Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Applications of nucleic acid probes in veterinary infectious diseases

Prem S. Paul
Veterinary Medical Research Institute, College of Veterinary Medicine, Iowa State University, Ames, IA, 50011, U.S.A.

ABSTRACT

Paul, P.S., 1990. Applications of nucleic acid probes in veterinary infectious diseases. Vet. Microbiol., 24:409-417.

Nucleic acid probe technology is increasingly being used in basic research in veterinary microbiology and in diagnosis of infectious diseases of veterinary importance. This review presents an overview of nucleic acid probe methodology and its applications in veterinary infectious diseases. The major applications of nucleic acid probes include detection of pathogens in clinical samples, especially those organisms which are fastidious and difficult to cultivate, differentiation of virulent from avirulent organisms and vaccine strains from wild type isolates, typing of microorganisms, mapping genes, screening libraries of cloned DNA for specific genes, detection of latently infected or carrier animals, study of mechanisms of pathogenesis, epidemiological studies and food safety.

INTRODUCTION

Nucleic acid probe technology is being increasingly used by veterinary medical researchers and diagnosticians. This has resulted from the increased awareness, commercial availability of reagents for the preparation of probes, the need for more sensitive methods for the detection of fastidious organisms, the need for more specific methods for the detection of nucleic acids, and recent advances in nucleic acid probe technology.

The key to the development of nucleic acid probes is to identify nucleotide sequences which are unique to the particular organism of interest. These sequences may be genomic DNA, plasmid DNA or ribosomal RNA. The nucleic acid which contains such sequences is isolated and amplified by recombinant DNA technology. The unique nucleotide sequence is then cleaved and is labelled with a reporter molecule such as a radioactive (\(^{32}\)P, \(^{35}\)S) or nonradioactive (biotin, digoxigenin) molecule. Alternatively, complementary DNA, RNA or synthetic oligonucleotides may be labelled and used as probes. The labelled DNA or RNA in single-stranded form is then hybridized to single-stranded nucleic acid (DNA or RNA) in tissues (in situ hybridization), on
paper, or in solution. If the nucleotide sequences in the nucleic acid probe are complementary to those in the sample, hybridization occurs and results in double-stranded nucleic acid being formed. Nonhybridized single strand probe is removed. Hybridization is monitored by autoradiography (exposure to X-ray film) in the case of probes labelled with radioactive molecules, or colorimetrically or visually for probes labelled with nonradioactive molecules.

The basic principles of nucleic acid hybridization and the effect of different hybridization conditions such as probe size, salt concentration, and temperature have been reviewed by Gillespie (1990). Gillespie also presents an overview of different hybridization formats which have either been developed or are being developed. Readers are also referred to reviews on nucleic acid probes by Minson and Darby (1982), Edberg (1985), Kulski (1985), Pereira (1986), Norval and Bingham (1987), Paul (1988), and Tenover (1988, 1989).

Major drawbacks of utilizing nucleic acid probes in the past have included sensitivity limits of hybridization technology, safety and short half-life of radioactive probes. The introduction of new technologies for nucleic acid amplification such as the polymerase chain reaction (Oste, 1988) have revolutionized probe technology. Sensitivity is no longer a major problem as target sequences can by amplified prior to hybridization. Amplification of target sequences by the polymerase chain reaction and transcription amplification system (TAS) is reviewed by Gingeras et al. (1990). Alternative methods for amplification are covered by Gillespie (1990). A number of nonradioactive detection systems are currently available and some of them are reviewed by Pereira (1986); however, improved technologies need to be developed for nonradioactive detection of nucleic acids in clinical samples, especially feces. Some of the potential applications of nucleic acid probes in veterinary infectious diseases are presented in this review.

