Review Article

Special Issue: Molecular Virology and Control of *Peste des Petits Ruminants* Virus

Factors Affecting PPRV in African Countries and their Countermeasures

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Abstract | *Peste des petits ruminants* virus (PPRV) causes an economically important plague of sheep and goats that serves as a major constraint in the development of the small ruminant's production within an infected area. The virus is endemic across much of the developing world and has spread into the developed European borders. The small ruminants industry within an infected state or region is often disproportionately affected with its attending impact on poverty in what are already the poorest areas of the globe. PPR is considered to be a transboundary disease of great significance through its effect on the development and maintenance of sustainable agriculture in developing countries, most notably in Western Africa and South Asia. Here, we review, using available data in research papers and reports of international organizations and databases, the factors that enables the spread of PPR in Africa and the required countermeasures that are required to control and eradicate it. However, with challenges such as uncontrolled movement of animals across porous borders, limited financial capacity of farmers to expand or improve the systems, and inadequate supply of quality vaccines and the problem of delivery to maintain cold chain, there is need for a very strong regional coordination for effective and sustainable control of PPR in Africa. The African continent is currently divided into 57 countries (or independent territories), many of which rely heavily on livestock for fuel, motor power and sustenance with many also endemic to the disease. PPRV continues to decimate the small ruminant populations across much of the African countries. Furthermore, given the continued occurrence of PPR and increasing global humans and animals movements,the virus has continued to be reported in previously PPR-free countries and thereby considered as an emerging pathogen.. However, the increased detection of the virus in the light of rinderpest eradication and the lack of awareness of the disease in areas where the virus has been detected for the first time in recent years given the educational status of farmers contributed to this emergence.

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Introduction

Peste des petits ruminants (PPR) is an acute, highly contagious and transboundary viral disease of sheep and goats. Morbidity and mortality can be as high as 100% and 90%, respectively, depending upon the endemicity in the area (Banyard et al., 2010). PPR virus (PPRV) belongs to the family *Paramyxoviridae*

and genus *Morbillivirus,* which is genetically similar to the measles virus (MeV), rinderpest virus (RPV), canine distemper virus (CDV) and a number of other viruses that infect aquatic mammals. Sheep and goats are the primary hosts for PPRV. In these species, the virus causes an acute, and contagious disease that is commonly associated with high morbidity and mortality rates among small ruminants. Viral transmission requires close contact between herd/flock members. Sheep are often less severely affected than goats (Swai et al., 2009; El-Yuguda et al., 2013). Clinically, the disease is characterized by pyrexia with rectal temperatures of 40°-41°C, erosive stomatitis, conjunctivitis, pneumonia, gastroenteritis, diarrhoea and death (FAO, 1999).

After the first report in 1942 in Ivorian sheep and goats (Gargadennec and Lalanne, 1942), the disease which was thought to be localized to the sub-saharian African continent, eventually spread to North, West, Central, East and Southern Africa. It was reported outside Africa in the Arabian Peninsula, Middle East and the Asian subcontinent and still spreading to countries and territories initially thought to be free of the disease (Banyard et al., 2010; Banyard et al., 2014). PPR spread through a large area covering the developing world where subsistence small ruminants farming remain a dominant source of trade and livelihood. The high morbidity and mortality characteristics of PPR bring to bear a negative impact on food production and animal welfare within endemic areas (FAO, 2013).

Although PPRV has been known to occur as a single strain or serotype, however, partial sequence analysis of either fusion (F) or nucleoprotein (N) genes (Forsyth and Barrett et al., 1995; Couacy-Hymann et al., 2002) indicates the occurrence of four lineages (I, II, III and IV) (Shaila et al., 1996; Dhar et al., 2002). Traditionally, lineages I and II are found in West Africa, while lineage III in East Africa and the Middle East, and lineage IV in Asia. Recent studies have shown great changes in this distribution including the emergence of PPRV lineage IV in northeastern and northern Africa (Kwiatek et al., 2011; Albina et al., 2013; Libeau et al., 2014) with co-circulation of more than one lineage in some territories (Luka et al., 2012; Woma et al., 2015).

