ARTICLE DE SYNTHESE

Update on PPR Epidemiology, Diagnosis and its Control

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Abstract

Peste des petits ruminants (PPR) is an acute, contagious and frequently fatal disease of goats and sheep characterized by fever, ocular and nasal discharges, oral secretions, diarrhoea and pneumonia. PPR is caused by a Morbillivirus of the Paramyxoviridae family, PPR virus (PPRV). Isolated in Ivory-Coast in 1942, the disease was located in West Africa up to 1980's. PPR spreaded to East Africa, Near and Middle-East, Western and South Asia on the period 1980 – 1990 and recently to most of the countries in North and South Africa. There are four different lineages based on the sequencing of the Np gene. The transmission is mainly due to a direct contact by aerosols. Being a viral disease the collection of samples requires a timely intervention and respecting the chain cold from the field to the laboratory for confirmatory diagnosis. After clinical and laboratory diagnosis the control of the disease could be implemented by restricting animal movements and carrying out the vaccination with the homologous conventional vaccine available commercially. This vaccine is effective and protects vaccinated animals for their lifetime. The control should be based on a thorough and planned programme taking into consideration the rapid turn-over of this production system owning by the vulnerable rural populations being small scale farmers living at remote areas where animal health services are weak (***RASPA,* 11** (S) : 59-65).

Key – Words: PPR - Morbillivirus - Paramyxoviridae - Africa - Near and Middle-East, West and South Asia - Vaccine - Animal disease control - TADs - Epidemiology.

Résumé

Point sur l'épidémiologie, le diagnostic et le contrôle de la PPR

La peste des petits ruminants (PPR) est une maladie d'évolution aiguë, contagieuse et fréquemment à issue fatale des ovins et caprins. Elle est caractérisée par une forte fièvre, un écoulement oculaire et nasal, des érosions buccales, de la diarrhée et accompagnée d'une pneumonie. La PPR est due à un virus de la famille des *Paramyxoviridae*, du genre *Morbillivirus* qui a été isolé pour la première fois en Côte-d'Ivoire en 1942. La PPR était localisée en Afrique de l'Ouest jusque dans les années 1980 puis elle a diffusé en Afrique de l'Est, au Proche et Moyen-Orient et en Asie, sur la période allant de 1980 à 1990. Récemment, elle s'est étendue à la plupart des pays de l'Afrique du Nord et de l'Afrique australe. Il existe quatre lignées différentes basées sur le séquençage du gène de la nucléoprotéine, Np. La transmission de la maladie se fait principalement par un contact direct par les aérosols émis par les animaux malades ou en incubation. Etant une maladie d'origine virale, la collecte d'échantillons doit se faire au moment adéquat et nécessite le respect strict de la chaîne du froid du terrain au laboratoire pour la confirmation du diagnostic clinique. Le contrôle de la maladie peut se mettre en place en imposant une restriction des mouvements d'animaux et la vaccination à l'aide du vaccin conventionnel homologue PPR 75/1 disponible sur le marché. Ce vaccin est efficace et protège l'animal durant toute sa vie après l'administration d'une dose unique. Le contrôle de la PPR doit être basé sur un programme bien planifié en prenant en compte le taux rapide de renouvellement du troupeau (turn-over) dans ce système de production tenu par la population rurale vulnérable vivant souvent dans des régions éloignées où l'intervention des services de santé animale est reconnue faible.

Mots-clés : PPR, Morbillivirus, Paramyxoviridae, Afrique, Proche et Moyen-Orient, Ouest et Sud Asie, Vaccin. Contrôle des maladies animales, Maladies animales transfrontalières (TADs), Epidémiologie.

Introduction

Peste des petits ruminants (PPR) is a highly contagious, very often fatal, viral disease of small ruminants which is found mainly in West Africa but over the past two decades it has spread rapidly over East Africa, the Middle-East, West and South Asia. Recently the disease attacked North and most of countries in southern Africa along with the European part of Turkey. PPR has caused major epidemics in sheep and goats. Such epidemics profoundly affect the rural economies of many developing countries and the poor, who depend more on small ruminants for their livelihoods, suffer disproportionately. PPR is one of the major notifiable disease of the World Organisation for Animal Health (OIE).

1. Aetiology

PPR is a viral disease and the causative agent, Peste-des-petits-ruminants virus (PPRV) is classified in the order Mononegavirales, family Paramyxoviridae, subfamily Paramyxovirinae, genus Morbillivirus [32] that includes measles virus (MeV), rinderpest virus (RPV), canine distemper virus (CDV) and other viruses infecting aquatic mammals: Phocine distemper virus (PDV), Dolphin Morbillivirus (DMV), Porpoise Morbillivirus (PMV) [18], [27], [39], [47], [51], [52], [77]. PPRV is an enveloped RNA virus with a non segmented, negative-strand genome encoding six structural proteins: Nucleoprotein (NP), Phosphoprotein (P), Matrix protein (M), Fusion protein (F), Haemagglutine protein (H), Polymerase protein (L) and two non-structural proteins : C and V. The Morbilliviruses are structurally pleomorphic with external glyproteins (H and F proteins) from the envelope which is originated from the infected cell membrane. RNA genome is linked to viral proteins to form the ribonucleoprotein (RPN) complex giving a helical structure [9], [10], [22], [53].

