World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(REVIEW ARTICLE)

LOOP-MEDIATED ISOTHERMAL AMPLIFICATION VERSUS POLYMERASE CHAIN REACTION IN VETERINARY SCIENCE: A COMPARATIVE REVIEW

Hrishikesh Jagtap, Prafullata Bashetti, Anil B. Bhosale Deepali T. Sakunde and Chandrakant D. Bhong *

Department of Veterinary Public Health and Epidemiology, KNP College of Veterinary Science, Shirwal, Dist. Satara, Maharashtra, India (Maharashtra Animal and Fishery Sciences University, Nagpur).
* Corresponding Author

World Journal of Biology Pharmacy and Health Sciences, 2026, 28(01), 209–216

Publication history: Received on 03 September 2026; revised on 11 October 2026; accepted on 13 October 2026

Article DOI: https://doi.org/10.30574/wjbphs.2026.28.1.0506

Copyright © 2026 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0

ABSTRACT

Rapid and accurate detection of pathogens is central to animal health, zoonosis control and food safety. The polymerase chain reaction (PCR) and its variants, particularly real-time PCR, remain the reference molecular tools in veterinary diagnostic laboratories because of their high sensitivity, specificity and capacity for quantification. However, PCR depends on thermal cyclers, trained staff and well-equipped laboratories, which limits its use in field and resource-limited settings. Loop-mediated isothermal amplification (LAMP), introduced in 2000, amplifies nucleic acids at a constant temperature of 60–65 °C using a strand-displacing DNA polymerase and four to six primers that recognise six to eight regions of the target. Results are obtained within 30–60 minutes and can be read by turbidity, fluorescence or a visible colour change without electrophoresis. LAMP is also more tolerant of inhibitors present in clinical samples, allowing simplified nucleic acid extraction. This review compares the principles, performance characteristics, cost and practical requirements of LAMP and PCR, and summarises their applications in the diagnosis of bacterial, viral and parasitic diseases of livestock, poultry and companion animals, including leptospirosis, brucellosis, foot-and-mouth disease, African swine fever, avian influenza, peste des petits ruminants, lumpy skin disease and rabies. Limitations of LAMP, such as complex primer design, carryover contamination and false-positive amplification, are discussed together with emerging solutions including uracil-DNA-glycosylase-supplemented LAMP, CRISPR-coupled detection and microfluidic point-of-care devices. LAMP and PCR are complementary: LAMP suits rapid field screening, while PCR remains the confirmatory and quantitative standard.

Keywords: Loop-mediated isothermal amplification; Polymerase chain reaction; Molecular diagnosis; Veterinary diagnostics; Point-of-care testing; One Health.

1 INTRODUCTION

Infectious diseases of animals cause major production losses, restrict trade and threaten human health, since about 60% of known human pathogens and most emerging infections are zoonotic [1]. Early and accurate diagnosis is therefore a cornerstone of disease surveillance, outbreak control and the One Health approach. Conventional methods such as

culture, microscopy and serology remain useful but are often slow, need viable organisms, or cannot distinguish current from past infection.

Nucleic acid amplification tests (NAATs) have transformed veterinary diagnostics over the last three decades [2]. The polymerase chain reaction (PCR), especially real-time PCR, is now the most widely used molecular method in veterinary laboratories and is prescribed for many notifiable diseases [3]. Its dependence on precise thermal cycling, costly instruments and skilled personnel, however, restricts its use at farm level, in veterinary dispensaries and in many laboratories of developing countries.

Loop-mediated isothermal amplification (LAMP), described by Notomi and colleagues in 2000 [4], amplifies DNA with high efficiency at a single temperature. Because it needs only a water bath or heat block and its products can be seen by eye, LAMP has been proposed as a practical alternative to PCR for field diagnosis of animal diseases [5]. The objective of this review is to compare LAMP and PCR in terms of principle, performance, cost and practicality, and to summarise their applications and future prospects in veterinary science.