DETECTION OF PATHOGENS IN CLINICAL SAMPLES

Conventional approaches of detecting etiologic agents of infectious disease include the isolation of organisms, direct detection of organisms in clinical samples by electron microscopy, and direct detection of antigens in tissue sections and clinical samples by immunofluorescence, immunocytochemistry or ELISA. The availability of monoclonal antibodies has provided specific detection of many infectious agents in clinical samples. Monoclonal antibodies will continue to play a significant role in diagnostics, however, in some instances monoclonal antibody based tests are unsuitable and alternative methods are needed. Monoclonal antibody assays may be ineffective on samples contaminated with other organisms either due to the condition of the samples or the sensitivity of the assays. Nucleic acid probes provide an alternative diagnostic tool for the detection of infectious agents. Nucleic acid
probes have been used to detect viruses, bacteria, and parasites in clinical samples. Among viruses of veterinary importance detected by nucleic acid probes are adenovirus (Jouvenne et al., 1987), African swine fever virus (Tabares, 1987), blue tongue virus (Dangler et al., 1988), bovine viral diarrhea virus (Brock and Potgieter, 1990), enterovirus (Bruce et al., 1989), infectious bursal disease virus (Jackwood, 1990), foot-and-mouth disease virus (Rossi et al., 1988), porcine parvovirus (Ridpath et al., 1987; Harding and Molitor, 1988; Oraveerakaul et al., 1989), pseudorabies virus (Gutekunst, 1979; Maes et al., 1990), rhinovirus (Gama et al., 1988), rotavirus (Dimitrov et al., 1985; Johnson et al., 1990; Rosen et al., 1990), and transmissible gastroenteritis virus (Shockley et al., 1987). Bacteria for which probes have been developed include *Campylobacter* spp. (Gebhart et al., 1990), *Escherichia coli* (Moseley et al., 1982; Maddox and Wilson, 1986), *Leptospira* spp. (Zuerner and Bolin, 1990), *Listeria* sp. (Wesley et al., 1990), *Mycobacterium paratuberculosis* (McFadden et al., 1987, 1988), *Mycobacterium tuberculosis* (Eisenach et al., 1988; McFadden et al., 1988), *Mycoplasma gallisepticum* (Geary et al., 1988) and other *Mycoplasma* spp. (Razin et al., 1987). Nucleic acid probes have also been developed to detect *Anaplasma marginale* (Eriks et al., 1989; Aboytes-Torres and Buening, 1990; Goff et al., 1990) and *Histoplasma capsulatum* (Keath et al., 1989).

The most important application of nucleic acid probes is the detection of fastidious organisms. Many microorganisms, such as *Mycoplasma* spp. and *Mycobacterium* spp., cannot be cultivated easily or require 3 weeks to 3 months of culture. Nucleic acid probes have been developed and are being successfully used for their detection either directly in clinical specimens or following a short culture period. Probes have also been used to detect specific microorganisms in tissues by in situ hybridization (Brigati et al., 1983; Dunn et al., 1986; Brown et al., 1990; Collisson et al., 1990).

DETECTION OF CONTAMINANTS IN CELL CULTURES

Mycoplasmas, parvovirus and bovine viral diarrhea virus are frequently present as contaminants in cell cultures. Their detection is sometimes difficult by inexperienced workers. Nucleic acid probes offer standardized reagents for their detection and such probes have been developed for these microorganisms (McGarrity and Kotani, 1986; Oraveerakaul et al., 1989).

DIFFERENTIATION OF VIRULENT FROM AVIRULENT ORGANISMS

The differentiation of virulent from avirulent organisms and vaccine strains from wild type isolates is extremely important in diagnostic medicine and epidemiological studies. This can be accomplished immunologically by monoclonal antibodies, and genetically by restriction endonuclease analysis, se-
quence analysis and nucleic acid probes. *Treponema hyodysenteriae*, causative agent of swine dysentery, cannot be easily distinguished from a nonpathogenic treponeme, *Treponema innocens*, which is commonly present in normal swine. A nucleic acid probe prepared from a plasmid associated with *Treponema hyodysenteriae* was successfully used to differentiate pathogenic and nonpathogenic treponemes (Joens, 1988). Similarly, probes have been developed to detect virulence genes. Moseley et al. (1982) used probes for the first time to identify organisms carrying genes for enterotoxins. Such probes are now routinely being used to determine potential pathogenicity of *Escherichia coli* by screening for genes of enterotoxins (Moseley et al., 1982; Maddox and Wilson, 1986; Karch and Meyer, 1989).