2. Susceptible Hosts range

PPR remains mainly the disease of sheep and goat with the latest more sensitive. However, it has been reported cases in India where sheep were more concerned than goats [34], [66]. Cattle and pig are susceptible to infection but do not contribute to the epidemiology as they are not capable to excrete virus while they produce specific antibodies against PPRV (COUACY-HYMANN, personal communication ; [10]). A case of PPR involving camels in Ethiopia was reported with the positive detection of PPRV antigens and nucleic acid but no virus isolation was obtained [55], [56]. In Sudan, on the period August- October 2004, an outbreak occurred in a camel flock causing death with an average mortality rate of 7.4%. It was confirmed as PPR with the isolation of the virus [40], [61]. PPR in wild ungulates from various species have been reported with death [2], [10], [41]. Infection with PPRV followed by the detection of specific antibodies and nucleic acids without any clinical signs has been also reported in Ivory-Coast [15].

3. Clinical Symptoms of PPR

Clinical manifestation for PPR can be seen in per-acute, acute and sub-acute forms. However, PPR in sheep and goats is generally observed as an acute disease. The per-acute form of disease is often seen in kids infected at the age of 3 to 4 months and older during the time frame where there is any pre-existing maternal antibody levels wane. This per-acute form of disease has a short incubation period (2 days) with a rapid development of pyrexia with body temperature rising to 40-42^{o}C. Profound depression, congestion of mucous membranes, oculo-nasal discharge, dysponia and profuse watery diarrhea lead to the death of infected animals within 4-5 days [23], [49].

In the acute form of disease a 2-7 days incubation period precedes development of pyrexia (4-9 days) and the onset of other clinical disease signs including watery oculo-nasal discharge, congestion of the mucous membranes of the buccal cavity, conjunctiva of the eye and the vulva [1], [16]. As the disease progress, the watery oculo-nasal discharge become catarrhal and occludes around the nostrils that predisposes to dysponea. Pneumia is observed which could be followed by a secondary bacterial colonisation and that becomes a bronchopneumia mainly due to *Pasteurella haemolytica* / *P. multocida* type A or D. A diarrheic phase follows, leading to dehydration and ultimately death of the animal.

In the sub-acute form of disease, the animals do not develop severe clinical disease and low mortality rates are seen. With this form of infection the animals may develop temperatures ranging from 39-40oC but do not develop the characteristic clinical signs normally associated with PPRV infection and animals usually recover from disease within 10-14 days. This form is usually observed with the Nigeria 75/1 wild type strain´ [16].

However, the severity of disease may be influenced by a number of factors such as: the virulence of the PPRV strain, the route of infection; the species and breed of infected animal; the immunological and nutritional status of the infected animal and probably the climatic conditions.

4. Diagnosis of PPR

4.1. Clinical diagnosis

In the past, it was possible to make a confusion with RPV in small ruminants since the symptoms are similar with what is given by PPRV in the same species. Nowadays, with the eradication of Rinderpest, PPR is quite easier to clinical diagnose in the field based on the symptoms described above: pyrexia, lachrymation, nasal discharges, oral erosion, pneumonia, diarrhea and death and historic epidemiological information of PPR in the region or farms, can help field personnel to report a suspicious PPR case. A differential clinical diagnosis should be made with other syndromic diseases. However, it is recommended to sample sick animals for a confirmatory diagnosis.

4.2. Sample Collection

Good quality samples should be taken from sick animals at the onset of hyperthermia (viremia phase) after it has been slaughtered or on fresh dead animal. Samples consist of : lachrymal, nasal and oral swabs, blood for serum and whole blood on EDTA, on live animal and with tissue collected on autopsy : lung, lymph nodes (bronchial, mesenteric), tonsils, spleen along with intestine. These samples should be on ice or better in liquid nitrogen (from the field) and rapidly sent to the laboratory on the same day if possible.

4.3. Laboratory diagnosis of PPR

Various techniques exist nowadays to confirm the diagnosis of PPR which can grouping into two main categories : i)- conventional techniques and ii)- molecular techniques.

4.3.1. Conventional techniques

- Virus isolation :

this is the ideal way to confirm the disease [28]. However, the technique needs a cell culture facilities which are not common in many laboratories in the developing countries. Where this is possible, primary cell culture from lamb or kid kidney [74], lung, were used for the virus isolation along with different cell lines such as : Vero cells [35], MDBK (Madin-Darby Bovine Kidney), marmoset-derived cell line (B95a) [70]. Recently, it has been developed a new and very sensitive cell line using the monkey cell expressing sheep-goat SLAM (Signaling Lymphocyte Activation Molecule) receptor [4], [73]. Usually, cultures are examined for the cytopathic effect in the days following infection of a monolayer with suspect material. The identity of the virus can be confirmed by virus neutralisation or molecular techniques [10], [67].

