Microalgae - Successful Transition from Lab to Pond: Integrated Strategy of Strain Characterization, Growth Modeling, and Pond Culturing

Pacific Northwest NATIONAL LABORATORY

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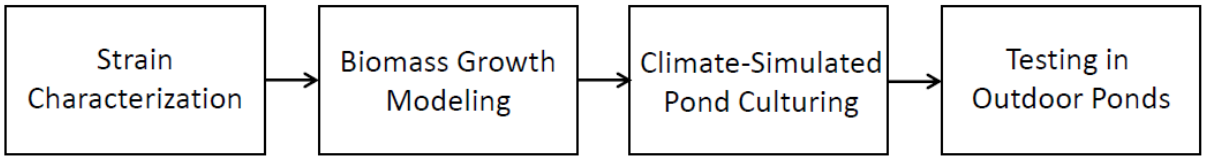
The Challenge: Predicting Industrial-Scale Performance of Novel Strains

Improving the economics of microalgal biofuels production requires the identification of novel microalgae strains with superior biomass and lipid productivities. However, **it is very difficult to predict a novel strain's performance in outdoor ponds using laboratory data**. Selecting the best strain for outdoor cultivation and subsequent commercialization requires answers to critical questions such as:

- What is the maximum achievable biomass and lipid productivity of this strain in outdoor ponds (i.e., under optimal temperature and light conditions)?
- How would this strain perform in outdoor ponds at different geographic locations and in different seasons? Can performance be optimized by matching a strain to a suitable climate or by selecting different strains for winter and summer cultivation?
- How can pond operations be optimized and **financial risks be minimized**?

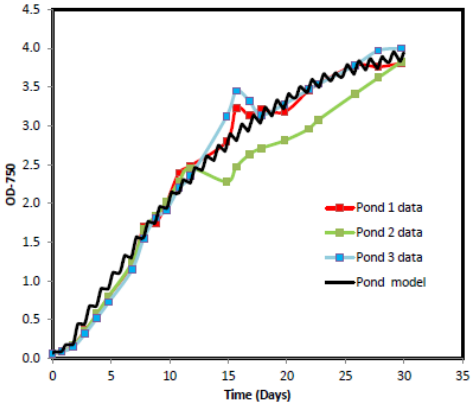
The Solution: An Integrated Strategy for Selecting High-Productivity Microalgae

We have developed the following integrated strategy for efficiently and cost-effectively screening strains for their potential to exhibit high biomass productivities in outdoor ponds.

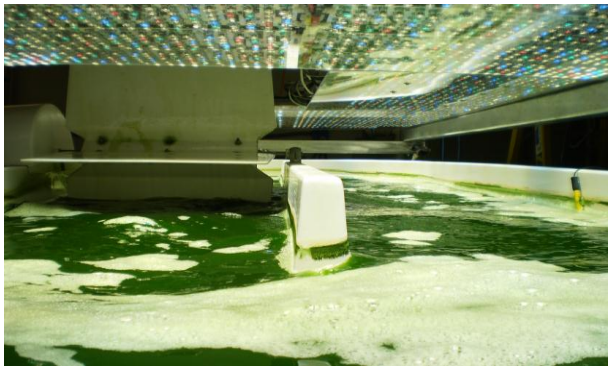


Strain Characterization: Since light intensity and water temperature are the key determinants of biomass productivity, we use a specifically designed *thermal gradient incubator* to determine the strain's maximum specific growth rate as a function of light intensity and temperature.

Biomass Growth Modeling: We have developed and validated a *microalgae biomass growth model* that is capable of predicting a strain's performance in photobioreactors and outdoor ponds using species-specific temperature and light response functions determined during the strain characterization step. The model (see black wavy line) was highly successful in predicting the biomass growth, including biomass loss at night due to dark respiration, in three replicate Arizona outdoor pond cultures subjected to daily fluctuations in sunlight and water temperature. The biomass growth model can also be used in conjunction with PNNL's



Biomass Assessment Tool (BAT) to predict the biomass productivity of a given strain in hypothetical outdoor pond cultures at any geographic location of choice.



Climate-Simulated Pond Culturing: The selected strain's superior performance is validated under climate-simulated conditions before transitioning to outdoor ponds. PNNL has designed and built *LED-lighted and temperature-controlled indoor raceway ponds* to enable the cultivation of microalgae strains under extremely accurate climate-simulated conditions which reproduce the light and water temperature fluctuations encountered in outdoor ponds at any geographic location in the world. Meteorological data in conjunction with PNNL's pond water temperature model are used to control lighting and temperature variations to simulate the environment of outdoor ponds at any selected site using freshwater, seawater, or wastewater.

Testing in Outdoor Ponds: After confirming the high productivity performance of a selected strain under low-risk climate-simulated conditions, the strain is then grown in the client's outdoor ponds, or, if not available, in PNNL's ponds located in Arizona.

The Benefits: Accelerated and Low-Risk Transition to Large-Scale Pond Culturing

Employing an integrated strategy for strain screening and testing translates into the following benefits and advantages, enabling you to:

- Obtain fast, cost-effective and reliable results regarding the performance of promising strains in photobioreactors and raceway ponds, either under optimal conditions, climate-simulated conditions, or any other light and temperature conditions of choice.
- Choose the optimal geographic location (climate) for the envisioned large-scale outdoor cultivation system based on biomass growth model predictions as well as the performance of promising strains under climate-simulated conditions (i.e., find the best match between strain & location).
- Optimize culture operations by identifying the best culture depth, dilution rate, and harvesting time.
- Avoid problems associated with risky pilot-scale outdoor pond culturing such as time delays, capital and operating expenses, sub-optimal geographic locations, inclement weather, invasive species, etc.

About Pacific Northwest National Laboratory

The Pacific Northwest National Laboratory, located in southeastern Washington State, is a U.S. Department of Energy Office of Science laboratory that solves complex problems in energy, national security and the environment, and advances scientific frontiers in the chemical, biological, materials, environmental and computational sciences. The Laboratory employs 4,000 staff members, has a $760 million annual budget, and has been managed by Ohio-based Battelle since 1965.

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