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Black Box Solutions for Bioprocess Production Optimization

V Ramamurthy*
Department of Biomedical Engineering, Sri Ramakrishna Engineering College, Coimbatore 641022, India

Description

Biological processes can provide several essential ingredients for our needs and welfare, but it requires some understanding of their capabilities and limitations for sustained exploitation. Inherently biological systems are complex and thus provide some challenge to our efforts to confidentially characterize the full scope of their capabilities and limitations. To overcome this problem we can attempt to shortchange the obstacles by many conflicting and redundant regulatory processes using a numerical analytical approach to model the system before we could model it physically or biologically. As an example, we have tried to model a complex system such as outdoor growth of the photosynthetic cyanobacterium Spirulina platensis using artificial neural network model [1,2]. The success of such an exercise can help decide the rate and frequency of harvesting the product from a continuously ongoing process and maximize return from the process investments like consumables, infrastructure costs and time.

Main useful products such as nutrients, fuel, inhibitors, catalysts, industrial feed stock, etc. can be obtained as byproducts of microbial metabolism. For large scale production heterotrophs have been the preferred organisms because they could be grown to a high density in well contained growth chambers with good control over feeding and removal of substrates and products/waste products, respectively. However, this strategy is difficult to be applied to phototrophic organisms since 'feeding' light is limited to surface exposure and is scalable only in two dimensions. Thus, traditionally, production driven by photosynthetic process has relied on expansion of area, like increased acreage in the case of agriculture derived production. Even in recent innovations like vertical tiered gardens and non-soil substrates like hydroponics, etc. while trying to overcome the space limitation, particularly in urban settings, the core of the process is still limited to surface availability for exposure to light. The growth of microalgae in engineered environments faces other challenges like competition from other photosynthetic contaminants, predatory organisms like *protozoa*, and chemical concentration gradients and the ensuing stress to the organism of interest. Problems from contaminants could be minimized or eliminated by developing hermetically sealed systems for maintaining growth, but this leads to poor gas exchange and hence nutrient (CO_2) limitation and waste (O_2) removal. Soon, the complexity of the system increases and maintaining favorable cultivation conditions become a challenge. Such problems provide a good platform for understanding system performance from process parameters which could be obtained on a regular basis without involving complex analytical procedures.

For any process we work with the paradigm that inputs determine outputs which decide outcomes. If we are able to flip this logic then predicting outputs could be achieved by determining and controlling the inputs. However, complex systems do not conform to such simplistic logic, may be because many critical influential input parameters may not be known or difficult to be determined. To overcome this obstacle, we might exploit to the statistical nature of parameter distribution within a reasonably narrow range and the output prediction can then lie within a narrow range. A black box approach to solve this problem is influenced by the number of data points that determines the spread of the error function, more the data less the error in prediction. For managing operations of photosynthetic production one has to balance amount of product (biomass) that could be harvested versus amount left in the reactor to propagate further. When the propagation is influenced by many unpredictable factors such as photorespiration, antenna density, oxidative stress, dark respiration, etc., it will be useful to have some guidance on what can be expected in the near future-good growth or poor growth, decisions to retain or harvest could be made to maximize benefits from the process.

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***Address for Correspondence:** V Ramamurthy, Department of Biomedical Engineering, Sri Ramakrishna Engineering College, Coimbatore 641022, India, E-mail: ram.bio@psgtech.ac.in*

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