In general, virus isolation is time consuming and needs well trained laboratory personnel to perform it. Alternatively specific antigens and antibodies can be detected.

- Antigen detection :

Counter-Immuno-Electrophoresis (CIEP) and AGID test [65] using hyperimmune PPR serum. The latest is simple and can be performed in a basic laboratory but remains relatively insensitive. Moreover it cannot distinguish PPRV from RPV. CIEP is able to differentiate PPRV from RPV.
Direct immunofluorescence : sensitive and specific technique but an adequate equipment is needed [52], [71]. Immuno-histochemestry (IHC) on tissue samples [54]. It allows the localisation of specific PPRV antigens in a pathological tissue sample.

- Antibodies detection :

Viral neutralization test (VNT) [28], [58]: applied to a serum sample, this technique needs also a cell culture facilities.

4.3.2. Molecular techniques

- Antigens detection:

Immunocapture ELISA (ICE): sensitive and specific method to detect the presence of PPRV antigens. It is easy to run it and is well established in many laboratories in developing countries [26], [45], [62], [67].

- Antibodies detection:

Detection of antibodies against PPRV is carried out by using ELISA techniques. Currently the use of competitive PPRV-specific anti-H (H-cELISA) [6] or anti-N (N-cELISA) [46] monoclonal based ELISA is routinely effective in laboratories where the disease exists. Both competitive ELISA tests can be used equally for the detection of PPRV antibodies [17].
There is also an indirect ELISA developed by ISMAIL *et al.*[38] which is not currently used in Africa.

- Genome detection

The conventional RT-PCR has been developed for the specific amplification of the NP gene [13], [14] or for the amplification of the fusion gene [30] and is established in various laboratories. The Real-Time RT-PCR assay specific for PPRV [8], [42] and the loop-mediated isothermal amplification technique (LAMP-RT-PCR) [79] are also available for the genome detection of PPRV. Extensive validation of these latest diagnostic techniques is required before they can be accepted as approved OIE methods [10].

5. Epidemiology of PPRV

5.1. Spatial distribution

PPRV was first described in Ivory-Coast in 1942 [31] and the first virus isolation was obtained from Senegal [33]. Similar syndromic disease involving small ruminants was reported in some West African countries [48],[80] which was later on confirmed as PPR using either a comparative study between RPV and PPRV [59], [60] or a molecular technique [11], [19], [20]. Historically, PPR was found mainly in West Africa but it has spread during the last twenty years to East Africa, the Near and Middle-East [2], [3], [44], [74], [76] and West and South Asia [50], [66], [67] with the recent cases in China, in Tibet region, in July 2007 [78]. In the recent years, the disease has been reported in many of central, eastern and southern African countries: Gabon, Democratic Republic of Congo, Somalia, Kenya, Tanzania (SWAI *et al.* [72] quoted by ALBINA *et al.* [5]) and Angola in October 2012 threatening neighbouring countries such as Zambia, Mozambique. In the north of Africa, Morocco reported its first case in 2008 [29] then after in Tunisia [7] and Algeria [25]. PPR in Egypt is well known since 1989 [36]. Since the incursion of PPR in Turkey in 1996 and its extension throughout the country, the disease represents nowadays a real threat to Europe [10], [82].

5.2. Phylogenetic Analysis

There are four lineages of PPRV based on the differentiation determined by the sequence comparison of a small region of the F gene [30] or the N gene [13], [14]. However, it has been demonstrated recently that the N gene is more divergent therefore more suitable for phylogenetic distinction between closely related PPRV viruses (KWIATEK *et al.*[43] , cited by BANYARD *et al.*[10]. So the PPRV phylogenetic analysis in this document is referred to the results from the N gene. Historically, African PPRV isolates were lineages I, II, III (with mainly West African countries harbouring lineages I and II and East African countries with lineage III) and the Middle-East and Asian isolates were lineage IV. Within a short time this distribution has deeply changed : in West Africa : lineage II is spreading with the trend to push out lineage I confined to Ivory-Coast, Conakry Guinea and Burkina-Faso with a co-circulation of lineage I. Moreover in 2009, lineage II was identified in Ivory-Coast [4] where probably the two lineages are co-circulating. Lineage IV has been found in Africa with an extension from East Africa (mainly Sudan, lineages III and IV) up to Nigeria where lineage II is still circulating [5, [10] and to Southern part : Democratic Republic of Congo (DRC) and Angola (DIALLO, personal communication).

Northern African countries have Lineage IV too [5]. In addition, PPR serology positive was reported from Rwanda and Burundi.

Interestingly, lineage III has crossed the red sea and has been found in the Arabian Peninsula countries: Yemen, Oman and Qatar (having both lineages III and IV) [5], [10].

In conclusion, PPRV is still spreading from countries to countries with a very dynamic change in the phylogenetic distribution. If in certain circumstances, this phylogenetic distribution of PPRV strains can contribute to the traceability of the occurrence of the disease, i.e in the Arabian Peninsula countries which is likely linked to the exportation of live small ruminants from the horn of Africa countries or lineage II in Ivory-Coast which is the consequence of lineage II in Burkina-Faso, Mali and Niger because of the importation of live animals from these sahalian countries. However, this is not the case regarding the incursion of PPRV in Morocco in 2008 with lineage IV.