2 POLYMERASE CHAIN REACTION: PRINCIPLE AND VARIANTS

PCR, developed by Mullis and Faloona [6], exponentially amplifies a defined DNA segment through repeated cycles of three temperature steps: denaturation of double-stranded DNA at about 94–95 °C, annealing of two oligonucleotide primers at 50–65 °C, and extension by DNA polymerase at 72 °C. The introduction of the thermostable *Taq* DNA polymerase by Saiki et al. [7] made the process automatable and is the basis of all modern thermal cycling. Twenty-five to forty cycles typically yield millions of copies of the target within 1.5–3 hours, followed by detection of products by agarose gel electrophoresis in conventional PCR.

Several variants have extended its diagnostic use in veterinary medicine:

- **Reverse transcription PCR (RT-PCR)** converts RNA to complementary DNA before amplification and is essential for RNA viruses such as foot-and-mouth disease, avian influenza, bluetongue and peste des petits ruminants viruses [3].
- **Real-time (quantitative) PCR** monitors amplification during each cycle using intercalating dyes such as SYBR Green or sequence-specific hydrolysis (TaqMan) probes [8]. It removes post-amplification handling, reduces contamination, gives results in about 1–2 hours and allows quantification of pathogen load. Reporting of such assays should follow the MIQE guidelines [9].
- **Multiplex PCR** uses several primer pairs in one reaction to detect multiple pathogens or genes simultaneously, saving time and reagents [10].
- **Nested PCR** uses two successive rounds of amplification with outer and inner primers to increase sensitivity, at the cost of a higher risk of contamination.

Real-time PCR is now the reference molecular method for many diseases listed by the World Organisation for Animal Health (WOAH) [11], and validated real-time RT-PCR protocols underpin national control programmes for major livestock diseases [3]. Its main constraints are the need for a thermal cycler (and an optical module for real-time PCR), stable electricity, purified nucleic acid, and trained staff working in separated pre- and post-amplification areas.

3 LOOP-MEDIATED ISOTHERMAL AMPLIFICATION: PRINCIPLE

LAMP amplifies DNA at a constant 60–65 °C using a DNA polymerase with strong strand-displacement activity, most commonly the large fragment of *Bst* DNA polymerase from *Geobacillus stearothermophilus* [4]. Because the enzyme displaces the downstream strand as it synthesises, no heat denaturation step is required after the start of the reaction.

3.1 Primer design

A basic LAMP assay uses four primers that recognise six distinct regions of the target (F3, F2, F1 upstream and B1c, B2c, B3c downstream) [4]:

- **Outer primers (F3 and B3)** displace newly synthesised strands.
- **Inner primers (FIP and BIP)** each consist of two target-binding sequences (F1c + F2 and B1c + B2) joined together, so that the products fold back on themselves.
- **Loop primers (LF and LB)**, added optionally, bind the loop regions and cut reaction time roughly in half, often to under 30 minutes [12].

The requirement for six to eight binding sites gives LAMP very high specificity, but it also makes primer design more demanding than for PCR. Free software such as PrimerExplorer is widely used for this purpose [13].

3.2 Amplification mechanism

In the initiation phase, an inner primer anneals and is extended, and its product is displaced by synthesis from the outer primer. The released strand forms a loop at its 5′ end; the same events at the other end produce a dumbbell-shaped structure with loops at both ends. This dumbbell is the starting structure for the cycling phase, in which inner primers repeatedly bind the loops and self-primed extension generates long stem-loop concatemers containing many inverted repeats of the target. Notomi et al. [4] showed that a few copies of target DNA can be amplified to about 10^9 copies in less than one hour. RNA targets are detected in a single tube by adding reverse transcriptase (RT-LAMP).

3.3 Detection of LAMP products

LAMP generates large amounts of DNA and of the by-product magnesium pyrophosphate, which allows several simple read-outs:

- **Turbidity:** a white precipitate of magnesium pyrophosphate is visible by eye or measurable in a real-time turbidimeter [14].
- **Fluorescent dyes:** SYBR Green I or calcein give a colour change visible under daylight or ultraviolet light [13].
- **Metal-indicator dyes:** hydroxy naphthol blue changes from violet to sky blue as free magnesium falls; it is added before amplification, so tubes need not be opened [15].
- **pH-sensitive dyes:** phenol red and similar indicators change colour as protons released during synthesis acidify a weakly buffered reaction [16].
- **Other formats:** agarose gel electrophoresis (characteristic ladder pattern), lateral flow dipsticks with labelled primers, and real-time fluorescence on portable devices.

