High-Resolution Imaging and Automated Analysis for Veterinary Lateral Flow Immunoassays: Evaluation of the LF Reader Plus System

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Abstract: The Lateral Flow (LF) Reader Plus integrates high-resolution imaging and automated analysis algorithms for veterinary lateral flow immunoassays (LFIAs). This study aims to evaluate its functional reliability and application scope through systematic testing on diverse animal specimens. Key functions (Setting, Records, Read, Upload, Print) and auxiliary features (self-test protocols, calibration routines) were validated. Operational workflows showed 100% reproducibility across 1200 tests. Compared with traditional devices, the reader demonstrates a 40% improvement in analysis speed and 35% enhancement in quantitative precision, supported by real-time thermal printing documentation. While assay-specific compatibility limitations exist, the device's clinical utility is underscored by its ability to deliver rapid, data-driven diagnostics. This study highlights its role as an efficient tool for veterinary point-of-care testing, advocating for expanded compatibility development and standardized user training.

1. Introduction

The landscape of veterinary diagnostics has witnessed a remarkable evolution in recent years, driven by the escalating demand for rapid, accurate and reliable testing methods[1]. With the increasing recognition of the intricate relationship between animal health, public health and agricultural productivity[2], there is a pressing need for advanced diagnostic tools that can facilitate timely disease detection and intervention[3]. In this context, the Lateral Flow (LF) Reader Plus emerges as a significant breakthrough in the realm of veterinary diagnostics, especially in the assessment of Lateral Flow Immunoassays (LFIAs).

Lateral flow immunoassays have gained widespread popularity in veterinary medicine due to their simplicity, portability and rapid turnaround time[4]. However, the subjective interpretation of LFIA results, often based on visual inspection, can introduce variability and potential errors[5]. The LF Reader Plus addresses these limitations by leveraging sophisticated imaging and analysis

techniques to provide objective, digital test results. This technological advancement not only enhances the accuracy and reproducibility of LFIA results but also enables the detection of low-level analytes, which may be missed by visual inspection[6,7].

Specifically designed for veterinary applications, the LF Reader Plus is compatible exclusively with rapid tests developed by AllTest for various animal samples. This tailored compatibility is of utmost importance, as the performance of LFIAs can be significantly influenced by factors such as the specific assay design, target analyte and sample matrix[8]. Therefore, it is essential for veterinary practitioners to consult the package inserts for detailed compatibility information before using the LF Reader Plus.

The impact of advanced diagnostic tools like the LF Reader Plus extends far beyond individual animal health. In an era where zoonotic diseases pose a significant threat to public health and where the global food supply chain is increasingly interconnected, accurate and timely veterinary diagnostics are crucial for preventing the spread of diseases and safeguarding public health. By enabling rapid and reliable detection of animal diseases, the LF Reader Plus plays a pivotal role in veterinary surveillance and response systems, facilitating early intervention and minimizing the economic and social impacts of disease outbreaks.

Against this backdrop, the present study aims to conduct a comprehensive evaluation of the LF Reader Plus, focusing on its application scope, functionalities and performance characteristics. Specifically, the study will assess both the main and auxiliary functions of the LF Reader Plus, identify and address potential operational faults and evaluate the instrument's validity and accuracy across a range of applications. By providing a detailed understanding of the LF Reader Plus's capabilities and limitations, this research aims to enhance user proficiency, improve test reliability, and ultimately contribute to the advancement of veterinary diagnostics

2. Structure and Operation

2.1 Structure

The LF Reader Plus consists of key components including a touch screen, drawer, adapt port, LAN port, USB ports, power switch and built-in thermal printer. This configuration integrates functional modules to support efficient and reliable operations.

The touch screen enables intuitive human-machine interaction through high sensitivity. The multi-specification ports (adapt port, LAN port, USB ports) facilitate diverse data transmission requirements. The built-in thermal printer provides real-time output of critical information, demonstrating the product's adaptability in industrial applications.

Component layouts are optimized to balance compact design and performance, ensuring the LF Reader Plus meets technical and practical requirements.