6. Prevention and Control of PPR

Historically, small ruminants were protected against PPR by using the heterologous RPV vaccine due to the cross-reactivity between RPV and PPRV [12], [13], [79]. This vaccine was abandoned in the course of the Rinderpest eradication programme to avoid any confusion that its use could create. In 1980's a homologous PPR attenuated vaccine, Nigeria 75/1 was developed [21]. It is very efficient and commercially available. This vaccine provides a life-long immunity after administration of a single dose by subcutaneous route [13]. However it has a low thermal stability: half-life of 2-6h at 37°C after reconstitution (DIALLO [24], cited by ALBINA *et al.*[5]. Therefore the use of this vaccine in Africa conditions needs a well and sustained cold chain during the vaccination process. In Asia, three live-attenuated vaccines with India PPRV isolates, lineage IV have been developed in India for use: Sungri96, Arasur 87 and Coimbatore 97 [63]. Recently, the thermostability of the vaccine Nigeria 75/1 has been improved by incorporating a cryo-protector with trehalose allowing the vaccine to stay at 5-14 days at 45°C in the lyophilized form and 21h at 37°C after reconstitution [5], [64]. So this vaccine can be distributed to a remote area where there is no or less cold chain facilities.

To control the disease after quick investigation and confirmation, vaccination is strongly recommended which will be applied to contact herds in the control area including the surveillance zone. In the infected zone housing the infected herds, control measures such as separation of sick animals from other should be in place and these animals be vaccinated even though one week

is required for an effective protective immune response [BODJO, personal communication, [13]). This emergency vaccination should be immediate and well planned to be efficient since the disease is still spreading and shall be stopped. Usually, in an endemic area of PPR, nomadic farmers establish a ban on the live animal market, water point or pasture. Elsewhere owners try to keep their animals in appropriate and separated pens. The disposal of carcasses is weak and no real disinfection is applied. Fortunately the virus is fragile in the external conditions and rapidly destroyed during the putrefaction phase. Very often, there is no follow up after these waves of PPR. It is like living with the disease forever!

In a non endemic region of PPR, the control of the disease is more effective to stop its diffusion by applying efficient control measures such as : slaughter of the infected herd along with a correct disinfection and an adequate disposal of carcasses, movements control, emergency vaccination, quarantine, etc.

The prevention and control of PPR are feasible since an efficient vaccine is available even with the conventional thermo labile vaccine. Moreover, applicable control measures able to stop the diffusion of the disease are known but not effectively implemented into the field mainly at the remote area where the Veterinary services are also weak.

Conclusion

PPR remains a dread disease for small ruminants causing huge economic losses which impact negatively the livelihoods of the rural populations. With the current knowledge on the epidemiology of the disease and the various diagnostic tools available along with the presence of an efficient homologous vaccine, PPR can be effectively prevented and controlled. For this purpose, Veterinary Authorities should take appropriate actions to build capacities up for better interventions with an established and operational disease surveillance system throughout countries. The disease surveillance system shall be sustained by the national funds for its long-life.

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Bibliography

1- ABUBAKAR M. ; ALI O. ; KHAN H.A ; 2008.- Prevalence and mortality rate of peste des petits ruminants (PPR): possible association with abortion in goat. *Trop. Anim. Health Prod.* 40, 317 – 321.

2- ABU ELZEIN E.M.E. ; HASSANIEN M.M. ; ALFALEG A.I.A ; ABD ELHADI M.A. ; HOUSAWI F.M.T. ;1990.- Isolation of PPR virus from goats in Saudi Arabia. *Vet. Rec.*, 127: 309-310.

3- ABU ELZEIN E.M.E. ; HOUSAWI F.M.T. ; BASHAREEK Y. ; GAMEEL, A.A. ; AL- AFALEQ A.I. ; ANDERSON E.C. ; 2004.- Severe PPR infection in Gazelles kept under semi-free range conditions in Saudi Arabia. *J. Vet. Med. B Infect. Dis. Vet. Public. Health.*, 51: 68-71.

4- ADOMBI C.M. ; LELENTA M. ; LAMIEN C.E. ; SHAMAKI D. ; KOFFI Y.M. ; TRAORE A. ; SILBER R. ; COUACY-HYMANN E. ; BODJO S.C. ; DJAMAN J.A. ; LUCKINS A.G. ; DIALLO A. ; 2011.- Monkey CV1 cell line expressing the sheep-goat SLAM protein: a highly sensitive cell line for the isolation of peste des petits ruminants virus from pathological specimens. *J. Virol. Methods*, 173, 306 – 313.

5- ALBINA E. ; KWIATEK O. ; MINET C. ; LANCELOT R. ; DE ALMEIDA R.S. ; LIBEAU G. ; 2013.- Peste des petits ruminants. The next eradicated animal disease ? *Vet. Microbiol.* http://dx.doi, org/10.1016/j.vetmic.2012.12.013.