**Typing of Microorganisms**

Typing of microorganisms has usually been based on biologic and antigenic characteristics. These classical procedures have been found to be unsatisfactory in many cases. Monoclonal antibodies have provided useful methods for typing many organisms where conventional reagents have not worked. Production of type specific monoclonal antibodies is often difficult, time consuming and sometimes an impossible task, especially when bacterial and parasitic organisms are used due to the large number of proteins. Genetic tools have been useful in typing organisms where serologic tests were unsuccessful, tedious or gave ambiguous results. Nucleic acid probes have been used to type pillus and enterotoxin gene types to differentiate *Campylobacter* spp. (Chevrier et al., 1988; Gebhart et al., 1990), *Escherichia coli* (Maddox and Wilson, 1986), *Leptospira* spp. (Zuerner and Bolin, 1990), *Mycobacterium* spp. (McFadden et al., 1988), and rotavirus groups, subgroups and serotypes (Dimitrov et al., 1985; Johnson et al., 1990; Rosen et al., 1990).

**Mapping Genes**

Nucleic acid probes provide a powerful tool for evaluating homology between related DNAs (Howley et al., 1979). This can be accomplished by dot blot, Southern blot or Northern blot hybridization. For example, homology between polyoma and papovavirus was analyzed by Southern blot hybridization (Howley et al., 1979). Similarly, homology between porcine and canine parvovirus was evaluated using Southern blot hybridization (Ridpath et al., 1987). Location of homologous sequences on the physical map of these viruses was also revealed in these studies by using probes from subgenomic fragments. Hybridization has also been successfully used to identify genetic reassortants (Midhun et al., 1987) and gene rearrangement (Paul et al., 1988) among rotaviruses. These strategies can also be employed to map specific genes of interest using well studied genes from related organisms. A complete map
of bovine adenovirus 7 was generated by Southern blot hybridization at low stringency with probes prepared from human adenovirus 3 DNA (Hu et al., 1984). Transcriptional maps for specific genes and identification of microbe-specific RNAs can be identified by Northern blot hybridization. Additionally, coding assignments for genes can be established by a combination of Northern blot hybridization and in vitro translation (Collins et al., 1984). Probes have also been useful for screening libraries for specific genes (Rigas et al., 1986) and cloning genes by oligonucleotide hybridization (Mayaux et al., 1987). The latter method is being extensively used for cloning specific genes or subcloning regions of interest.

**STUDY OF MECHANISMS OF PATHOGENESIS**

Nucleic acid probes are an excellent tool for the determination of molecular mechanisms of pathogenesis. Mechanisms of latency induction by herpesviruses have been studied by in situ hybridization. Rock et al. (1987) found that with bovine herpesvirus-1 (BHV-1), causative agent of infectious bovine rhinotracheitis, the nucleic acid is present in ganglionic neurons of rabbits latently infected with BHV-1. Furthermore, only selected regions of the viral genome were transcribed in neurons of latently infected rabbits, whereas all regions of the genome were transcribed in lytically infected cells. These studies indicated that transcription of BHV-1 is restricted during the latent phase of infection and suggested that transcription of specific genes may be important in the establishment and maintenance of latency. The mechanism of persistent infection by equine infectious anemia virus (EIAV) was determined using Southern blot hybridization by Rasty et al. (1990). They found that the degree of provirus integration may be important in the establishment of persistent infection since 30% of provirus was randomly integrated in persistently infected cells, whereas 65–90% of provirus was integrated in lytically infected cells. Hybridization technology was also used to better understand the mechanisms of leukemogenesis by bovine leukemia virus (BLV) (GREGOIRE et al., 1984). These studies revealed that BLV-induced tumors in sheep were monoclonal in the same sheep, integration was observed at different sites in the animals and there was nonintegrated BLV in tumors. Hybridization procedures can provide information on organs and cell types harboring organisms, the number of genome copies per cell, whether genes are integrated, and the transcription status and regulation of the genes. These studies, combined with immunocytochemistry, can provide valuable information on the presence of viral nucleic acid and antigens in cells and can provide information on the status of virus expression.
EPIDEMIOLOGICAL STUDIES