The combination of isothermal incubation, short run time and visual read-out underlies the description of LAMP as a rapid, accurate and cost-effective diagnostic method [17]. LAMP is also less affected than PCR by inhibitors in culture media and biological substances, so crude or heat-treated samples can often be used [18].

4 COMPARATIVE EVALUATION OF LAMP AND PCR

LAMP and PCR reach comparable analytical sensitivity in most published veterinary assays, but they differ sharply in speed, equipment and suitability for field use (Table 1).

Table 1: Comparison of LAMP with conventional and real-time PCR

Parameter	Conventional PCR	Real-time PCR	LAMP
Temperature profile	Cycling, 3 steps (≈95, 55–65, 72 °C)	Cycling, 2–3 steps	Isothermal, 60–65 °C
Enzyme	*Taq* DNA polymerase	*Taq* DNA polymerase	*Bst* (strand-displacing) DNA polymerase
Primers / target regions	2 primers / 2 regions	2 primers ± probe / 2–3 regions	4–6 primers / 6–8 regions
Time to result	2–4 h including electrophoresis	1–2 h	15–60 min
Equipment	Thermal cycler, electrophoresis, gel documentation	Real-time thermal cycler with optics	Water bath or heat block; optional turbidimeter or portable fluorometer
Detection	Agarose gel	Fluorescence curves (Ct value)	Visual turbidity or colour, fluorescence, lateral flow, gel
Quantification	No	Yes	Semi-quantitative (time to positivity)
Tolerance to inhibitors	Low	Low to moderate	High

Sample preparation	Purified nucleic acid	Purified nucleic acid	Crude or heat-treated samples often adequate
Multiplexing	Well established	Well established	Limited
Primer design	Simple	Simple	Complex; specialised software
Carryover contamination risk	Moderate	Low (closed tube)	High if tubes are opened after amplification
Cost per test	Moderate	Highest	Low
Suitability for field / point-of-care	Poor	Poor (portable units emerging)	Good
Regulatory standing	Accepted	Reference method for many WOAH-listed diseases	Validated for some diseases; fewer standardised protocols

Sources: compiled from references [3–5, 11, 13, 17–22].

4.1 Sensitivity and specificity

Many studies report that LAMP detects as few as 1–10 copies of target, a limit equal to real-time PCR and often 10–100 times lower than conventional PCR [5, 20, 21]. The use of six to eight recognition sites gives LAMP high specificity, provided primers are carefully designed and validated against related organisms. Diagnostic performance, however, depends on the assay, sample type and target, and must be established for each test against a reference method.

4.2 Speed, cost and practicality

LAMP results are typically available in 30–60 minutes, without electrophoresis. Equipment costs are a fraction of those of a real-time thermal cycler, and lyophilised or ready-to-use master mixes reduce the need for a cold chain [17, 22]. A multicentre robustness evaluation found that LAMP performed reliably when transferred to laboratories with limited experience in molecular diagnostics [19].

4.3 Where PCR remains superior

Real-time PCR offers accurate quantification, mature multiplexing, extensive validation data and international acceptance for trade and confirmatory testing [3, 11]. Conventional PCR products are also readily sequenced for genotyping and molecular epidemiology, whereas LAMP concatemers are less suitable for direct sequencing. For these reasons the two methods are best viewed as complementary rather than competing [22].

5 APPLICATIONS IN VETERINARY SCIENCE

LAMP and RT-LAMP assays have now been developed for most economically important bacterial, viral and parasitic pathogens of animals, usually with PCR or real-time PCR as the comparator (Table 2).

Table 2: Selected LAMP assays developed for pathogens of veterinary and zoonotic importance

Disease	Pathogen	Category	Assay	Reference
Leptospirosis	Pathogenic *Leptospira* spp.	Bacterial, zoonotic	LAMP	[23, 24]
Brucellosis	*Brucella* spp.	Bacterial, zoonotic	LAMP	[25]
Johne's disease	*Mycobacterium avium* subsp. *paratuberculosis*	Bacterial	LAMP (IS900)	[26]
Salmonellosis	*Salmonella* spp.	Bacterial, food-borne	LAMP	[27]
Foot-and-mouth disease	FMD virus	Viral (RNA)	RT-LAMP	[28]
African swine fever	ASF virus	Viral (DNA)	LAMP	[29]
Avian influenza (H5)	Influenza A virus	Viral (RNA), zoonotic	RT-LAMP	[30]
Peste des petits ruminants	PPR virus	Viral (RNA)	RT-LAMP	[31]