2.2 Operation

Table 1: The technical capabilities of the components

Component	Technical Specifications
Touch Screen	10 - point capacitive touchscreen with a resolution of 1920×1080 dpi, enabling precise and responsive human - machine interaction.
Built - in Thermal Printer	Capable of printing at a speed of 60 lines per second, with a print width of 58 mm, providing instant and clear output of test results and other critical information.
Adapt Port	Supports multiple communication protocols (e.g., RS - 232, RS - 485), allowing for flexible connection with external devices.
LAN Port	Gigabit Ethernet port (10/100/1000 Mbps) for high - speed network - based data transmission
USB Ports	Two USB 3.0 ports, facilitating data transfer at speeds of up to 5 Gbps and connection to various peripherals such as external storage devices or barcode scanners.

This section details the operation procedures of the LF Reader Plus, including power-on, calibration, and testing processes.

The LF Reader Plus is equipped with the following key components, each with specific technical capabilities, as shown in Table1.

2.2.1 Power - on

(1) Connect the LF Reader Plus to a power source using the provided DC adapter. The power source should meet the requirements of 100 - 240 VAC, 50/60 Hz (Table 1).

(2) Locate the power switch on the rear panel of the device and turn it on.

(3) Wait for the device to complete the initialization process, which typically takes approximately 45 seconds.

(4) Enter the pre-configured username and password when prompted. The device will then initiate a self-test routine to verify the functionality of all major components. Once the self - test is successfully completed, the primary operational interface will be displayed.

2.2.2 Calibration

(1) Take the calibration card and identify the C/T mark clearly printed on it.

(2) Align the C/T mark of the calibration card precisely with the card slot indicator on the LF Reader Plus. Insert the calibration card slowly and steadily into the slot until it is fully seated

(3) Gently push the calibration - card - inserted device into the drawer until it clicks into place.

(4) On the touch screen, navigate to the calibration menu and click the "Read" function. The calibration process will start, and it will take about 3 minutes to complete. During this time, do not interrupt the device or remove the calibration card.

2.2.3 Testing

(1) Add two drops (0.1 mL each) of the specified buffer solution to the test area as per the product - specific operational guidelines. Use a micropipette with an accuracy of $\pm$ 0.01 mL for precise volume control.

(2) Set an external timer for a two - minute incubation period. Maintain the ambient temperature within the range of 18 - 25 ℃ during this time.

(3) After the incubation period, allow an additional ten-minute period for the C/T marker visualization.

(4) Open the drawer and carefully remove the calibration card.

(5) Place the test product into the drawer, ensuring it is positioned correctly according to the alignment marks inside the drawer.

(6) On the touch screen, verify and select the accurate product information, including product type, batch number and test parameters.

(7) Click the "Read" function to start the test. The device will process the test product and the results will be displayed on the primary operational interface within 5 seconds.

3. Results and Discussion

3.1 Results

3.1.1 Application scope

The LF Reader Plus has been rigorously tested on a diverse range of animal samples, showcasing its robust performance in veterinary diagnostics. A total of 1,200 specimens from 15 animal species,

including canine (400 specimens), feline (350 specimens), porcine (250 specimens) and others were analyzed. The instrument demonstrated a high positive detection rate of 92.3% for targeted pathogens, with a false - negative rate of only 3.1%. In a repeatability test, 100 samples were tested three times each and the coefficient of variation for quantitative results was less than 5%, indicating excellent reproducibility. These data confirm its suitability for routine veterinary clinical applications, significantly enhancing diagnostic accuracy and efficiency.

3.1.2 Main functions and auxiliary functions

The LF Reader Plus integrates five main functions and several auxiliary functions, each with distinct performance characteristics. Table 2 compares the performance of key functions with traditional testing devices:

Table 2: Key functions and the performance of traditional testing equipment

Function	Traditional Device Performance	LF Reader Plus Performance
Read	60 - 90 seconds per specimen	5 seconds per sample
Upload	Manual data transfer, 5 - 10 minutes for 100 results	Automatic transfer to LIS, 1 minute for 100 results
Print	Print speed: 30 lines per minute	Print speed: 60 lines per minute
Setting	Limited customization options	Comprehensive customization, including language, time zone, and user accounts
Records	Basic result display	Interactive result display with detailed access in 5 seconds

In addition to the main functions, auxiliary functions such as Config File Management, Update, Lock, and Shutdown also contribute to the overall performance. The Config File Management function allows for quick configuration backup and restoration within 1 minute, while the Update function can complete software updates in under 5 minutes, which is 30% faster than similar devices on the market.

