4.3 Rapid detection and intelligent monitoring technologies

In recent years, shrimp disease detection technologies have shifted from centralized laboratory-based systems toward field-based and rapid diagnostic approaches. Given the rapid transmission and short response window of aquaculture diseases, technologies that enable on-site detection within a short time frame have become a major focus of research and application (Bohara et al., 2023). These methods emphasize simplicity, rapid response, and minimal equipment requirements, providing immediate support for on-site management decisions.

Among rapid molecular detection methods, isothermal amplification technologies show great potential. RPA, in particular, has attracted attention due to its low reaction temperature, fast processing time, and minimal equipment requirements. For example, RPA combined with lateral flow strip (RPA-LFS) can detect WSSV within approximately 30 minutes at 37 °C, with a detection sensitivity of around 20 copies and results consistent with qPCR. Similar approaches have been applied for detecting AHPND and EHP, with detection times of 20-35 minutes and sensitivity ranging from 10 to 100 copies. These techniques do not require complex thermal cycling equipment, making them suitable for field applications.

In terms of detection platforms and monitoring systems, current developments are moving toward integration and intelligence. Microfluidic chip technology enables the integration of nucleic acid amplification and signal detection into a single platform, allowing simultaneous detection of multiple pathogens. For example, microfluidic-based RPA systems can complete multi-pathogen detection within approximately 20 minutes (Li et al., 2023). In addition, CRISPR-based diagnostics combined with LAMP amplification can achieve highly sensitive detection within 30 minutes and support visual readouts (Major et al., 2023). Furthermore, biosensors, environmental DNA (eDNA) detection, and monitoring systems based on the Internet of Things (IoT) and artificial intelligence are increasingly being applied in aquaculture management (Figure 2) (Bohara et al., 2023; Zwetlana et al., 2023). By integrating water quality parameters, pathogen data, and behavioral information, these systems enable disease risk assessment and early warning. Overall, disease detection technologies are evolving from single-point diagnostics toward integrated systems featuring real-time monitoring, risk prediction, and precision intervention.

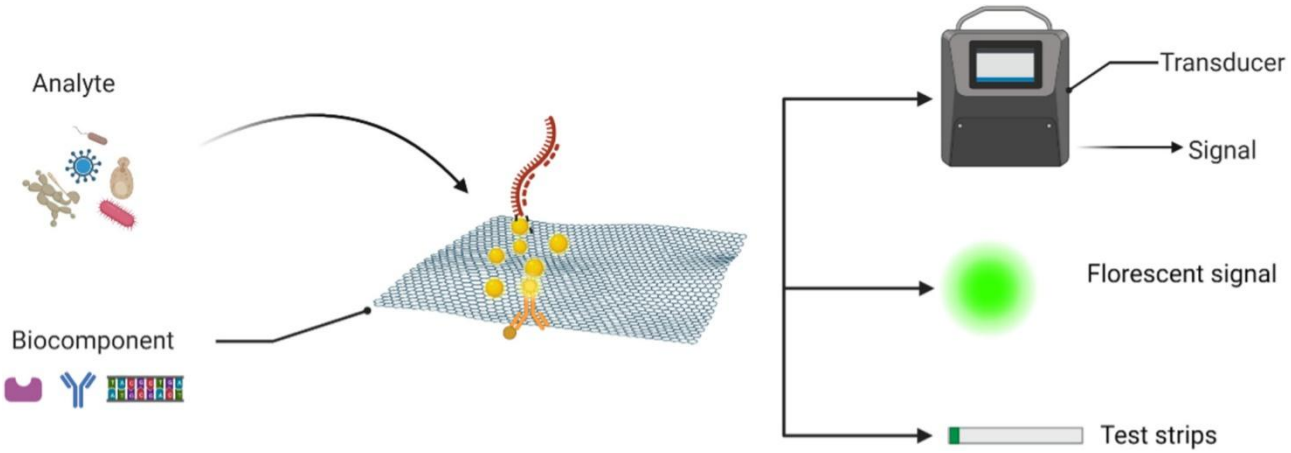

Figure 2 A chronological overview of disease diagnostic tool development (Adopted from Bohara et al., 2023)

5 Key Technologies for Disease Prevention and Control in Shrimp Aquaculture

5.1 Aquaculture management and ecological regulation

Aquaculture management and ecological regulation constitute the fundamental strategies for disease prevention and control in shrimp farming. Their core objective is to establish a stable aquaculture system characterized by low stress and low pathogen load through environmental optimization, standardized management practices, and reduced pathogen introduction risks. In recent years, disease control strategies have shifted from traditional drug-based treatments toward integrated management approaches centered on ecological regulation and biosecurity (Kumar et al., 2025). In this context, biosecurity systems based on specific pathogen-free (SPF)