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The Intelligent Management of Lighting: Prerequisites for Achieving Maximum Yield in Algae PhotoBioReactors

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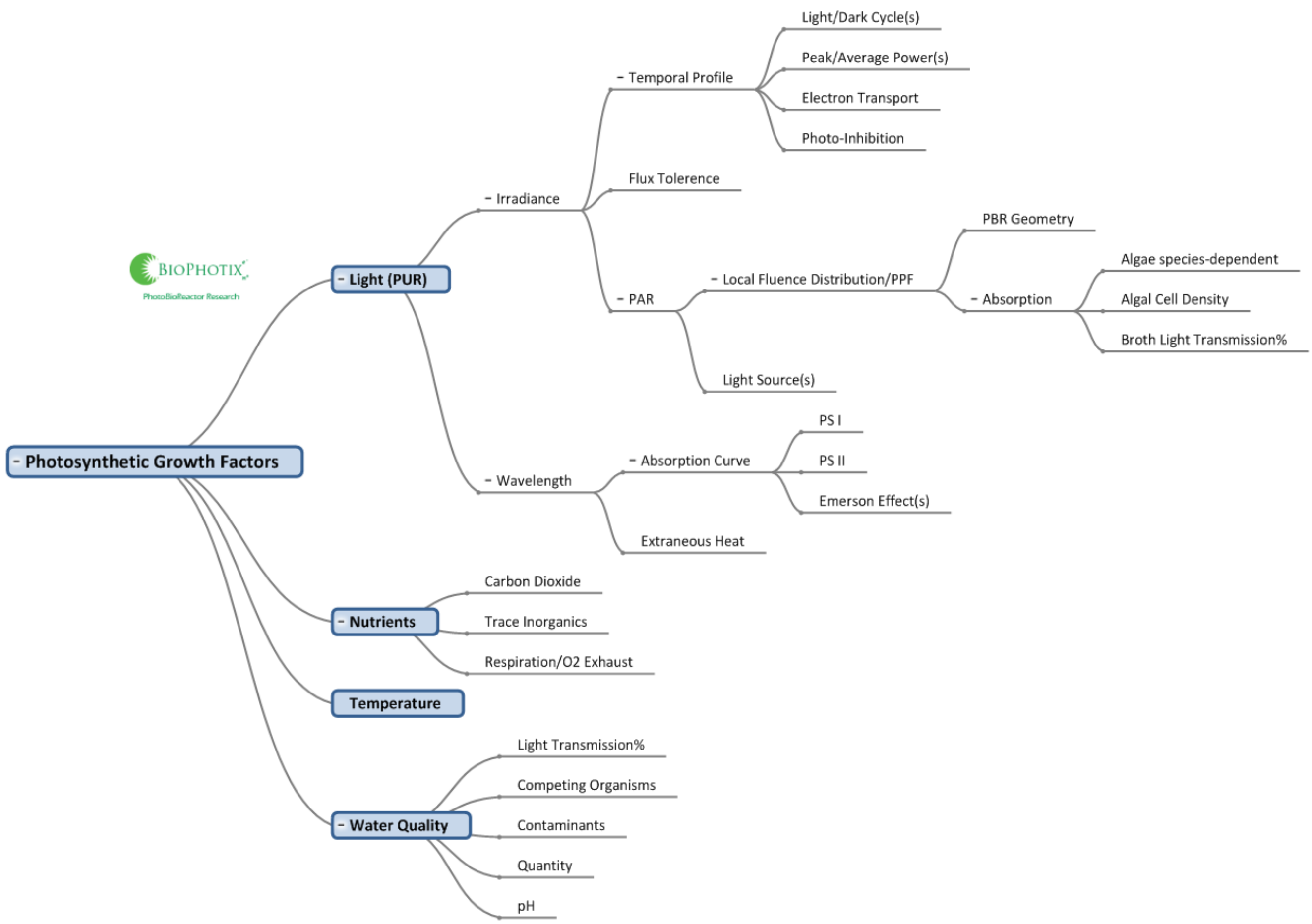
An exciting new industry is being birthed by the growing interest in algal biomass production technology and its potential for becoming a major solution for sustainable energy and food supply. Given the current divergent strategies for growing and selling algal biomass, it is difficult for nascent producers to sort through the claims and counter-claims of the earliest entrants, particularly since few are currently producing products anywhere near price-points that are considered viable. Additionally, little information regarding the effectiveness of specific lighting methods is currently publicly shared, while the available research literature can be difficult, contradictory, and confusing to the "algaepreneur"[1] . For example, consider the long-enduring disparity between what has generally been touted as "typical yields" for open pond solar-based algae production, and the publicly available "documented yields" of actual producers. BioPhotix Corporation's "Apparent Conflict in the Determination and Reporting of Open Pond Algae Oil Production" shows that the ubiquitously published "typical yields" is a factor of about 2.5 to 7.5 times that of "documented yields". Given such a schism between reality and what appears to be "fantasy taken as truth", is it no wonder that the algae industry has unfortunately suffered with failing and failed enterprises that unknowingly operate(d) at the "bleeding edge" of insufficiently informed "knowledge"? We'll never find that "pot of gold at the end of the rainbow" if we're wearing rose-colored glasses and chasing rainbows that aren't really there.