Despite the availability of a potent homologous vaccine for the prevention and control of PPR (Diallo, 1990), the disease has continued to spread in African and Asian countries. Three methods may be used to diagnose and monitor the epidemiology of the disease: case recording of PPR outbreaks, detection of the virus or its nucleic acid (RNA), followed by sequencing, and serological detection of PPRV-specific antibodies. However, case recording of outbreaks may clarify the epidemiology of the disease in an area coupled with a good disease reporting system. Laboratory diagnostics remains essential for confirmation (Kumar et al., 2014). The conventional diagnostic techniques for PPRV include virus neutralization test (VNT), agar gel immunodiffusion test (AGID) and virus isolation in cell culture which require time and are laborious. Reverse transcriptase polymerase chain reaction (RT-PCR) is a more rapid and sensitive test that is now widely used for rapid diagnosis of the PPRV both in clinical materials or laboratory specimens (Couacy-Hymann et al., 2002; Albina et al., 2013).

This review critically analyses available data on public domains and databases of different international organization. Based on these assessments, the factors enabling the spread of PPR in Africa and the required countermeasures to control and subsequent eradicate disease are discussed.

Epidemiologic and Historical Distribution of PPR

PPRV is a non-segmented, single stranded, negative sense RNA virus with genome of approximately 15-16kb in length and virion size of 200 nm diameters. The virus contains six tandemly arranged transcription units that encodes six structural proteins: the nucleocapsid protein (N), the phosphoprotein (P), the matrix protein (M), the fusion protein (F), the haemagglutinin protein (H), the polymerase protein (L) and the two non-structural proteins, C and V (Diallo, 1990; Bailey et al., 2005).

Based on a small fragment of either fusion (F) protein (Forsyth and Barrett, 1995) or nucleoprotein (N) genes (Couacy-Hymann et al., 2002), PPRV isolates have been genetically grouped into four distinct lineages; i.e. lineage I-IV which are distributed globally (Dhar et al., 2002; Banyard et al., 2010). The reason for the spread of the virus has not yet been understood but genetic relationship between PPRV isolates from different geographical regions has been studied by

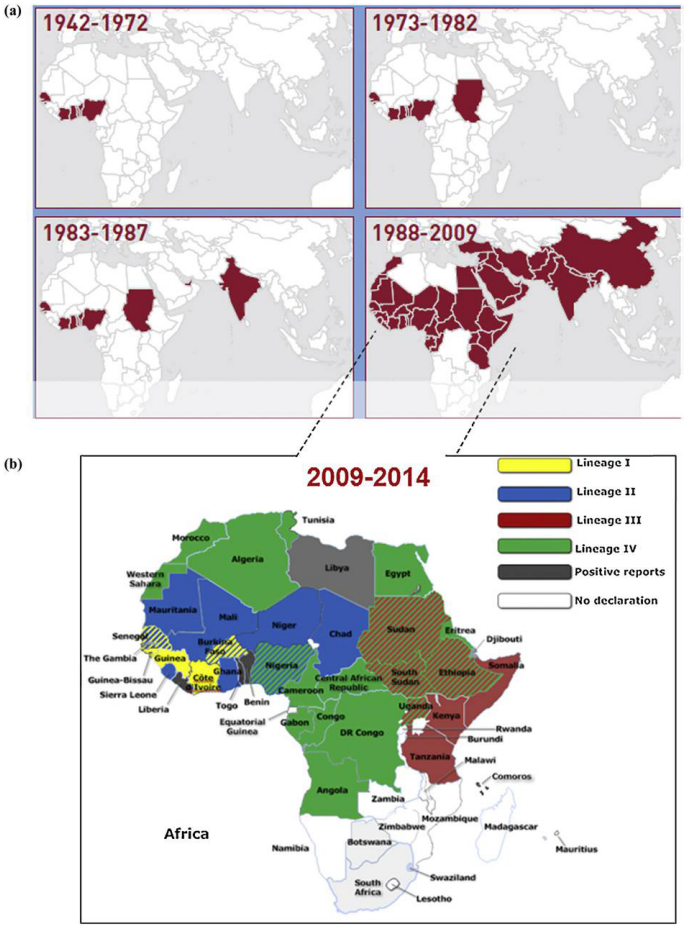

Figure 1: *Spatio-temporal distribution of PPR (adapted from the Parida et al., 2015)*

sequence comparison of the F and N protein genes (Figure 1). Lineage I and II have been found exclusively to West Africa from isolates of the 1970s to the 1980s and very recently, lineage IV co-circulating in Nigeria (Woma et al., 2015). Lineage III strains are being reported from East Africa, Arabia, and India; however, it was never reported in India again since the first report in 1992. Lineage IV has been distinct to Asia even though it has been reported in north, west, central east and southern Africa thereby becoming the most widely circulating lineage (Banyard et al., 2010; Kwiatek et al., 2011; Luka et al., 2012; Misinzo et al., 2015; Woma et al., 2015; Parida et al., 2015).

