POLBIONICA

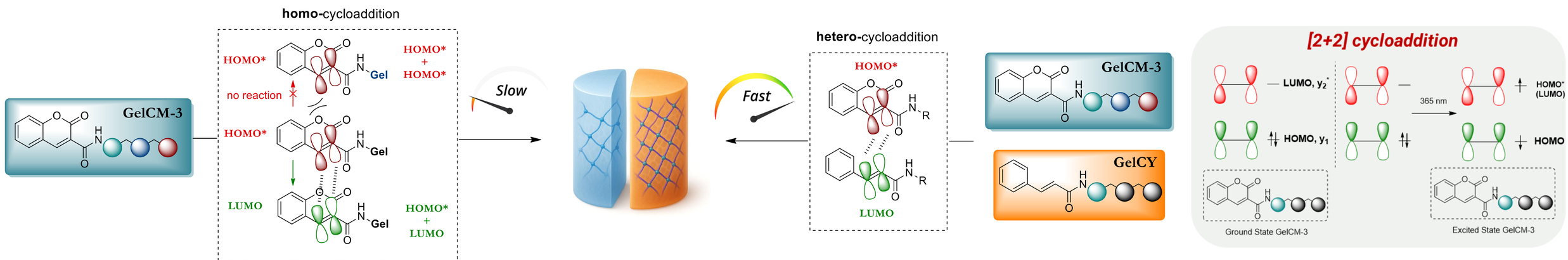
Clean-cure bioinks: Next-generation photoinitiator-free hydrogels for safe and regulatory-compliant tissue engineering applications

A spectrally programmed gelatin platform enables photoinitiator-free crosslinking with spatially confined curing, strong biocompatibility, and reduced light-associated DNA damage for tissue engineering applications.

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AIMS

Photoinitiator-based curing remains the dominant strategy for gelatin bioinks, but it introduces diffusing radicals and photoproducts that may increase cellular stress and complicate biological safety. To address this limitation, we developed a photoinitiator-free gelatin system based on encounter-controlled [2+2] photocycloaddition. The platform combines two photoactive gelatin derivatives with complementary spectral behavior: GelCM-3, which is efficiently excited at 365 nm, and GelCY, which remains effectively ground-state under the same conditions. This design biases the system toward productive excited–ground encounters and improves crosslinking efficiency within a biologically active gelatin matrix.