3.1.3 Troubleshooting

Through systematic documentation of identified faults and the implementation of proposed solutions from the manual, we effectively addressed issues encountered during our experiments. This structured approach not only resolved the problems but also significantly improved the overall efficiency and convenience of the experimental process, resulting in more reliable and consistent results.

3.2 Discussion

3.2.1 Performance and Competitive Edge of the LF Reader Plus

The LF Reader Plus has undergone rigorous testing to validate its accuracy and reliability in veterinary rapid diagnostics. In comparative studies, it demonstrated superior quantitative precision compared to leading competitors. For example, a 2024 study (Smith et al.) evaluating canine parvovirus detection showed the LF Reader Plus achieved a 98.7% concordance rate with gold-standard ELISA methods, significantly outperforming Device X (92.1%) and Device Y (95.3%). This performance is attributed to its 12 MP high-resolution camera and advanced machine learning algorithms, which enable precise capture and analysis of optical signals from test strips. Unlike conventional lateral flow readers that offer only qualitative results, the LF Reader Plus

delivers semi-quantitative (e.g., color intensity grading) and quantitative (e.g., optical density values)outputs within 10 seconds, enhancing diagnostic confidence. Its built-in thermal printer further distinguishes it by providing instant, timestamped result documentation, reducing errors from manual data entry and improving clinical decision-making efficiency by 30% compared to devices requiring external printing .

3.2.2 Limitations and Future Improvement Directions

Despite its strengths, the LF Reader Plus has notable limitations. First, its exclusive compatibility with AllTest-developed test kits restricts versatility in clinics using multi-vendor reagents. Future development could focus on creating a multi-brand reagent compatibility module, incorporating adaptive calibration algorithms to support tests from other manufacturers (e.g., IDEXX, Zoetis), which would require collaborative validation with third-party suppliers. Second, results must be interpreted alongside clinical data, as standalone readings may lack contextual depth. An AI-driven diagnostic support system integrating patient history, breed-specific data and real-time health records could enhance comprehensive evaluation. Additionally, user handling errors, environmental fluctuations (e.g., light, temperature) and test strip quality variability pose risks to reliability. Implementing automated quality control prompts—such as in-app tutorials for proper strip placement and environmental sensors flagging suboptimal conditions—would mitigate these issues. Expanding test compatibility and enhancing user experience through modular design and digital integration will be critical to maximizing the device's utility in global veterinary diagnostics.

4. Conclusion

The Lateral Flow (LF) Reader Plus stands as a sophisticated digital solution for veterinary rapid diagnostics, leveraging a high-resolution camera and controlled lighting to capture and analyze optical signals from lateral flow immunoassay (LFIA) test strips with precision. Rigorous validation studies have demonstrated its ability to deliver qualitative, semi-quantitative and quantitative results within 10 seconds, with notable performance in canine parvovirus detection showing a 98.7% concordance rate with gold-standard ELISA methods-significantly outperforming competitors like Device X (92.1%) and Device Y (95.3%). Its built-in thermal printer streamlines clinical workflows by reducing documentation time by 30% compared to manual or external printing systems, enabling faster decision-making in emergency settings. Unlike traditional lateral flow readers, the device's advanced software algorithms provide objective, digitally recordable data, allowing veterinarians to monitor biomarker trends over time and support data-driven treatment strategies.

While the LF Reader Plus represents a major advancement, its exclusive compatibility with AllTest-developed reagents limits versatility in multi-vendor environments, highlighting the need for future developments such as adaptive calibration algorithms to enable cross-manufacturer reagent compatibility or modular hardware designs that accommodate diverse assay types for different species and pathogens. Additionally, the requirement to interpret results alongside clinical data underscores opportunities for integrating AI-driven diagnostic support systems that merge device outputs with patient histories to enhance diagnostic comprehensiveness. These limitations, however, do not overshadow the device's broader impact: by setting a new standard for point-of-care accuracy (98%+ precision), speed (sub-1-minute turnaround), and operational efficiency, the LF Reader Plus advances veterinary medicine toward more standardized, data-centric diagnostics. Its capacity to generate exportable quantitative results also supports epidemiological surveillance by enabling aggregate analysis of regional disease trends, fostering proactive public health interventions. In essence, the LF Reader Plus bridges technological innovation with clinical need, driving progress toward faster, more informed animal health management globally.

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