PPR is now present within a broad belt of sub-Saharan Africa, North Africa, the Middle East, and Asia subcontinent. Recent outbreaks in Turkey, Morocco, Algeria, Tunisia, Tibet-China, Tanzania and Kazakstan had signified the rising global spread of PPR and confirmed some of the hypothesis of PPR already circulating before being confirmed in some of those areas (Banyard et al., 2010; Kardjadj et al., 2015; Banyard et al., 2014; Kock et al., 2015). Apart from being confused with rinderpest, subclinical infection to varying mortalities has been reported in cattle, buffalo, pigs and camels (Nawathe and Taylor, 1979; Roger et al., 2001; El-Hakim, 2006).

A recent study by Muniraju et al. (2014) suggested that PPR evolved in the West Africa around the start of the twentieth century. The time lapse prior to Gargadennec and Lalanne's first description can be explained in terms of its chronic misdiagnosis as rinderpest. In the course of the last hundred years or so, PPRV diverged into four distinct lineages each possibly gaining a selective advantage in the serial host populations lying successively to the east of the original one. Indeed, over the last 40 years, the virus has made a remarkable rapid spread from West Africa through Central and Eastern Africa, on to the Arabian Gulf, Iran, Pakistan, India and lately to China (Shaila et al., 1989; Wang et al., 2009; Banyard et al., 2010).

Factors affecting the Distribution of PPR in Africa

Although PPR was first reported in Africa in the 1942 (Figure 1), the number of countries in Africa reporting PPR outbreaks to the African Union – Inter-African Bureau for Animal Resources (AU-IBAR, 2013) has increased from 19 – 27 between 2008 and 2011. Earlier and recent infections in the North, West, Central and East African regions have turned the entire region into endemic foci. From this "foci", the disease has spread northwards into Morocco (De Nardi et al., 2011), Algeria (Kardjard et al., 2015) and Tunisia (Sghaier et al., 2014) and southwards into Tanzania, Zambia and Angola (Banyard et al., 2010; Misinzo et al., 2015; Parida et al., 2015). Out of the 27 countries that reported PPR in 2011, a majority were recorded during the past three years. A total of 1185 epidemiological units were affected by PPR in 27 countries causing 101,016 cases and 62,388 deaths with a case fatality rate of 61.8%. The top three countries with highest number of outbreaks in descending order are Benin (285 outbreaks), Ghana (184 outbreaks) and Nigeria (126 outbreaks) (AU-IBAR, 2013).

North Africa

Husbandry and ownership of small ruminants

Countries in the North African region are Morocco, Western Sahara, Mauritania, Algeria, Tunisia, Lib-

ya and Egypt. By virtue of the regions geographical location and its borders with the Middle East and Sahel countries, North African countries are vulnerable to several transboundary diseases including PPR (Kardjadj et al., 2015). Currently, the population of livestock (sheep and goats) susceptible, and at risk to PPR in these countries is more than 100 million heads. Interestingly, the epidemiological situation and control measures applied by nations are not homogeneous. Small ruminants are one of the main sources of meat production and an important financial income of many North African households. Both sheep and goats are reared under traditional extensive systems, although intensive husbandry systems have recently been introduced in these countries (FAO, 2013).

