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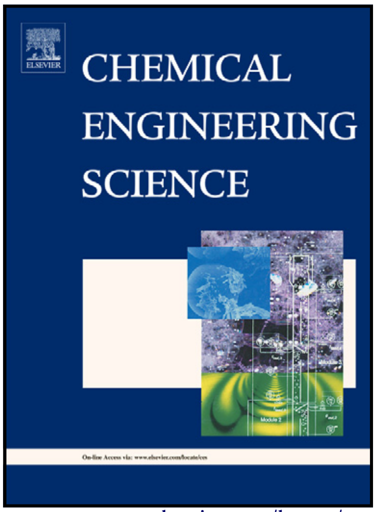

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Exergy Efficiency of Plant Photosynthesis

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Abstract

With recent concerns about sustainability and environmental protection, growing attention has been focused on biological sources for both chemicals and fuels; however, to analyze such bioprocesses for commercial viability, and to investigate possible efficiency improvements, the theoretical efficiencies must be known as an upper-bound on performance. Since almost all exergy contained in biomass originates from solar radiation, photosynthesis is the gateway to sustainable bioprocess development. The literature shows a wide range of efficiency predictions, 2.6% to 41%, due to different definitions and methods of analysis. Therefore, the objective of this study is to dissect the complex bio-processes involved in photosynthesis and analyze the exergy flows through the system, analyzing photosynthesis so as to be understandable by both biologists and thermodynamicists. The initial absorption of light has the lowest exergy efficiency, and it accounts for over 64 percent of the exergy lost throughout the system. For the light reactions, reduction potentials are used to analyze the flow of excited, high-energy electrons through photosystems II and I, resulting in an exergy efficiency for the light reactions of 32 percent. For the dark reactions, the chemical exergy method proposed by Lems et al. (Lems et al., 2007) is appropriate. The resulting efficiency of the dark reactions is 81 percent. Exergy losses to transpiration and photorespiration are taken into account, although their effects are relatively small. The overall exergy efficiency of photosynthesis is calculated to be 3.9 percent. The efficiencies of the sub-processes, as well as the overall efficiency, show good agreement with recent publications. Ultimately, the largest losses are due to poor absorption of light and the inefficient electron transfer through the photosystems.

Keywords: Photosynthesis; carbon dioxide; glucose; thermodynamics; exergy; solar energy; bio-energy