponds are attractive because they are cost-effective to build and maintain. Such ponds offer the most bang for the buck, but there are more factors to consider in raceway style ponds. Temperature, incident radiation, whether to cover a pond with a greenhouse, nutrient distribution and availability, depth flow characteristics, geometry and channel dimensions and predation all have an impact on algal health, and are much more difficult to control in a raceway pond. Previously, Sandia researchers, Scott James and Patricia Gharagazloo (8365) had begun to develop a computational model, which relied on modified versions of models from the EPA and the US Army Corps of Engineers, predict algal growth in outdoor raceways under a variety of system configurations.

“Using our discoveries in basic algal biology and the technology we developed, we were able to replace variable relationships gathered from sparse literature with highly improved and accurate measurements relevant to production strains of algae. This results in a predictive model where you could change conditions or understand – using a computer – what is going to happen to a pond without building it,” Jeri says.

The LDRD wrapped up last year, and Jeri says she is thrilled with the amount of knowledge her project contributed to both the industry and Sandia. “We brought several of Sandia’s capabilities together in a unique and interdisciplinary fashion to study a largely unexplored area of biofuels,” Jeri says. “In doing that, we made important contributions to Sandia’s biofuels infrastructure, developed new technical capabilities that enabled key algal biology discoveries, and helped add more visibility to Sandia’s biofuels program. It is important work, and I’m extremely pleased with the hard work of our team and our contributions to the field.”