6- ANDERSON J. ; MC KAY J.A. ; 1994.- The detection of antibodies against peste des petits ruminants in cattle, sheep and goats and possible implications to rinderpest control programmes. *Epidemiol. and infect.*, 112: 225-234.

7- AYARI-FAKHFAKH E. ; GHRAM A. ; BOUATTOUR A. ; LABRI I. ; GRIBAA-DRIDI L. ; KWIATEK O. ; BOLOY M. ; LIBEAU G. ; ALBINA E. ; CETRE-SOSSAH C. ; 2010.- First serological investigation of peste des petits ruminants and rift Valley fever in Tunisia. *Veteterinary Journal*, DOI:10.1016/j.tvjl.2010.01.007.

8- BAO J. ; LI L. ; WANG Z. ; BARRETT T. ; SUO L. ; ZHAO W. ; LIU Y. ; LI J. ; 2008.- Development of one-step real-time RT-PCRassay for detection and quantitation of peste des petits ruminants virus. *J. Virol. Methods,* 148, 232 – 236.

9- BARRETT T. ; ROMOE C.H. ; BARON M.D. ; YAMANOUCHI K. ; DIALLO A. ; BOSTOCK C.J. ; BLACK D ; 1993.- The molecular biology of rinderpest and peste-des petits-ruminants. *Am Med Vet* 137, 77-85.

10- BANYARD A.C. ; PARIDA S. ; BATTEN C. ; OURA C. ; KWIATEK O. ; LIBEAU G. ; 2010. – Global distribution of peste des ruminants virus and prospects for improved diagnosis and control. *J. Gen. Virol.* 91, 2885 – 2897.

11- BODJO S.C. ; 2007.- Etude de la nucléoprotéine des virus de la peste bovine et de la peste des petits ruminants : Caractérisation moléculaire des interactions protéiques et des structures antigéniques. Thèse de Doctorat de l'Université Montpellier II. France.

12- BOURDIN P. ; RIOCHE M. ; LAURENT A. ; 1970.- Emploi d'un vaccin antibovipestique produit sur cultures cellulaires dans la prophylaxie de la peste des petits ruminants au Dahomey. *Rev. Elev. Méd. vét. Pays trop.*, 23, 295-300.

13- COUACY-HYMANN E. ; 1994.- La lutte contre la peste bovine en Côte d'Ivoire: Coûts et Bénéfices des campagnes de prophylaxie, Problèmes posés pour son éradication. Thèse Doctorat de l'Université de Paris XII. France.

14- COUACY-HYMANN E. ; ROGER F. ; HURARD C. ; GUILLOU J.P. ; LIBEAU G. ; A DIALLO ; 2002.- Rapid and sensitive detection of peste des petits ruminants virus by a polymerase chain reaction assay. *J. Virol Methods.*, 100, 17-25.

15- COUACY-HYMANN E. ; BODJO S.C. ; DANHO T. ; LIBEAU G. ; DIALLO A. ; 2005.- Surveillance of wildlife as a tool for monitoring rinderpest and peste des petits ruminants in West Africa. *Rev. sci. tech. Off. int. Epiz.*, 24, 869-877.

16- COUACY-HYMANN E. ; BODJO C. ; DANHO T. ; LIBEAU, G. ; DIALLO A. ; 2007a.- Evaluation of the virulence of some strains of peste-des-petits-ruminants virus (PPRV) in experimentally infected West African dwarf goats. *Vet. Journal.*, 173, 178-183.

17- COUACY-HYMANN E. ; BODJO S.C. ; TOUNKARA K.; KOFFI, M.Y. ; OHUI A.Y. ; DANHO T. ; BRONSVOORT B.M.D. ; 2007b.- Comparison of two competitive ELISAs for the detection of specific Peste-Des-Petits-Rminants antibodies in sheep and cattle populations. *Afr. J. Biotechnol.*, 6, 732-736.

18- COSBY S.L ; MCQUAID S. ; DUFFY N. ; LYONS C. ; RIMA B.K. ; ALLAN G.M. ; MCCULLOUGN S.J. ; KENNEDY S. ; SMYTH J.A. ; MCNEILLY F. ; ORWELL C. *et al.* ; 1988.- Characterization of a seal morbillivirus. *Nature*, 336, 115-116.

19- DIALLO A. ; BARRETT T. ; LEFÈVRE P.C. ; TAYLOR W.P. ; 1987.- Comparison of proteins induced in cells with Rinderpest virus and Peste des Petits Ruminants virus. *J. Gen. Virol.*, 68, 2033-2038.

20- DIALLO A. ; BARRETT T. ; BARBRON M. ; SUBBARAO S.M. ; TAYLOR W.P. ; 1989a.- Differentiation of rinderpest and peste des petits ruminants viruses using specific cDNA clones. *J. Virol. Methods.*, 23, 127-136.

21- DIALLO A. ; TAYLOR W.P. ; LEFÈVRE P.C. ; PROVOST A. ; 1989b.- Atténuation d'une souche du virus de la PPR. Candidat pour un vaccin homologue vivant. *Rev. Elev. Méd. vét. Pays trop.*, 42, 311-319.

