Abstract

Interest in photosynthesis continues to increase with a global focus on developing alternative fuel sources such as biofuels. It is the various forms of biomass that provide the raw materials for the production of biofuels such as bioethanol and biodiesel. The vast majority of these materials are grown by the photosynthesis process. Developing a mathematical model of the process allows for a clearer understanding of what limits and propels the process, and what this reaction might be capable of in terms of biomass growth on an industrial scale.

The primary driving force of photosynthesis, solar energy, is a crucial aspect of this model. Relating the amount of light to organism growth is done by exploring the concept of quantum requirement, which is essentially the amount of photons needed to drive the photosynthesis reaction. The theoretical quantum requirement calculated is dependent on the wavelength of incoming photons in the photosynthetically active radiation (PAR) spectrum, and varies between 9.94 moles of photons per mole of biomass (approximated as glucose) at 400nm, and 17.8 moles of photons per mole of biomass at 700 nm. Measured, experimental values of quantum requirement from the literature considered here average a value of 61.7 moles of photons per mole of biomass required.

The conclusion is that the theoretical lower limit of operation, which is therefore the absolute minimum quantum requirement, occurs when the photosynthesis process operates reversibly. It is suggested that the large difference between theoretical and measured quantum requirement values may indicate that the photosynthesis process is irreversible in nature. By the model developed, two other observations of interest are made: photon entropy has little effect on the calculated quantum requirement; heat must be rejected from the process, and increases in magnitude with increasing irreversibility.

In the final chapter, the theoretical model for quantum requirement is utilised in conjunction with spectral irradiance data to obtain estimates of theoretical photosynthetic growth rates. With a reversible photosynthetic process, a growth rate of 81.0 g/m^2.hr of biomass would be possible if all light energy in the PAR spectrum were absorbable. Applying the absorption capabilities of a commonly-occurring pigment such as chlorophyll *a*, this theoretical growth rate is reduced to 20.0 g/m^2.hr, to indicate the light saturation and absorption-limited effect of a plant's cell biology.

Both values are still largely above experimentally determined growth rates from literature. These discrepancies are discussed with focus on relevant enzymes and proteins in the light-dependent and light-independent reactions of

photosynthesis that limit its kinetics and efficiency. The importance of calculating maximum possible biomass growth rates is that they, in essence, set the upper limits on biomass production in our environment. With this knowledge, large-scale estimates can be made, and improved efficiencies can be targeted and measured against the ideal, theoretical case.