Sheep pox, goat pox, lumpy skin disease	Capripoxviruses	Viral (DNA)	LAMP	[32]
Canine parvoviral enteritis	Canine parvovirus	Viral (DNA)	LAMP	[33]
Rabies	Rabies virus	Viral (RNA), zoonotic	RT-LAMP	[34]
Trypanosomosis	African trypanosomes	Parasitic	LAMP	[35]
Toxoplasmosis	*Toxoplasma gondii*	Parasitic, zoonotic	LAMP	[36]
MRSA contamination of chevon	Methicillin-resistant *Staphylococcus aureus*	Bacterial, food-borne, AMR	LAMP vs PCR	[37]

5.1 Bacterial diseases

Leptospirosis illustrates the value of LAMP in endemic, resource-limited settings. Culture of *Leptospira* is slow and insensitive, and the microscopic agglutination test detects antibodies only after the first week of illness. LAMP assays targeting pathogenic leptospires have shown sensitivity comparable to or better than PCR [23], and a prospective clinical evaluation in Thailand [24] underlined that diagnostic accuracy in patient samples must be established separately from analytical sensitivity. Such assays are relevant to dogs, cattle and buffaloes in leptospirosis-endemic regions of India, where field diagnosis is a recurring challenge. LAMP assays have also been reported for *Brucella* spp., which are hazardous to culture [25], for *M. avium* subsp. *paratuberculosis*, whose culture takes weeks [26], and for *Salmonella* in food and faecal samples [27].

5.2 Viral diseases

RT-LAMP has been developed for transboundary animal diseases where speed directly limits spread. Assays for foot-and-mouth disease virus [28] and African swine fever virus [29] have shown sensitivity comparable to real-time PCR and are suited to pen-side or mobile laboratory use. RT-LAMP for H5 avian influenza [30] and peste des petits ruminants [31], and LAMP for capripoxviruses causing sheep pox, goat pox and lumpy skin disease [32], are particularly relevant to India and other endemic countries. In companion animals, LAMP has been applied to faecal samples for canine parvovirus [33], and RT-LAMP to brain tissue for rabies virus [34], a key zoonosis in India.

5.3 Parasitic diseases

Parasitic infections are often of low intensity and difficult to confirm microscopically. LAMP has been developed for African trypanosomes [35] and *Toxoplasma gondii* [36], and similar assays have been reported for *Babesia*, *Theileria*, *Anaplasma* and *Fasciola* species [5]. The ability to test blood with minimal processing makes LAMP useful for epidemiological surveys of haemoprotozoan infections in cattle.

5.4 Food safety and One Health

In veterinary public health, LAMP is used to screen foods of animal origin for food-borne pathogens, to detect zoonotic agents in reservoir hosts and vectors, and to support rapid surveillance during outbreaks [5, 21]. For example, Thakur et al. [37] compared LAMP with PCR for methicillin-resistant Staphylococcus aureus (MRSA) in 26 S. aureus isolates recovered from 150 raw chevon samples. Both methods detected MRSA in 2 samples (1.33%) with 100% specificity, but the detection limit of LAMP was 10-fold lower than that of PCR, supporting its use for antimicrobial resistance surveillance in meat. Its portability allows testing at slaughterhouses, dairy collection centres and border check-posts, linking animal, human and environmental health surveillance.

6 LIMITATIONS, CHALLENGES AND FUTURE PERSPECTIVES

6.1 Limitations of LAMP

- **Primer design:** designing four to six compatible primers is difficult for short, highly variable or GC-rich targets, and limits multiplexing [21].
- **False-positive amplification:** primer dimers and self-amplifying hairpins can produce non-specific products, especially in RT-LAMP, which visual read-outs cannot distinguish from true amplification [38].
- **Carryover contamination:** the very large amount of product generated means that opening tubes after amplification can contaminate the laboratory and later reactions [20].
- **Limited quantification and sequencing:** time to positivity is only semi-quantitative, and the concatemeric products are poorly suited to downstream sequencing.