22- DIALLO A. ; 1990.- Morbillivirus group: genome organization and proteins. *Vet. Microbiol.*, 23, 155-163.
23- DIALLO A. ; 2003.- Peste des petits ruminants. In Principales maladies infectieuses et parasitaires du bétail, Europe et régions chaudes, Volume 1. Lefèvre P.C., Blancou J. et R. Chermette (eds). Editions TEC & DOC, Paris: 307-322.
24- DIALLO A. ; 2004.- Peste des petits ruminants. In : Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, OIE Terrestrial Manual, fifht ed. ISBN 92-9044-622-6.
25- DE NARDI M. ; LAMIN SALEH S.M. ; BATTEN C. ; OURA C. ; DI NARDO A. ; ROSSI D. ; 2012.- First evidence of peste des petits ruminants (PPR) virus circulation in Algeria (Sahrawi territories) : outbreak investigation and virus lineage identification. *Transbound. Emerg. Dis.* 59, 214 – 222.
26- DIOP M. ; SARR J. ; LIBEAU G. ; 2005.- Evaluation of novel diagnostic tools for peste des petits ruminants virus in naturally infected goat herds. *Epidemiol. Infect.*, 133: 4, 711-717.
27- DOMINGO M. ; FERRER L. ; PUMAROLA M. ; MARCO A. ; PLANA J. ; KENNEDY S. ; MC ALISKEY M. ; RIMA B.K. ; 1990.- Morbillivirus in dolphins. *Nature*, 348: 21.
28- FAO ; 1996.- FAO Animal Health Manual – Manual on the diagnosis of rinderpest, 2nd ed.
29- FAO-EMPRESS, August ; 2008.- Peste des petits ruminants (PPR) au Maroc.
30- FORSYTH M. ; BARRETT T. ; 1995.- Evaluation of the polymerase chain reaction for the detection and characterisation of rinderpest and peste des petits ruminants viruses for epidemiological studies. *Virus Res.*, 39, 151-163.
31- GARGADENNEC L. ; LALANNE A. ; 1942.- La peste des petite ruminants. *Bull. Serv. Zoot. Epizoot. AOF*, 5, 16-21.
32- GIBBS E.PJ. ; TAYLOR W.P. ; LAWMAN M.J.P. ; BRYANT J. ; 1979.- Classification of peste des petits ruminants virus as the fourth member of the Genus *Morbillivirus*. *Intervirology*, 11, 268-274.
33- GILBERT Y. ; MONNIER J. ; 1962.- Adaptation du virus de la peste des petits ruminants aux cultures cellulaires. *Rev. Elev. Med. Vét. Pays trop.*, 15, 321-335.
34- GOVINDARAJAN R. ; KOTEESWARAN A. ; VENUGOPALAN A.T. ; SHYAM G. ; SHOUNA S. ; SHAILA M.S. ; S. RAMACHANDRAN. ; 1997.- Isolation of peste des petits ruminants from an outbreak in Indian buffalo (*Bubalus bubalis*) *Vet. Rec.*, 141, 573-574.
35- HAMDY F.M. ; DARDIRI A.H. ; 1976.- Response of white tailed deer to infection with peste des petits ruminants virus. *J. Wildlife Dis.*, 12, 516-522.
36- ISMAIL T.M. ; HOUSE J. ; 1990.- Evidence of identification of peste des petits ruminants from goats in Egypt. *Arch. Exp. Veterinarned*, 44, 471 – 474.
37- ISMAIL T.M. ; HASSAS H.B. ; NAWAL M.A. ; RAKHA G.M. ; ABD EL-HALIM M.M. ; FATEBIA M.M. ; 1992.- Studies on prevalence of rinderpest and peste des petits ruminants antibodies in camel sera in Egypt. *Vet. Med. J. Giza*, 10, 49-53.
38- ISMAIL T.M. ; YAMANAKA M.K. ; SALIKI J.T. ; EL-KHOLY A. ; MEBUS C. ; YILMA T. ; 1995.- Cloning and expression of the nucleoprotein of peste des petits ruminants virus in baculovirus for use in serological diagnosis. *Virology*, 208, 776 – 778.
39- KENNEDY S. ; SMYTH J.A. ; CUSH. P.F. ; MCCULLOUGN S.J. ; ALLAM G.A. ; S. MCQUAID. ; 1988.- Viral distemper now found in porpoises. *Nature*, 336: 21.
40- KHALAFALLA A.I. ; SAEED I.K. ; ALI Y.H. ; ABDURRAHMAN M.B. ; KWIATEK O. ; LIBEAU G. ; OBEIDA A.A. ; ABBAS Z. ; 2010.- An outbreak of peste des petits ruminants (PPR) in camels in the Sudan. *Acta Tropica.* Doi: 10.1016/j.actatropica.2010.08.002.
41- KINNE I. ; KREUTZER R. ; KREUTZER M. ; WERNERY U. ; WOHLSEIN P. ; 2010.- Peste des petits ruminants in Arabian wildlife. *Epidemiol. I nfect.* 138, 1211 – 1214.
42- KWIATEK O. ; MINET C. ; GRILLET C. ; HURARDY C. ; CARLSSONZ E. ; KARIMOVZ B. ; ALBINA E. ; DIALLO A. ; LIBEAU G. ; 2007.- Peste des Petits Ruminants (PPR) Outbreak inTajikistan. *J. Comp. Path.*, 136, 111-119.
43- KWIATEK O. ; KEITA D. ; GIL P. ; FERNANDEZ-PINERO J. ; JIMENEZ CLAVERO M.A. ; ALIBINA E. ; LIBEAU G. ; 2010.- Quantitative one-stepreal-time RT-PCR for the fast detection of the four genotypes of PPRV. *J. Virol. Methods*, 165, 168 – 177.
44- LEFÈVRE P.C. ; DIALLO A. ; 1990.- La peste des petits ruminants. *Rev. Sci. Tech. Off. Int. Epiz.*, 9, 935-981.
45- LIBEAU G. ; DIALLO A. ; COLAS F. ; GUERRE L. ; 1994.- Rapid differential diagnosis of rinderpest and peste des petits ruminants using an immunocapture ELISA. *Vet. Rec.*, 134, 300-304.
46- LIBEAU G. ; PREHAUD C. ; LANCELOT R. ; COLAS F. ; GUERRE L. ; BISHOP D.H. ; DIALLO A. ; 1995.- Development of a competitive ELISA for detecting antibodies to the peste des petits ruminants virus using a recombinant nucleoprotein. *Res Vet Sci.* 58, 50-55.
