Abstract

Flavin derivatives, essential redox-active compounds in biological systems, have gained significant attention as sustainable and versatile organic photocatalysts. The overarching goal of this research was to synthesize and systematically investigate new flavin analogues to optimize their spectral, photophysical, and photochemical properties for advanced photocatalytic applications. This comprehensive study encompassed four core families of flavin-related compounds: isoalloxazines, 5-deazaisoalloxazine, alloxazines, and 5-deazaalloxazines.

Detailed investigations utilized steady-state and time-resolved spectroscopy, including UV-Vis absorption, fluorescence measurements, time-correlated single-photon counting (TCSPC) for lifetimes (τ_F, τ_Δ), and laser flash photolysis (LFP) for transient species characterization.

The research successfully developed modular synthetic strategies, notably palladium-catalysed Suzuki C–C coupling reactions, to introduce aryl moieties onto the flavin core. This modification provided precise tuning of photophysical properties, yielding desired bathochromic shifts (up to 3100 cm^{-1}, $S_0 \rightarrow S_1$ transition) and enabling the effective suppression of singlet oxygen generation (Φ_Δ) in several isoalloxazine, deazaisoalloxazine and alloxazine derivatives, thereby favouring photooxidative electron-transfer mechanisms. Conversely, other tailored derivatives, such as tetramethylalloxazines (TMeAll), were identified as highly efficient singlet oxygen ($^1O_2$) photosensitizers (Φ_Δ up to 0.98), demonstrating potential for Type II photooxygenation and as redox-sensitive agents in biological imaging.

Furthermore, this work expanded the scope of flavin catalysis into challenging reductive transformations. It established novel systems based on the highly reducing excited-state isoalloxazine anion ($2a^-$), which exhibits an estimated oxidation potential of $\boldsymbol{E_{ox}^* \approx -1.50}$ **V** vs. SCE in the singlet excited state, capable of dehalogenation and C-P coupling, even under aerobic conditions. Finally, an interesting study was performed on 5-deazaalloxazine (5-DAll) derivatives. To access these structures, we developed three synthetic strategies depending on the substitution pattern at position 5: 1) Unsubstituted derivatives were obtained via Vilsmeier-Haack formylation of anilinouracils, 2) 5-Aryl derivatives were synthesized through a three-component reaction of aniline, an aromatic aldehyde, and barbituric acid and, 3) 5-Trifluoromethyl derivatives were prepared by trifluoroacetylation of anilinouracils followed by condensation. These derivatives possess superior photostability and exhibit robust reducing capabilities (estimated $\boldsymbol{E_{ox}^* \approx -3.3}$ **V** vs. SCE), enabling the reduction of highly inert substrates like aryl fluorides via a consecutive photoinduced electron transfer (conPET) mechanism.

This body of work contributes to the rational design of flavin photocatalysts for sustainable and selective organic synthesis.