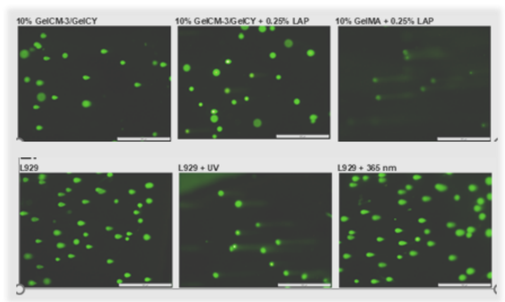


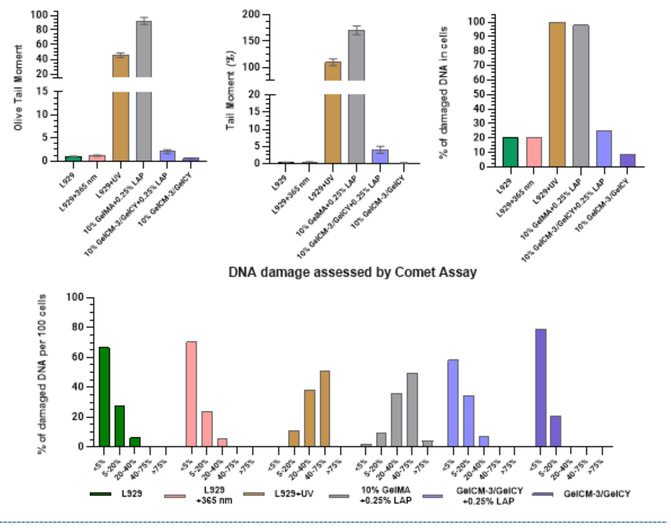
LIGHT ABSORPTION AND PHOTOPROTECTION

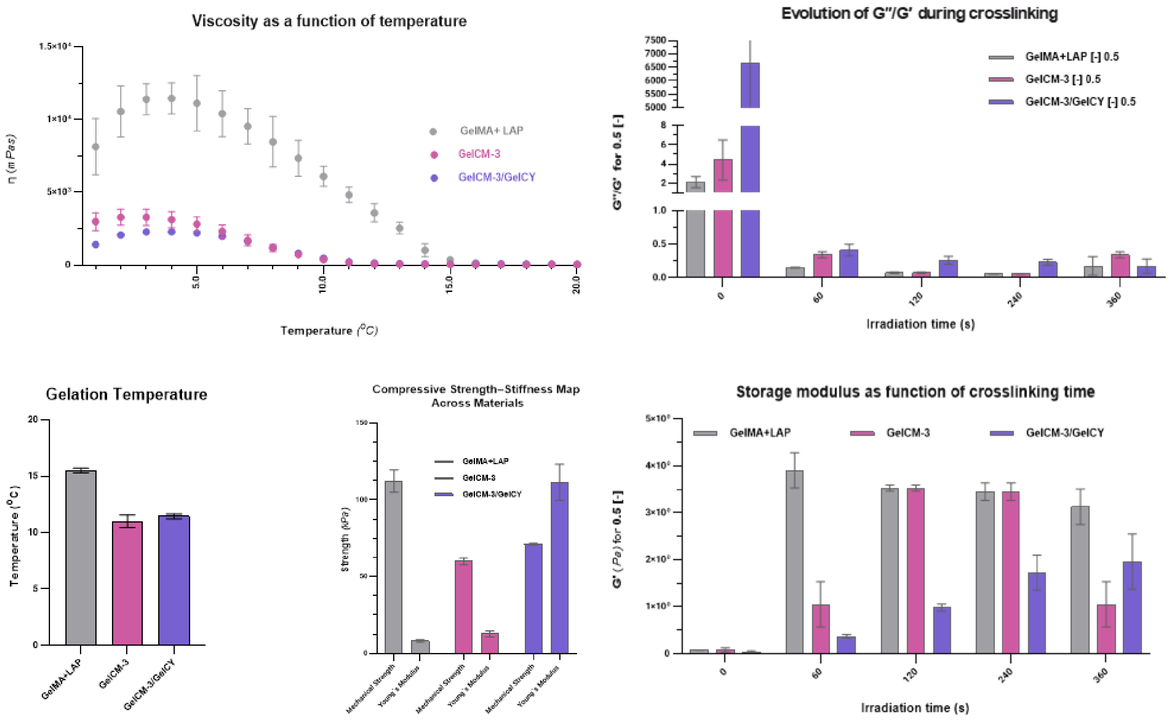
The chromophore-as-linker design acts not only as a curing motif but also as an intrinsic light-management system. GelCM-3-based materials showed high optical density at 365 nm, supporting the idea that photon absorption is redirected into local [2+2] chemistry and may reduce the photochemical burden associated with conventional PI-mediated curing.

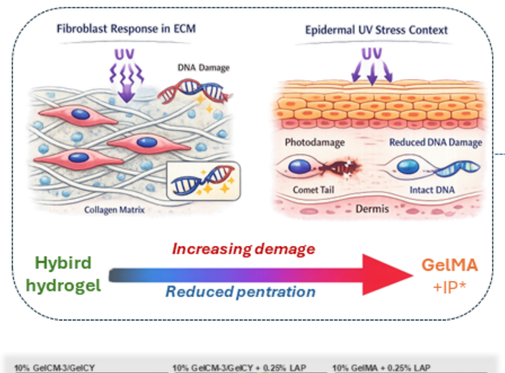
RHEOLOGY AND MECHANICS

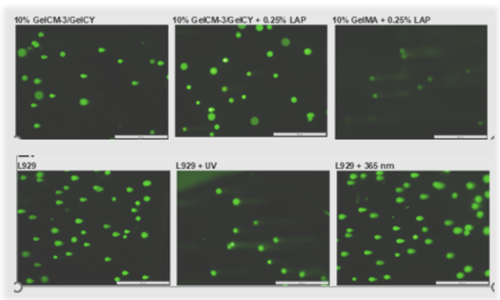
The hybrid formulation combined a lower gelation temperature and lower viscosity than GelMA + LAP, supporting gentler extrusion and improved handling before curing. At the same time, after 240–360 s irradiation, GelCM-3/GelCY approached the stiffness range of GelMA + 0.25% LAP, indicating efficient network formation despite the absence of a photoinitiator.