- **Standardisation:** fewer LAMP assays have undergone formal multi-laboratory validation or been adopted in WOAH reference procedures than real-time PCR assays [11].

6.2 Limitations of PCR

PCR requires costly instruments, stable electricity, purified nucleic acid and skilled staff, and is sensitive to inhibitors in faeces, blood and tissues. Turnaround time, including sample transport to a central laboratory, can delay control measures during outbreaks [2, 3].

6.3 Emerging solutions and future directions

- **Contamination control:** closed-tube dyes added before amplification [15] and uracil-DNA-glycosylase-supplemented LAMP (UDG-LAMP), which destroys carryover amplicons [39], reduce false positives.
- **CRISPR-coupled detection:** Cas12 and Cas13 enzymes cut reporter molecules only after recognising a specific sequence [40]. Combined with RT-LAMP, this increases specificity, as shown for SARS-CoV-2 [41], and similar platforms are being adapted for animal pathogens.
- **Point-of-care devices:** microfluidic chips, battery-operated heaters, smartphone-based fluorescence readers and lateral flow read-outs bring testing to the farm and the veterinary clinic [42].
- **Reagent stabilisation:** lyophilised master mixes stable at ambient temperature remove the need for a cold chain in the field [22].
- **Portable PCR:** compact and rapid thermal cyclers are narrowing the gap from the other side, so the choice of method will increasingly depend on cost, throughput and validation status rather than portability alone.

For wider adoption in veterinary practice, LAMP assays need validation on field samples from local animal populations, inter-laboratory comparisons, and inclusion in national and WOAH diagnostic standards.

7 CONCLUSION

LAMP and PCR are complementary tools in veterinary diagnostics. LAMP offers speed, simplicity, low cost, tolerance to inhibitors and visual read-out, which make it well suited to field screening, outbreak response and laboratories with limited infrastructure, as are common in India. Real-time PCR remains the confirmatory and quantitative standard, with mature multiplexing, international acceptance and extensive validation. A tiered approach, in which LAMP is used for rapid screening near the animal and PCR for confirmation, quantification and genotyping in reference laboratories, can strengthen disease surveillance and zoonosis control. Wider adoption of LAMP will depend on robust field validation, contamination-resistant formats and integration with CRISPR-based and point-of-care technologies.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The author thanks the Associate Dean, KNP College of Veterinary Science, Shirwal, for providing facilities.

Disclosure of conflict of interest

The author declares no conflict of interest.

REFERENCES

[1] Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. Philos Trans R Soc Lond B Biol Sci. 2001; 356(1411):983-9.

[2] Belák S. Molecular diagnosis of viral diseases, present trends and future aspects: a view from the OIE Collaborating Centre for the Application of Polymerase Chain Reaction Methods for Diagnosis of Viral Diseases in Veterinary Medicine. Vaccine. 2007; 25(30):5444-52.

[3] Hoffmann B, Beer M, Reid SM, Mertens P, Oura CA, van Rijn PA, et al. A review of RT-PCR technologies used in veterinary virology and disease control: sensitive and specific diagnosis of five livestock diseases notifiable to the World Organisation for Animal Health. Vet Microbiol. 2009; 139(1-2):1-23.

[4] Notomi T, Okayama H, Masubuchi H, Yonekawa T, Watanabe K, Amino N, et al. Loop-mediated isothermal amplification of DNA. Nucleic Acids Res. 2000; 28(12):E63.

[5] Dhama K, Karthik K, Chakraborty S, Tiwari R, Kapoor S, Kumar A, et al. Loop-mediated isothermal amplification of DNA (LAMP): a new diagnostic tool lights the world of diagnosis of animal and human pathogens: a review. Pak J Biol Sci. 2014; 17(2):151-66.

[6] Mullis KB, Faloona FA. Specific synthesis of DNA in vitro via a polymerase-catalyzed chain reaction. Methods Enzymol. 1987; 155:335-50.

[7] Saiki RK, Gelfand DH, Stoffel S, Scharf SJ, Higuchi R, Horn GT, et al. Primer-directed enzymatic amplification of DNA with a thermostable DNA polymerase. Science. 1988; 239(4839):487-91.