The development of specific probes specific for organisms, groups of organisms, or specific serotypes provides a valuable tool for epidemiological studies. Such tests can be developed in a few reference laboratories and distributed to diagnostic laboratories to determine prevalence and incidence of a specific organism. Probes will be especially useful for determining the epidemiology of microorganisms which are difficult to cultivate or type.

FOOD SAFETY

There is increasingly more emphasis on the rapid detection and identification of microorganisms in foods. In the past, this has generally been accomplished by the isolation and identification of bacteria using conventional methods that are time consuming and require the presence of viable microorganisms. Nucleic acid probes provide a more rapid method for the identification of microorganisms in food. Nucleic acid probes have been developed and are commercially available for the detection of several microorganisms of public health importance e.g., toxigenic Escherichia coli, Listeria sp., Salmonella spp., and Yersinia enterocolitica (Hill, 1989). Probes for additional microorganisms and improved methodology for their detection in foods will enhance their use in food safety.

In this review, some of the applications of nucleic acid probes are highlighted. Additional potential applications will become evident as newer technologies are developed. Automation in nucleic acid probe technology will significantly enhance its acceptance in diagnostic medicine. In the meantime, nucleic acid probes will continue to serve as a powerful tool to researchers and to diagnosticians in selected cases.

REFERENCES

Aboytes-Torres, R. and Buening, G.M., 1990. Development of a recombinant Anaplasma marginale DNA probe. Vet. Microbiol., 24: 391–408.
Brigati, D.J., Myerson, D., Leary, J.J., Spalholz, B., Travis, S.Z., Fong, C.K.Y., Hsiung, G.D. and Ward, D.C., 1983. Detection of viral genomes in cultured cells and paraffin-embedded tissue sections using biotin-labeled hybridization probes. Virology, 126: 32–50.
Brock, K.V. and Potgieter, L.N.D., 1990. Detection of bovine viral diarrhea virus in serum from cattle by dot blot hybridization assay. Vet. Microbiol., 24: 297–306.
Brown, T.M., Osorio, F.A. and Rock, D.L., 1990. Detection of latent pseudorabies virus in swine using in situ hybridization. Vet. Microbiol., 24: 273–280.
Bruce, C., Al-Nakib, W., Stanway, G. and Almond, J.W., 1989. Detection of enteroviruses using cDNA and synthetic oligonucleotide probes. J. Virol. Methods, 25: 233–240.
Chevrier, D., Megraud, F., Larzul, D. and Guesdon, J., 1988. A new method for identifying Campylobacter spp. J. Infect. Dis., 157: 1097–1098.
Collins, P.L., Huang, Y.T., and Wertz, G.W., 1984. Identification of a tenth mRNA of respiratory syncytial virus and assignment of polypeptides to the 10 viral genes. J. Virol., 49: 572–578.

Collisson, E.W., Li, J., Sneed, L.W., Kemp, M.C., Peters, M.L., and Wang, L., 1990. Detection of avian infectious bronchitis virus infection using in situ hybridization and recombinant DNA. Vet. Microbiol., 24: 261–271.

Dangler, C.A., Dunn, S.J., Squire, K.R.E., Stott, J.L. and Osburn, B.I., 1988. Rapid identification of bluetongue virus by nucleic acid hybridization in solution. J. Virol. Methods, 20: 353–365.