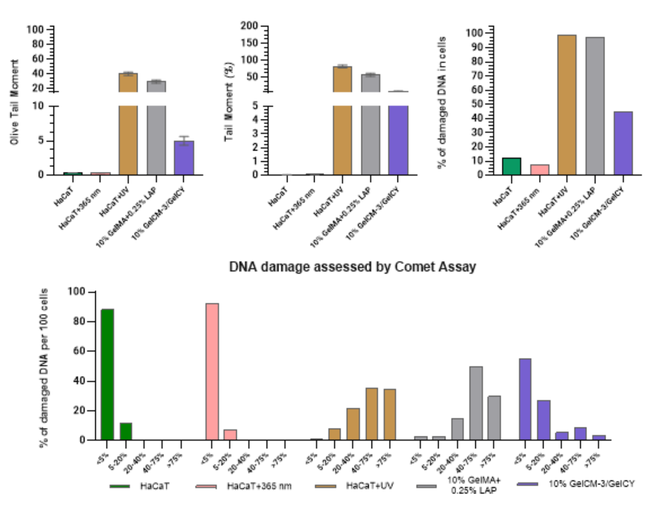




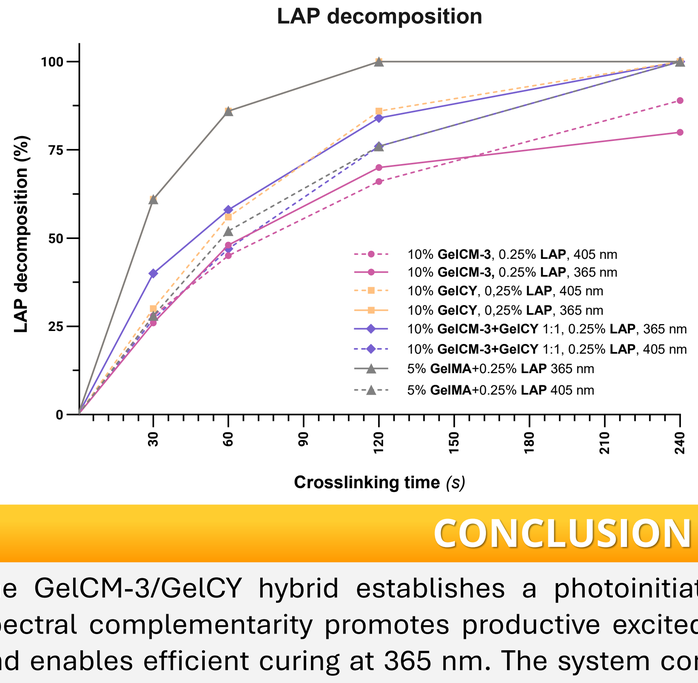




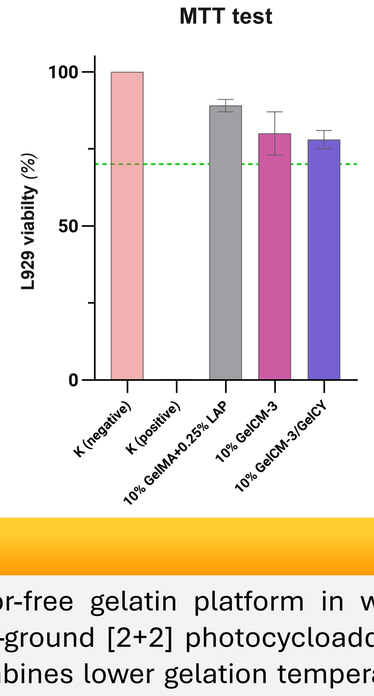




A.

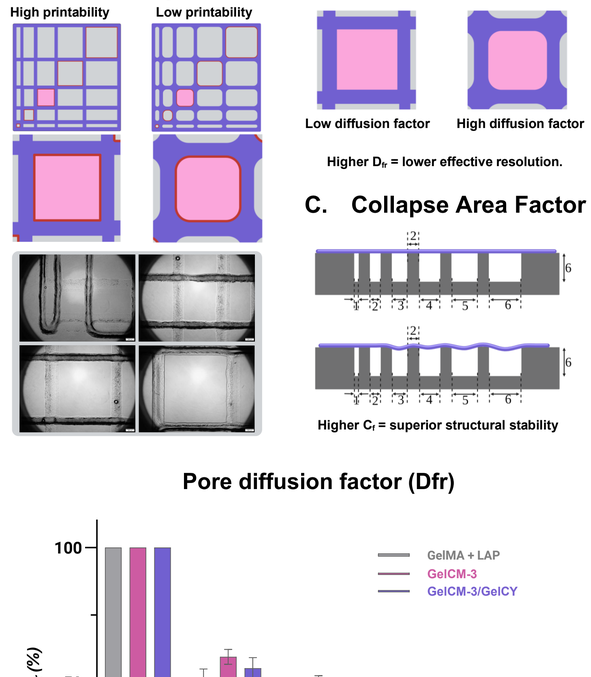


B.



PRINTABILITY

The hybrid bioink produced continuous filaments, high dimensional fidelity, and stable bridge formation under mild printing conditions. In quantitative printability tests, GelCM-3/GelCY achieved near-ideal printability across practical pore sizes and matched or exceeded the performance of the GelMA reference while remaining fully photoinitiator-free.



CONCLUSION

The GelCM-3/GelCY hybrid establishes a photoinitiator-free gelatin platform in which spectral complementarity promotes productive excited–ground [2+2] photocycloaddition and enables efficient curing at 365 nm. The system combines lower gelation temperature and lower viscosity with post-cure mechanical performance approaching GelMA + LAP, supporting both gentle extrusion and effective network formation. Voxel-confined curing, sharp pattern fidelity, and robust printability further show that this strategy is well suited for high-precision biofabrication. Importantly, the hybrid maintained good biocompatibility and consistently reduced DNA damage relative to GelMA + 0.25% LAP in both L929 and HaCaT models.