INNOVATING CROSS-DOMAIN SOLUTIONS TO DETECT EMERGING BIOLOGICAL THREATS

The Development Of A Modular Platform Technology For The Early Detection Of Zoonotic Diseases

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Animal diseases pose significant economic, health, and security threats, potentially devastating livestock populations and jeopardizing food industries. Rapid and accurate diagnosis is critical for effective containment. Prion diseases, including Bovine Spongiform Encephalopathy (BSE), present particular challenges due to their infectious and fatal nature. Current detection methods, such as real-time quaking-induced conversion (RT-QuIC) and Western blotting, are laborious and unreliable. Addressing this pressing need, we present a comprehensive approach to animal disease detection by developing a modular, point-of-care (POC), microfluidic bio-detection system. This electrochemical sensing method utilizes a flow-through Nanoporous Capacitive Electrode microfluidic chip, offering a compact and efficient platform for on-site testing. The chip integrates carbon-based transducer material (CBTM) functionalized with aptamers specific to PrP, ensuring high sensitivity and selectivity in detecting the target biomolecule. Using the automated ESSENCE detection system, the α-PrPSC aptamer functionalized CNT CBTM was run against decreasing concentrations of PrP protein in PBS buffer solution. While our goal is to detect actual PrPSC prions and degenerated PrP proteins, we have used PrP protein (precursor to the prion) as a surrogate instead. Through automated fluid control and Electrochemical Impedance Spectroscopy (EIS) data acquisition, our system provides a user-friendly, field-deployable solution for animal disease surveillance. The integration of single-walled carbon nanotubes (SWCNTs) as the CBTM further enhances the sensor's performance, offering rapid and reliable detection of PrP. The 45-mer Aptamer-functionalized SWCNTs demonstrate remarkable selectivity for PrP, enabling the accurate identification of BSE-related biomarkers. Detection experiments with our system reveal promising results, with a detection limit of 0.13 ng/mL PrP. This translates to a concentration of 4.8 picomolar (pM), highlighting the system's sensitivity to trace amounts of the target biomolecule. A calibration curve generated from the experimental data exhibits a linear relationship (R2 = 0.93) between PrP, demonstrating the system's quantitative capabilities. The preliminary results underscore the feasibility of employing aptamer-functionalized SWCNTs in a microfluidic electrochemical sensor for BSE detection. The development of this system represents a significant advancement in animal disease surveillance, offering a rapid, sensitive, and reliable tool for on-site testing. Furthermore, our approach lays the foundation for further optimization and potential integration with sample preparation systems, enabling comprehensive disease surveillance and early detection of emerging threats. Our study presents a novel strategy for animal disease detection, leveraging cutting-edge technology to address the growing challenges of infectious pathogens. By combining microfluidics, electrochemical sensing, and aptamer-based molecular recognition, we have developed a versatile platform capable of revolutionizing the field of veterinary diagnostics.

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