ESSENCE- Enzyme Split System Enabling Non-Wash Colorimetric Evaluation: A Novel Colorimetric Inducing Dual Biopolymer Nanocomposite Fixed Within an Anisotropic Vertical-Flow Nitrocellulose Matrix for the Spatial Mapping of Interleukin-1a and Cathepsin-K for Skin Cancer Differentiation and Staging

Madhu, Rahul (School: Arizona College Prep High School)

Skin cancer drives a global crisis with >7 million projected annual cases, yet clinical diagnostics remain inaccessible. This profound socioeconomic barrier is mirrored in Arizona, where the five counties with the highest mortality rate fall below the state-wide average median household income. This study engineered ESSENCE, a novel material system combining a dual biopolymer complex utilizing antibody-beta-galactosidase conjugates functionalized on a vertical-flow framework anisotropic platform, to noninvasively map CTSK and IL-1a skin cancer biomarker clusters directly from the surface through proximity-based ligation and subsequent colorimetric reactions through hydrolysis of CPRG substrate. Material optimization via a checkerboard titration determined the ideal biopolymer concentration of 1 ug/ul and analytical wavelength 572nm. JSX-coded software used sRGB values converted into a CIE 1931 color space to remap the colorimetric reaction across a broadened 380–750 nm wavelength to enhance cluster resolution. The structural accuracy of the biomaterial system for skin cancer differentiation was validated against melanoma, SCC, and BCC tissue microarray samples across stages. Statistical modeling confirmed that the system's anisotropic flow (SNR=4.73) successfully captured stage and cancer-specific biomarker signatures ($p < 0.001$) across three distinct colorimetric metrics: mean absorbance, asymmetry, and ratio. Linear Discriminant Analysis (LDA) captured >97% of biological variance along a dual discriminant axis, and ROC curve modeling yielded an AUC of 1.000 at terminal stages. Ultimately, ESSENCE achieved a differentiation accuracy of 96% at a cost of just $0.274 per unit, delivering a biomaterial system for noninvasive skin cancer staging in underserved communities.

Awards Won:

Third Award of $1,200

Arizona State University: Arizona State University ISEF Scholarship (valued at up to $32,000 each)