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Smart Fabric-Integrated Biosensor Using Lawsone and Silk Proteins: A Visually Responsive Approach for Glucose and Pathogen Detection in Biomedical Fabrics

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ABSTRACT

Herein, we report the engineering of a smart textile-integrated colorimetric biosensing platform through the molecular incorporation of lawsone, a naturally occurring redox-active naphthoquinone chromophore derived from Lawsonia inermis, within regenerated silk fibroin matrices for the visual detection of glucose and pathogen-associated metabolites. The resulting silk fibroin–lawsone hybrid system exhibited pronounced chromogenic transitions upon exposure to glucose in the presence of hydrogen peroxide, demonstrating efficient redox-mediated signal transduction within the proteinaceous sensing matrix. Comprehensive physicochemical characterization using UV–Vis spectrophotometry, Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), circular dichroism (CD), differential scanning calorimetry (DSC), and scanning electron microscopy (SEM) confirmed successful chromophore immobilization, preservation of fibroin secondary structural integrity, and the formation of a morphologically stable sensing interface. Furthermore, the functionalized sensing architecture was successfully immobilized onto cotton and spunbond polypropylene substrates to fabricate pathogen-responsive textile interfaces exhibiting discernible chromatic responses upon interaction with pathogen-derived metabolic by-products. Collectively, these findings establish the silk fibroin–lawsone composite as a sustainable and scalable biosensing architecture capable of enabling visually interpretable detection in smart biomedical fabrics, thereby offering considerable potential for low-cost point-of-care diagnostics and next-generation wearable health monitoring technologies.