Dimitrov, D.H., Graham, D.Y. and Estes, M.K., 1985. Detection of rotaviruses by nucleic acid hybridization with cloned DNA of simian rotavirus SA11 genes. J. Infect. Dis., 152: 293–299.

Dunn, D.C., Blair, C.D., Ward, D.C. and Beaty, B.J., 1986. Detection of bovine herpes virus-specific nucleic acids by in situ hybridization with biotinylated DNA probes. Am. J. Vet. Res., 47: 740–746.

Edberg, S., 1985. Principles of nucleic acid hybridization and comparison with monoclonal antibody technology for the diagnosis of infectious diseases. The Yale J. Biol. Med., 58: 425–442.

Eisenach, K.D., Crawford, J.T. and Bates, J.H., 1988. Repetitive DNA sequences as probes for Mycobacterium tuberculosis. J. Clin. Microbiol., 26: 2240–2245.

Eriks, I., Palmer, G.H., McGuire, T.C., Allred, D.R. and Barbet, A.F., 1989. Detection and quantitation of Anaplasma marginale in carrier cattle by using a nucleic acid probe. J. Clin. Microbiol., 27: 279–284.

Gama, R.E., Hughes, P.J., Bruce, C.B. and Stanway, G., 1988. Polymerase chain reaction amplification of rhinovirus nucleic acids from clinical materials. Nucleic Acids Res., 16: 9346.

Geary, S.J., Intres, R.J. and Gabridge, M.G., 1988. Species-specific biotinylated DNA probe for the detection of Anaplasma marginale in carrier cattle by using a nucleic acid probe. J. Clin. Microbiol., 27: 279–284.

Gebhart, C.J., Murtaugh, M.P., Lin, G.-F. and Ward, G.E., 1990. Species-specific DNA probes for Campylobacter species isolated from pigs with proliferative enteritis. Vet. Microbiol., 24: 367–379.

Gillespie, D., 1990. The magic and challenge of DNA probes as diagnostic reagents. Vet. Microbiol., 24: 217–233.

Gingeras, T.R., Richman, D.D., Kwoh, D.Y. and Guatelli, J.C., 1990. Methodologies for in vitro nucleic acid amplification and their applications. Vet. Microbiol., 24: 235–251.

Goff, W.L., Stillier, D., Roeder, R.A., Johnson, I.W., Falk, D., Gorham, J.R. and McGuire, T.C., 1990. Comparison of a DNA probe, complement-fixation and indirect immunofluorescence tests for diagnosing Anaplasma marginale in suspected carrier cattle. Vet. Microbiol., 24: 381–390.

Gregoire, D., Couez, D., Deschamps, J., Heuerstz, S., Hors-Cayla, M.C., Szpirer, J., Sepirer, C., Burny, A., Huez, G. and Kettman, R., 1984. Different bovine leukemia virus-induced tumors harbor the provirus in different chromosomes. J. Virol., 50: 275–279.

Gutierrez, D.E., 1979. Latent pseudorabies virus infection in swine detected by RNA-DNA hybridization. Am. J. Vet. Res., 40: 1568–1572.

Harding, M.J. and Molitor, T.W., 1988. Porcine parvovirus: replication in and inhibition of selected cellular functions of swine alveolar macrophages and peripheral blood lymphocytes. Arch. Virol., 101: 105–117.

Hill, W.E., 1989. Detection of bacteria in foods using DNA hybridization. In: F.C. Tenover (Editor), DNA Probes in Infectious Diseases. CRC Press, pp. 43–52.

Howley, P.M., Israel, M.A., Law, M. and Martin, M.A., 1979. A rapid method for detecting and mapping homology between heterologous DNAs. J. Biol. Chem., 254: 4876–4883.