Putting commercial preconceptions and bias aside, the smart manager will identify and address those lighting conditions within the algae growth process that, separately or in combination, eventually impact the economic viability of his or her algae business. The efficiency and effectiveness of the PBR lighting strategy can be the difference between failure and success, as well as between break-even and impressive profits. While it should not be considered to be an exhaustive list of criteria, the following illustration (Figure 1) is an example of the factors that need to be formally addressed in order to achieve an intelligent management of PBR lighting. Exactly which issues are applicable depends upon if the light source is solar or synthetic, and if the PBR is open or closed.

Figure 1.	Factors Affecting Photoautotrophic Microalgae Growth



Note that Photosynthetically Usable Radiation (PUR) is our first focus, which is one that is often contrary to that of many researchers and process engineers, who instead primarily focus on first achieving an irradiance level for Photosynthetically Available Radiation (PAR, or 350 nm to 700 nm, per Tyler, 1966). Within whatever practical constraints that are dictated by the characteristics of the chosen microalgae strain, it is essential that we manage the process variables in order to create the optimum conditions that will stimulate and support photoautotrophic growth. Otherwise, the resulting *unspecified* biological processes will “manage” the algal growth, and its subsequent product profit margins and viability. Since PS II is driven by the often unique action spectra that are associated with the algae of interest, an intelligent PBR design and process will begin with an understanding of the ideal action spectra. In terms of product growth and process energy efficiency, any extraneous wavelengths of light are generally counterproductive. It is the relative spectral quality and availability of PUR that actually drives algal biomass yield, and not PAR; therefore, a PUR specification is the most informed starting point in any managed photoautotrophic growth process.

The two primary characteristics of PUR are the action spectra and the level of irradiance. The action spectra (wavelength absorption and utilization in the RuBisCO and other Calvin cycle processes), is the wavelength “match” for providing the correct form of energy that will allow initiation of the photosynthesis processes; all other PAR (as well as IR light) is extraneous energy. In turn, it is the level of that irradiance (of the action spectra) that then determines the relative volume of electro-chemical conversion and subsequent process yield. For example, for a typical solar PBR, throughout much of the usable daylight time there often are “over exposure” conditions whereby the excessive irradiance photo-inhibits the biomass growth process. The act of “accepting” (i.e., without proactive management) whatever Photosynthetic Photon Flux (PPF) that nature (or a synthetic light source) delivers to the microalgae light antennae is tantamount to “giving up” on achieving better than what has now been learned to be an untenable process efficiency.

Intelligent light management techniques can create impressive and also *crucial* improvements in both action spectra “matching”, and irradiance “smoothing” throughout the PBR volume. Volumetric utilization efficiencies are typically lacking in the absence of such proactive design implementations. Here is where the beauty of, as well as the necessity for advanced PBR modeling techniques become apparent; prior to commitment of materials, labor, time, and finance, a design can be analyzed and then optimized. The resulting risks mitigation and newly-acquired scientifically proven, solid design also beneficially serves both the Company and its investors.

Today many companies are looking beyond the box of solar-constrained lighting, and towards the rapidly-improving technology of synthetic lighting, which is entirely controllable 24/7. One of the real advantages of certain synthetic light sources is the ability to exploit the vastly superior range of flux tolerance that can be attained through the use of lower duty cycle and relatively high peak power pulses of light. For this and other related reasons, researchers([2,3,4,5,6]) have demonstrated yields that are conservatively up to 40x those which are possible by means of continuous wave (CW) light sources. Additionally, this technology’s simultaneous contribution to an important increase in device quantum efficiency and lifetime means that the increased electrical costs can be more than offset by increases in yield and overall system energy efficiency, which always must include the water & energy nexus.

BioPhotix Corporation serves at the progressive forefront of delivering to our discerning clients the most efficient PUR light analysis and designs that are practical for their particular needs and circumstances. BioPhotix clients range from startups seeking validation of existing or proposed IP or a first design, to established players seeking contracted expertise not internally available, to large corporations desiring additional validation, enhancement, or ideation. We invite you to explore how BioPhotix PURe Light™ management can analyze your PBR design, identify any problems or opportunities, and deliver solutions that will give your PBR the “PUR Efficient Light” advantage.

[1] Our collective "Thanks" to Barry Cohen (and his lovely wife, Lisa) of the National Algae Association for "growing" this new type of entrepreneur.

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