Data Analytical Simulation System of Polyculture Microalgae for Biofuel Production Using Machine Learning Approach

July 2019

SUPRIYANTO

Data Analytical Simulation System of Polyculture Microalgae for Biofuel Production Using Machine Learning Approach

A Dissertation Submitted to
The graduate School of Life and Environmental Sciences,
the University of Tsukuba
in Partial Fulfilment of the Requirements
for Degree of Doctor of Philosophy in Bioresource Engineering
(Doctoral Program in Appropriate Technology and Sciences for
Sustainable Development)

SUPRIYANTO

Abstract

Microalgae are potential biomass energy sources with higher photosynthetic efficiency compared to terrestrial plant. The production of the microalgae consists of several activities such as site selection, facility construction, algae strain selection, cultivation, dewatering, oil extraction and upgrading the microalgae production. The open raceway pond (ORP) was the most popular culturing techniques due to the lowest energy consumption compared to others. However, ORP has disadvantages such as seasonally change the environmental parameter, easy to contamination from unwanted species and difficult to control. Native polyculture microalgae would be highly efficient for high production of algae biomass even in cool temperate climates to solve the problem.

However, bringing the microalgae production to commercial was challenging due to the complex environmental condition and technological combination. This could provide new opportunity to optimize the production of the microalgae. In the present work, there is little comprehensive data analytical simulation system of the microalgae production especially in polyculture microalgae. Therefore, this study aims to explore and developed the Data Analytical Simulation System of Polyculture Microalgae for Biofuel Production Using Machine Learning Approach. The data analytical simulation system was also assisting the design and evaluation of the process, especially for future large-scale production.

First, database management system was proposed as solution to manage the data in microalgae production that consist of cultivation, harvesting, and extraction of the microalgae. The database management system (DBMS) was designed and implemented using the MySQL. To make the user flexibility to manage the data, user interfaces developed using PHP, HTML, CSS, and JavaScript that can manage the tabular and chart.

Second, the problem in polyculture microalgae is the general composition of microalgae and bacteria species in the same culture. As a result, modelling of algae growth in polyculture in an ORP under varying conditions in different locations is complicated. The Artificial neural network (ANN) proposed to estimate the growth of microalgae in semi-continuous ORP culture. The backpropagation neural network used with eight input parameter, one hidden layer, and one output layer. The input parameter such as initial algal concentration, harvesting period (between two and three days after the growth have begun), hydraulic retention time, the addition of sodium acetate, average solar radiation (μmole m^{-2} s^{-1}), average water temperature (°C), pH condition, and nitrate ion (NO_3^-) concentration. The output variable is the microalgae concentration observed during the cultivation period.

The output is represented using a single neuron. The result of the study showed that the designed three-layer ANN achieved a high prediction accuracy (R^2 = 0.93) for all combinations of inputs. Others result from this experiment was the water temperature and solar irradiance was the best parameter to an estimate the microalgae. That parameter was difficult to control due to the seasonal and diurnal condition. Other parameters such as HRT, pH, nitrate ion concentration best for the control of ORP.

Third, based on the previous experiment showed that the solar irradiance and water temperature was the potential parameter to estimate the growth of the microalgae. Machine Learning Approach was proposed to estimate the polyculture microalgae productivity using the meteorological parameter. The machine learning algorithm used in this research were support vector machine (SVM), multiple linear regression (MLR) and artificial neural network (ANN). The model developed using Statistical and Machine Learning Toolbox, MATLAB 2019a. The input parameter used in estimating the productivity (P, g m^{-2} day^{-1}) was the meteorological parameter such as air temperature (T, °C) and solar irradiance (I, µmol s^{-1} m^{-2}). Based on the result, the best performance of the model was the 4 hidden layers (2-2-2-2-2-1), 3 hidden layers (2-2-2-2-1), and 2 hidden layers (2-2-2-1) with R^2 were 0.92, 0.92 and 0.91, respectively. The performance of R^2 followed by the SVM-gaussian, MLR, SVM-polynomial, and SVM-Linear with the R^2 0.9, 0.81, 0.78, and 0.77, respectively. Based on this experiment concluded that the meteorological parameter was able to predict productivity.

Fourth, bringing the microalgae to the business was challenging, due to the complex process of the microalgae production from cultivation, dewatering, and biorefining process. The decision support system was important to develop to make a robust analysis in one platform. This chapter proposed the integrated process model simulator of microalgae to produce biofuel. The simulator provided the simulation suitable tools and frameworks for businessperson to support the decision.

Data analytical simulation system of polyculture microalgae for biofuel production using machine learning approach successfully developed and validated. The database management system was used to manage the data and machine learning approach to estimate the productivity. The process model and simulation were integrated the forecasting model to the down streaming process of the microalgae to estimate the biocrude production and energy requirement.

Keywords: artificial neural network, data analytical system, microalgae, open raceway pond, polyculture, process model