Hu, S.L., Battles, J.K. and Potts, D.E., 1984. Restriction analysis and homology studies of the bovine adenovirus 7 genome. J. Virol., 51: 880–883.
Jackwood, D.J., 1990. Development and characterization of nucleic acid probes to infectious bursal disease viruses. Vet. Microbiol., 24: 253–260.

Joens, L.A. and Marquez, R., 1988. The diagnosis of swine dysentery using a labeled nucleic acid probe. Proc. 10th Congress International Pig Veterinary Society, Rio de Janeiro, Brazil, 120 pp.

Johnson, M.E., Paul, P.S., Gorziglia, M. and Rosenbusch, R., 1990. Development of specific nucleic acid probes for the differentiation of porcine rotavirus serotypes. Vet. Microbiol., 24: 307–326.

Jouvenne, P., Dion, M. and Hamelin, C., 1987. Cloning, physical mapping and cross hybridization of the canine adenovirus types 1 and 2 genomes. Gene, 60: 21–28.

Karch, H. and Meyer, T., 1989. Evaluation of oligonucleotide probes for identification of shiga-like-toxin-producing Escherichia coli. J. Clin. Microbiol., 27: 1180–1186.

Kulski, J.K. and Norval, M., 1985. Nucleic acid probes in diagnosis of viral diseases of man. Arch. Virol., 83: 3–15.

Keath, E.J., Spitzer, E.D., Painter, A.A., Travis, S.J., Kobayashi, G.S. and Medoff; G., 1989. DNA probe for the identification of Histoplasma capsulatum. J. Clin. Microbiol., 27: 2369–2372.

Maddox, C.W. and Wilson, R.A., 1986. High technology diagnostics: detection of enterotoxigenic Escherichia coli, using DNA probes. J. Vet. Med. Assoc., 188: 57–59.

Maes, R.K., Beisel, C.E., Spatz, S.J. and Thacker, B.J., 1990. Polymerase chain reaction amplification of pseudorabies virus DNA from acutely and latently infected cells. Vet. Microbiol., 24: 281–295.

Mayaux, J.-F., Soubrier, F. and Latta, M., 1987. Cloning E. coli genes by oligonucleotide hybridization. Nucleic Acids Res., 15: 10593–10595.

Midthun, K., Valdesuso, J., Hoshino, Y., Flores, J., Kapikian, A.Z. and Chanock, R.M., 1987. Analysis by RNA-RNA hybridization assay of intertypic rotaviruses suggests that gene reassortment occurs in vivo. J. Clin. Microbiol., 25: 295–300.

Minson, A.C. and Darby, G., 1982. Hybridization techniques. In: New Developments in Practical Virology. Alan R. Liss, New York, NY, pp. 185–229.

McFadden, J.J., Butcher, P.D., Chiodini, R. and Hermon-Taylor, R., 1987. Crohn's disease-isolated mycobacteria are identical to Mycobacterium paratuberculosis, as determined by DNA probes that distinguish between Mycobacterial species. J. Clin. Microbiol., 25: 796–801.

McFadden, J.J., Green, E. and Herman-Taylor, J., 1988. DNA probes to identify and detect Mycobacterium paratuberculosis in clinical and veterinary samples. Proc. 2nd International Colloquium on paratuberculosis, Ecole Nationale Veterinaire Alfort, Alfort Cedex, pp. 201–205.

McGarrity, G.J. and Kotani, H., 1986. Detection of cell culture mycoplasmas by a genetic probe. Exp. Cell Res., 163: 273–278.

Moseley, S.L., Echeverria, P., Serivatana, J., Tirapat, C., Chaicumpa, W., Sakuidalpeara, T. and Falkow, S., 1982. Identification of enterotoxigenic Escherichia coli by colony hybridization using three enterotoxin gene probes. J. Infect. Dis., 145: 863–869.

Norval, M. and Bingham, R.W., 1987. Advances in the use of nucleic acid probes in diagnosis of viral diseases of man. Arch. Virol., 97: 151–165.