[8] Higuchi R, Fockler C, Dollinger G, Watson R. Kinetic PCR analysis: real-time monitoring of DNA amplification reactions. Biotechnology (N Y). 1993; 11(9):1026-30.

[9] Bustin SA, Benes V, Garson JA, Hellemans J, Huggett J, Kubista M, et al. The MIQE guidelines: minimum information for publication of quantitative real-time PCR experiments. Clin Chem. 2009; 55(4):611-22.

[10] Elnifro EM, Ashshi AM, Cooper RJ, Klapper PE. Multiplex PCR: optimization and application in diagnostic virology. Clin Microbiol Rev. 2000; 13(4):559-70.

[11] World Organisation for Animal Health. Manual of diagnostic tests and vaccines for terrestrial animals [Internet]. Paris: WOAH; 2024 [cited 2026 Oct 10]. Available from: https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-manual-online-access/

[12] Nagamine K, Hase T, Notomi T. Accelerated reaction by loop-mediated isothermal amplification using loop primers. Mol Cell Probes. 2002; 16(3):223-9.

[13] Tomita N, Mori Y, Kanda H, Notomi T. Loop-mediated isothermal amplification (LAMP) of gene sequences and simple visual detection of products. Nat Protoc. 2008; 3(5):877-82.

[14] Mori Y, Nagamine K, Tomita N, Notomi T. Detection of loop-mediated isothermal amplification reaction by turbidity derived from magnesium pyrophosphate formation. Biochem Biophys Res Commun. 2001; 289(1):150-4.

[15] Goto M, Honda E, Ogura A, Nomoto A, Hanaki K. Colorimetric detection of loop-mediated isothermal amplification reaction by using hydroxy naphthol blue. Biotechniques. 2009; 46(3):167-72.

[16] Tanner NA, Zhang Y, Evans TC Jr. Visual detection of isothermal nucleic acid amplification using pH-sensitive dyes. Biotechniques. 2015; 58(2):59-68.

[17] Mori Y, Notomi T. Loop-mediated isothermal amplification (LAMP): a rapid, accurate, and cost-effective diagnostic method for infectious diseases. J Infect Chemother. 2009; 15(2):62-9.

[18] Kaneko H, Kawana T, Fukushima E, Suzutani T. Tolerance of loop-mediated isothermal amplification to a culture medium and biological substances. J Biochem Biophys Methods. 2007; 70(3):499-501.

[19] Francois P, Tangomo M, Hibbs J, Bonetti EJ, Boehme CC, Notomi T, et al. Robustness of a loop-mediated isothermal amplification reaction for diagnostic applications. FEMS Immunol Med Microbiol. 2011; 62(1):41-8.

[20] Parida M, Sannarangaiah S, Dash PK, Rao PV, Morita K. Loop mediated isothermal amplification (LAMP): a new generation of innovative gene amplification technique; perspectives in clinical diagnosis of infectious diseases. Rev Med Virol. 2008; 18(6):407-21.

[21] Wong YP, Othman S, Lau YL, Radu S, Chee HY. Loop-mediated isothermal amplification (LAMP): a versatile technique for detection of micro-organisms. J Appl Microbiol. 2018; 124(3):626-43.

[22] Soroka M, Wasowicz B, Rymaszewska A. Loop-mediated isothermal amplification (LAMP): the better sibling of PCR? Cells. 2021; 10(8):1931.

[23] Lin X, Chen Y, Lu Y, Yan J, Yan J. Application of a loop-mediated isothermal amplification method for the detection of pathogenic Leptospira. Diagn Microbiol Infect Dis. 2009; 63(3):237-42.

[24] Sonthayanon P, Chierakul W, Wuthiekanun V, Thaipadungpanit J, Kalambaheti T, Boonsilp S, et al. Accuracy of loop-mediated isothermal amplification for diagnosis of human leptospirosis in Thailand. Am J Trop Med Hyg. 2011; 84(4):614-20.

[25] Ohtsuki R, Kawamoto K, Kato Y, Shah MM, Ezaki T, Makino SI. Rapid detection of Brucella spp. by the loop-mediated isothermal amplification method. J Appl Microbiol. 2008; 104(6):1815-23.

[26] Enosawa M, Kageyama S, Sawai K, Watanabe K, Notomi T, Onoe S, et al. Use of loop-mediated isothermal amplification of the IS900 sequence for rapid detection of cultured Mycobacterium avium subsp. paratuberculosis. J Clin Microbiol. 2003; 41(9):4359-65.

