CASE STUDY

DEVELOPING THE NEXT GENERATION OF SUSTAINABLE BIOFUELS

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With the need to develop commercially viable alternative energy sources and increasing concerns about climate change, the growth in the use of biofuels over the past decade has been considerable. However, this has raised issues about the diversion of resources from traditional food crops to biofuel crops, putting greater focus on sustainability in the biofuel sector.

Mary-Grace Danao is an assistant professor in the Department of Agricultural and Biological Engineering at the University of Illinois at Urbana-Champaign. She is working as part of the “Engineering Solutions for Biomass Feedstock Production” (ESBFP) program of the Energy Biosciences Institute (EBI), a research effort funded by international energy company BP.

Grace’s role is leading research in storage-related issues, with the objective to develop guidelines for locating and sizing storage facilities, as well as storage and preservation methods that can improve the supply of high quality biomass to refineries.

The ESBFP program has a range of specific focus areas, including:

- Pre-harvest energy crop monitoring
- Harvesting of energy crops
- Transportation of biomass
- Storage of biomass
- Systems informatics and analysis

The EBI is investigating the use of dedicated energy crops including miscanthus (a commercial biofuel grass used in Europe), prairie cord grass, Napier grass, switchgrass, as well as corn stover, sorghum, sugarcane bagasse and energy cane bagasse.

“The advantage of using perennial grasses is that it doesn’t compete for food, can grow on marginal soils and potentially lower inputs such as water, fertilizer etc. This makes it more economical and has less impact on the environment and food crops compared to some other biomass,” explains Grace.

Once harvested, the biomass may be stored on the farm or sent to a central storage facility or to a refinery. There is only a small window of time when the biomass can be harvested, so in order to ensure that refineries can operate and deliver energy products year round, biomass needs to be stored.

Additionally, experience shows that corn and soybean farmers look at the market price of commodities and often hedge their bets. If the price is high, they sell immediately. However, if the price is low, especially if they have storage capacity, the farmers often stockpile the crop until the market prices rise again.

One result of this is that the raw material (i.e. the crop) arrives at the processing plant in different conditions depending on how long it has been stockpiled and how it was stored. To help improve the management of raw materials, the Energy Biosciences group is investigating the effects of weathering and dry matter losses.
Increasing yields through better process understanding

Grace’s team is doing research into measuring the rates of lignification, cellulose loss and determining ash content. Lignin is a tough material in plants which is hard to control. For refineries, this is a key issue because they must first break down the lignin to get to the cellulose, which is converted into sugar and then converted to fuel.

One of the limitations is that researchers don’t currently understand the process of lignification very well. Grace’s group is now exploring different storage methods that preserve cellulose and minimize the amount of lignin in the material, thereby increasing yield.

In commercial terms, a refinery needs to make the decision whether to receive material based on the quality of the crop or how to blend high grade with low grade materials to maintain a level of process efficiency. If there is too much lignin in the material, a refinery may decide it is too expensive to extract biofuels from it, so they will burn the crop. Alternatively, the refinery can also choose a different pre-treatment to convert the crop into fuel.

Using Near Infrared Spectroscopy in bio-fuel feedstock assessment

Another line of research for Grace’s group is the development of faster techniques to measure the composition of raw material. Traditionally, farmers send samples to the National Renewable Energy Labs (NREL) for measurement, which often takes a long time. However, recent studies have shown that Near Infrared (NIR) spectroscopy can be used to give a quick assessment of the composition of many materials.

NIR is used extensively in the food, pharmaceutical and timber industry to assess the purity of incoming raw materials and perform quality checks on their products. In the biofuels industry, the calibration models used to assess the composition or quality of the crop are usually based on freshly harvested material. However, in practice, the material a refinery receives is often not freshly harvested.

Grace explains, “Refineries want to have consistent quality of material, and if there is variability, develop ways to manage it.”

To more closely reflect actual practice, Grace’s group ran experiments whereby they kept some material for a period of time and left it exposed to the weather, then took samples from different materials stored either outside or indoors for up to 2 years and under different storage conditions. The data from these experiments was then analyzed with multivariate analysis methods, with the results showing that composition does not change dramatically over time but dry matter losses are significant.
Increasing refinery efficiency through faster assessment of raw material

To meet this need, Grace's group is also using multivariate data analysis methods to develop alternative strategies for determining the quality of biomass feedstock. She explains, *Most of the focus has been on predictive models using NIR spectra. An alternative approach is grading, involving the development of clusters, for example high quality, mid quality or low quality. This approach could be even better for refineries as it may enable them more quickly assess the raw material and give it a pass or fail grade.*

Grace believes there are opportunities in the biofuel sector to use plant material more efficiently, such as utilizing plant waste better.

"There is lots of potential to look at bagasse, which is the plant material left over after they squeeze the juice out, as well as the leafy materials left on farms after harvesting, known as 'trash.' Most of this is cellulose so it's possible this could be harvested for biofuel," she says.

"This could provide a more environmentally friendly way of disposing crop waste at the same time as providing fuel for bio-refineries. For example, the Brazilian state of São Paulo has the world's largest concentration of sugar cane farms and refineries used in biofuel production. They used to burn the waste, but that led to ash rain and a lot of soot in the air, which is obviously not good for the environment or for human health. Similarly, there are a lot of farms growing corn in the US, for example. The farmers harvest the corn and take it to market, leaving the waste behind, but some of it could also be harvested and sent to refineries for biofuel."

Understanding complex data using multivariate analysis

To analyze the complex biological and spectral data from their research, Grace's group use The Unscrambler® X software. The students mostly use Principal Component Analysis (PCA) for developing NIR calibrations (quantitative models) and derivatives.

"We're using The Unscrambler because it's powerful software for doing multivariate analysis. It is intuitive for students to use and the graphics are stellar," says Grace.

"One of my visiting scholars from China is very impressed with the software. It's much more powerful and has a lot more options than the software she has used before. Another student told me they were impressed with how fast they could transform and analyze data."

The ease of use and intuitive workflows are key features of The Unscrambler® X, especially for people who are not trained in multivariate analysis.

"My students, not having had a formal course in multivariate analysis yet, have also found the web tutorials in the program and the webinars on CAMO's website to be very useful. It gives them enough introductory information on some of the analytical techniques, so when they read about it in literature, it makes more sense and they can apply it to their own data set."

Grace adds "From my own perspective, I have recently started using The Unscrambler again. I very much like the new version. It's easy to upload data and do the different pretreatments. The Help function is good for giving students an introduction to the different data treatment techniques and how to interpret the results. The plots are also very easy to read and, in cases like ours where we need to have clear plots for publications and theses, it's easy to copy the graphs or the data. I think the latest version of Unscrambler will be very easy to use for those with introductory backgrounds to chemometrics."

Using powerful multivariate analysis, Mary-Grace Danao's group at the Engineering Solutions for Biomass Feedstock Production program is getting deeper insights in their quest to produce the next generation of sustainable bio-fuels.
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