Oraveerakul, K., Choi, C.S. and Molitor, T.W., 1989. Detection of porcine parvovirus using non-radioactive nucleic acid hybridization. Proceedings 70th Annual Meeting of the Conference of Research Workers in Animal Diseases, Chicago, Illinois, pp. 69.

Oste, C., 1988. Polymerase chain reaction. Biotechniques, 6: 162–167.

Paul, P.S., 1988. Applications of recombinant DNA technology in the development of vaccines, reagents and DNA probes. Proc. 10th Congress International Pig Veterinary Society, Rio de Janeiro, Brazil, pp. 7–9.

Paul, P.S., Lyoo, Y.S., Woode, G.N., Zheng, S., Greenberg, H.B., Matsui, S., Schwartz, K.J. and
Hill, H.T., 1988. Isolation of a bovine rotavirus with a "super-short" RNA electrophoretic pattern from a calf with diarrhea. J. Clin. Microbiol., 26: 2139–2143.
Pereira, H.G., 1986. Non-radioactive nucleic acid probes for the diagnosis of virus infections. BioEssays, 4: 110–113.
Rasty, S., Dhruva, B.R., Louis Schiltz, R., Shih, D.S., Issel, C.J. and Montelaro, R.C., 1990. Proviral integration and transcriptional patterns of equine infectious anemia virus during persistent and cytopathic infections. J. Virol., 64: 86–95.
Razin, S., Hyman, H.C., Nur, I. and Yoge', D., 1987. DNA probes for detection and identification of mycoplasmas (molluscites). Isr. J. Med. Sci., 23: 735–741.
Ridpath, J., Paul, P.S. and Mengeling, W.L., 1987. Comparison of porcine parvovirus to other parvoviruses by restriction site mapping and hybridization analysis of southern blots. J. Gen. Virol., 68: 895–900.
Rigas, B., Welcher, A.A., Ward, D.C. and Weissman, S.M., 1986. Rapid plasmid library screening using recA-coated biotinylated probes. Proc. Natl. Acad. Sci. U.S.A., 83: 9591–9595.
Rock, D.L., Beam, S.L. and Mayfield, J.E., 1987. Mapping bovine herpesvirus type 1 latency-related RNA in trigeminal ganglia of latently infected rabbits. J. Virol., 61: 3827–3831.
Rosen, B.I., Saif, L.J., Jackwood, D.J. and Gorziglia, M., 1990. Hybridization probes for the detection and differentiation of two serotypes of porcine rotavirus. Vet. Microbiol., 24: 327–339.
Rossi, M.S., Sadir, A.M. and Palma, E., 1988. Detection of foot-and-mouth disease virus with DNA probes in bovine esophageal-pharyngeal fluids. Arch. Virol., 99: 67–74.
Shockley, L.J., Kapke, P.A., Lapps, W. and Brian, D.A., 1987. Diagnosis of porcine and bovine enteric coronavirus infections using cloned cDNA probes. J. Clin. Microbiol., 25: 1591–1596.
Tabares, E., 1987. Detection of DNA viruses by radioactive and non-radioactive DNA probes: application to African swine fever virus. Arch. Virol., 92: 233–242.
Tenover, F.C., 1988. Diagnostic deoxyribonucleic acid probes for infectious diseases. Clin. Microbiol. Rev., 1: 82–101.
Tenover, F.C., 1989. DNA Probes for Infectious Diseases. CRC Press, Inc., Boca Raton, FL, 286 pp.
Wesley, I.V., Wesley, R.D., Heisick, J., Harrell, F. and Wagner, D., 1990. Characterization of Listeria monocytogenes isolates by restriction enzyme analysis and southern blot hybridization. Vet. Microbiol., 24: 341–353.
Zuener, R.L. and Bolin, C.A., 1990. Nucleic acid probe characterizes Leptospira interrogans serovars by restriction fragment length polymorphisms. Vet. Microbiol., 24: 355–366.