47- MAHY B.W.J. ; BARRETT T. ; EVANS S. ; ANDERSON E.C. ; BOSTOCK C.J. ; 1988.- Characterization of the seal Morbillivirus. *Nature*, 336: 115.
48- MORNET P. ; ORUE J. ; GILBERT Y. ; THIERY G. ; SOW M. ; 1956.- La peste des petits ruminants en Afrique occidentale française: ses rapports avec la peste bovine. *Rev. Elev. Med. Vet. Pays trop.*, 9, 313-342.
49- MUNIR M. ; ZOHARI S. ; BERG M. ; 2013.- Pathophysiology and clinical assessment of peste des petits ruminants virus. In M. Munir, S. Zohari & M. Berg (Eds.), Molecular biology and pathogenesis of Peste des Petits Ruminants virus (pp. 33-48). New York: Springer
50- NANDA Y.P. ; CHATTERJEE A. ; DIALLO A. ; LIBEAU G. ; ANDERSION J. ; BARRETT T. ; TAYLOR W.P. ; 1996.- The isolation of Peste des Petits Ruminants virus from Northern India. *Vet. Microbiology*, 51, 207-216.
51- OSTERHAUS A.D.M.E. ; GROEN J. ; DE VRIES P. ; UYTDEHAAG F. ; KLINGEBORN B. ; ZARNKE, R. ; 1988.- Canine distemper virus in seals. *Nature*, 335: 403.
52- OSTERHAUS A.D.M.E. ; GROEN J. ; UYTDEHAAG F. ; VISSER I.K.G. ; VAN DE BILDT M.W.G. ; BERGMAN A. ; KLINGEBORN B. ; 1989.- Distemper virus in Baikal seals. *Nature*, 338, 209-210.
53- PASTORET P.P. ; VAN BRESSEN M.F. ; DIALLO A. ; BARRETT T. ; TILLE A. ; THIRY E. ; LEFÈVRE P.C. ; BOSTOCH C. ; IDRISS, A.F. ; BIDJEH K. ; 1991.- La biologie des infections par Morbillvirus. *Ann. Méd. Vét.*, 135, 77-89.
54- POPE R.A. ; PARIDA S. ; BAILEY D. ; BROWNLIE J. ; BARRETT T. ; BANYARD A.C. ; 2013.- Early events following experimental infection with Peste-Des-Petits ruminants virus suggest immune cell targeting. *PLoS One*, 8(2), e55830. doi: 10.1371/journal.pone.0055830
55- ROGER F. ; YIGEZU L.M. ; HURARD C. ; LIBEAU G. ; MEBRATU G.Y. ; DIALLO A. ; FAYE B. ; 2000.- Investigations on a new pathological condition of camels in Ethiopia. *J. Camel. Pract. Res.*, 7, 163-165.
56- ROGER F. ; GUERRE YESUS M. ; LIBEAU G. ; DIALLO A. ; YIGEZU L.M. ; YILMA T. ; 2001.- Detection of antibodies of rinderpest and peste des petits ruminants viruses (Paramyxoviridae, Morbillivirus) during a new epizootic disease in Ethiopian camels (*Camelus dromedarius*). *Rev. Med. Vet.*, 152, 265-268.
57- ROSSITER P.B. ; JESSETT D.M. ; 1982.- Detection of rinderpest virus antigens *in vitro* and *in vivo* by direct immunofluorescence, *Res. Vet. Sci.*, 33, 198-204.
58- ROSSITER P.B. ; JESSETTT D.M. ; TAYLOR W.P. ; 1985.- Microneutralisation systems for use with different strains of peste des petits ruminants virus and rinderpest. *Trop. Anim. Hlth. Prod.*. 17, 75 – 81.
59- ROWLAND A.C. ; BOURDIN P. ; 1970.- The histological relationship between peste des petits ruminants and kata in West Africa. *Rev. Elév. Med. Vét. Pays trop.*, 21, 301-307.
60- ROWLAND A.C. ; SCOTT G.R. ; RAMACFHANDRAN S. ; HILL, H.D.A. ; 1971.- Comparative study of peste des petits ruminants and kata in West African dwarf goat. *Trop. Anim. Health Prod.*, 3, 241-247.
61- SAEED I.K. ; ALI Y.H. ; KHALAFALLA A.I. ; RAHMAN-MAHASIN ; E.A. ; 2010.- Current situation of Peste des petits ruminants in the Sudan. *Trop. Anim. Health Prod.* 42, 89-93. DOI: 10.1007/s11250-009-9389-5.
62- SALIKI J.T. ; HOUSE J.A. ; MEBUS C.A. ; DUBOVI, E.J. ; 1994.- Comparison of Monoclonal Antibody-Based Sandwich Enzyme-Linked Immunosorbent Assay and Virus Isolation for Detection of Peste des Petits Ruminants Virus in Goat Tissues and Secretions. *J Clin. Microbiol.*, 32, 1349-1353.
63- SARAVANAN P. ; SEN A. ; BALAMURUGAN V. ; RAJAK K.K. ; BHANUPRAKASH V. ; PALANISWAMI K.S. ; NACHIMUTHU K.; THANGAVELU A. ; DHINAKARRAI G. *et. al.* ; 2010.- Comparative efficacy of peste des petits ruminants (PPR) vaccines. *Biologicals*, 38, 479 – 485.
64- SILVA A.C. ; CARRONDO M.J. ; ALVES P.M. ; 2011.- Strategies for improved stability of peste des petits ruminants vaccine. *Vaccine*, 29, 4983 - 4991.
65- SCOTT G.R. ; BROWN R.D. ; 1961.- Rinderpest diagnosis with special reference to agar double diffusion test. *Bull. Epiz. Dis. Afr.*, 9, 83-125.
66- SHAILA M.S. ; PURUSHOTHAMAN V. ; BHAVASAR D. ; VENUGOPAL K. ; VENKATESAN R.A. ; 1989.- Peste des petits ruminants of sheep in India. *Vet. Rec*., 125, 602.
67- SINGH R.P. ; SREENIVASA B. P. ; DHAR P. ; BANDYOPADHYAY S.K. ; 2004a.- A sandwich-ELISA for the diagnosis of Peste des petits ruminants (PPR) infection in small ruminants using anti-nucleocapsid protein monoclonal antibody. *Arch. Virol.*, 149, 2155-2170.