[27] Hara-Kudo Y, Yoshino M, Kojima T, Ikedo M. Loop-mediated isothermal amplification for the rapid detection of Salmonella. FEMS Microbiol Lett. 2005; 253(1):155-61.

[28] Dukes JP, King DP, Alexandersen S. Novel reverse transcription loop-mediated isothermal amplification for rapid detection of foot-and-mouth disease virus. Arch Virol. 2006; 151(6):1093-106.

[29] James HE, Ebert K, McGonigle R, Reid SM, Boonham N, Tomlinson JA, et al. Detection of African swine fever virus by loop-mediated isothermal amplification. J Virol Methods. 2010; 164(1-2):68-74.

[30] Imai M, Ninomiya A, Minekawa H, Notomi T, Ishizaki T, Tashiro M, et al. Development of H5-RT-LAMP (loop-mediated isothermal amplification) system for rapid diagnosis of H5 avian influenza virus infection. Vaccine. 2006; 24(44-46):6679-82.

[31] Li L, Bao J, Wu X, Wang Z, Wang J, Gong M, et al. Rapid detection of peste des petits ruminants virus by a reverse transcription loop-mediated isothermal amplification assay. J Virol Methods. 2010; 170(1-2):37-41.

[32] Das A, Babiuk S, McIntosh MT. Development of a loop-mediated isothermal amplification assay for rapid detection of capripoxviruses. J Clin Microbiol. 2012; 50(5):1613-20.

[33] Cho HS, Kang JI, Park NY. Detection of canine parvovirus in fecal samples using loop-mediated isothermal amplification. J Vet Diagn Invest. 2006; 18(1):81-4.

[34] Boldbaatar B, Inoue S, Sugiura N, Noguchi A, Orbina JR, Demetria C, et al. Rapid detection of rabies virus by reverse transcription loop-mediated isothermal amplification. Jpn J Infect Dis. 2009; 62(3):187-91.

[35] Kuboki N, Inoue N, Sakurai T, Di Cello F, Grab DJ, Suzuki H, et al. Loop-mediated isothermal amplification for detection of African trypanosomes. J Clin Microbiol. 2003; 41(12):5517-24.

[36] Zhang H, Thekisoe OM, Aboge GO, Kyan H, Yamagishi J, Inoue N, et al. Toxoplasma gondii: sensitive and rapid detection of infection by loop-mediated isothermal amplification (LAMP) method. Exp Parasitol. 2009; 122(1):47-50.

[37] Thakur S, Brahmbhatt MN, Chaudhary JH, Parmar BC, Mistry UP, Bhong CD. Comparison of loop mediated isothermal amplification with polymerase chain reaction for detection of methicillin resistant Staphylococcus aureus in chevon. J Entomol Zool Stud. 2020; 8(6):1976-80. doi:10.22271/j.ento.2020.v8.i6aa.8111

[38] Meagher RJ, Priye A, Light YK, Huang C, Wang E. Impact of primer dimers and self-amplifying hairpins on reverse transcription loop-mediated isothermal amplification detection of viral RNA. Analyst. 2018; 143(8):1924-33.

[39] Hsieh K, Mage PL, Csordas AT, Eisenstein M, Soh HT. Simultaneous elimination of carryover contamination and detection of DNA with uracil-DNA-glycosylase-supplemented loop-mediated isothermal amplification (UDG-LAMP). Chem Commun (Camb). 2014; 50(28):3747-9.

[40] Chen JS, Ma E, Harrington LB, Da Costa M, Tian X, Palefsky JM, et al. CRISPR-Cas12a target binding unleashes indiscriminate single-stranded DNase activity. Science. 2018; 360(6387):436-9.

[41] Broughton JP, Deng X, Yu G, Fasching CL, Servellita V, Singh J, et al. CRISPR-Cas12-based detection of SARS-CoV-2. Nat Biotechnol. 2020; 38(7):870-4.

[42] Li Y, Fan P, Zhou S, Zhang L. Loop-mediated isothermal amplification (LAMP): a novel rapid detection platform for pathogens. Microb Pathog. 2017; 107:54-61.