75- **TAYLOR W.P. ; 1979b.-** Protection of goats against peste-des-petits-ruminants with attenuated rinderpest virus. *Rev. Sci. Tech. Off. Int. Epiz.*, 27, 321-324.
76- **TAYLOR W.P. ; AL BUSAIDY S. ; BARRETT T. ; 1990.-** The epidemiology of peste des petits ruminants in the Sultanate of Oman. *Vet. Microbiol.*, 22, 341-352.
77- **VAN BRESSEN M.F. ; VISSER I.K.G. ; DE SWART R.L. ; ORVELL C. ; STANZANI L. ; ANDROUKAKI E. ; SIAKAVARA K. ; OSTERHAUS A.D.M.E. ; 1992.-** Dolphin morbillivirus infection in differents parts of the mediteraranean sea. *Arch. Virol.*, 129, 235-242.
78- **WANG Z. ; BAO J. ; WU X. ; LIU Y. ; LI L. ; LIU C. ; SUO L. ; XIE Z. ; ZHAO W. ; *et al.* ; 2009.-** Peste des petits ruminants virus in Tibet, China. *Emerg. Infect. Dis.* 15, 299-301.
79- **WEI L. ; GANG L. ; XIAOJUAN F. ; KUN Z. ; FENGQUI J. ; LIJUN, S. ; UNHER H. ; 2009.-** Establishment of a rapid method for detection of PPR by a reverse transcription loop-mediated isothermal amplification. *Clin J. Prev. Vet. Med.* 31, 374 – 378.
80- **WHITNEY J.C. ; SCOTT G.R. ; HILL D.H. ; 1967.-** Preliminary observations on a stomatitis and enteritis of goats in southern Nigeria. *Bull. Epizoot. Dis. Afr.*, 15, 31-41.
81- **WORRALL E.E. ; LITAMOI J.K. ; SECK B.M. ; AYELET G. ; 2001.-** Xerovac: an ultra rapid method for the dehydratation and preservation of live attenuated Rinderpest and peste des petits ruminants vaccines. *Vaccine*, 19, 834-839.
82- **YESILBAG K. ; YILMAZ Z. ; GOLCU E. ; OZKUL A. ; 2005.-** Peste des petits ruminants outbreak in western Turkey. *Vet Rec.*, 157, 260-261.

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