Disease occurrence and distribution

Regular PPRV epizootic activity across the tropical and sub-tropical areas of North Africa has resulted in the spread of the disease into uninfected areas within the continent. Particularly, from 2008 to 2014 when PPRV first stretched northwards reaching Morocco in 2008 (FAO, 2009), Western Sahara, Tunisia, Libya, Algeria and Mauritania all in 2012 (DeNardi et al., 2012; Sghaier et al., 2014; Kardjadj et al., 2015; El Arbi et al., 2014). The recent results from the Food and Agriculture Organization (FAO)-funded project "Toward a harmonized strategy for the control of *peste des petits ruminants* in North Africa FAO Project (TCP/RAB/3302) provide insights into the situation on PPR in the Northern African countries (Algeria, Egypt, Libya, Morocco, Mauritania and Tunisia) updated up to 2012–2013. The results of this project showed a high herd seroprevalence in the region (40-70%), except in Morocco, which adopted four years of mass vaccination (the last was in 2011 in eastern Morocco) (EFSA, 2015). The project TCP/RAB/3302 was set up in 2010, following the emergence of PPR in Morocco in 2008. Indeed, Morocco was probably the last Northern African country to be infected by PPRV, which was first detected in Egypt during the 1980s (Ismail and House, 1990). An outbreak of PPR was later reported in the Nile delta in 2006 (Abd et al., 2010) and the phylogenetic analyses revealed that the causative strain of PPRV belonged to lineage IV and was closely related to PPRV isolated in Morocco in 2008 (Kwiatek et al., 2011). Moreover, serological evidence of PPRV infection was observed in Tunisia in small ruminant samples collected in 2006 (Ayari-Fakhfakh et al., 2011). On the other hand, retrospective surveys on a Moroccan serological bank could not detect PPRV antibodies in small ruminant sera collected before 2008 (Ettair, 2012). The results of the molecular studies in each country show that the lineage IV of PPRV is circulating throughout the sub-region (Abd et al., 2010; DeNardi et al., 2012; Sghaier et al. 2014; Kardjadj et al. 2015) except Mauritania, where El Arbi et al. (2014) reported the presence of the lineage II, therefore, highlighting the existence of a second lineage circulating in North Africa.

Improved veterinary infrastructure for prevention and control

North African national laboratories are fully associated and in partnership with the work of the European network of PPR reference laboratories. They participate in the annual ring trial and attend technical meetings for capacity building and cooperation, the regional FAO project such as TCP/RAB/3302 aimed to adopt a regional approach to fight the disease by strengthening the capacity of epidemiological surveillance and diagnosis in these countries. National laboratories in the North African countries are fully associated and in partnership with the work of the European network of PPR reference laboratories. They participate in the annual ring trial and attend technical meetings for capacity building and cooperation (FAO, 2013). However, the establishment of early warning systems and proper implementation of regional control measures are needed, including regular surveillance and vaccination, to improve animal welfare and reduce economic losses associated with outbreak episodes.

In Morocco, PPR was well controlled at the national level through mass vaccination, thus providing very strong evidence that PPR control can be achieved in Northern Africa, provided that adequate means are available and correctly implemented. Moreover, after the vaccination campaign, the epidemiological situation was assessed in 2012 under the FAO project (TCP/RAB/3302). No viral circulation could be observed among young unvaccinated animals, and a good immune protection rate was achieved in vaccinated adults (EFSA, 2015). However, assiduous vigilance is still needed because there is a risk of PPR reoccurrence given the illegal cross-border livestock movements. Indeed, due to mass vaccination campaigns during 2009-2011, PPR outbreaks were not seen until June 2015 when the PPR outbreaks reoccurred. The cause of recent outbreaks in Morocco is

unknown but is believed to be due to the transboundary movement of infected animals. Early detection of such reoccurrence is a necessary condition for a rapid response and effective management of possible outbreaks of PPR. This fragile PPR-free situation in Morocco highlights the importance of designing and actually implementing a regional PPR control strategy, relying on coordinated mass vaccination in infected countries, together with post-vaccination monitoring and efficient active surveillance measures. In particular, a better knowledge of legal and illegal livestock movements is of critical importance.

West Africa

Husbandry and ownership of small ruminants

In many West African countries (Benin, Burkina Faso, Ghana, Guinea, Mali, Niger, Nigeria and Sierra Leone), small ruminants husbandry are usually small scaled and casual, not so well developed and with widespread ownership (Sumberg and Cassaday, 1984; Jaitner et al., 2001). Traditional husbandry, where animals are allowed to roam without housing and feed supplementation, is the most common practice across the region (Baah et al., 2012; Dossa et al., 2015). In majority of practices, goats are kept at relatively higher proportion than sheep and mainly women are involved raising small ruminants (Clottery et al., 2007). The sector is barely keeping with the growing demand for small ruminant's meat without commensurate increase in numbers, productivity and efficiency of resource utilization (ILRI, 2011; OIE and FAO, 2015). A study across the region by Dossa et al., (2015) supports the fact that animals are kept basically for economic purposes, socio-religious and prestige. The animals are exported to countries within Africa and sometimes outside Africa to areas of demand such as Middle East, were meat is consumed during religious festivals and ceremonies (Awa et al., 2007; ILRI, 2011; Dossa et al., 2015). However, the traditional husbandry system practiced by most farmers predisposes to various diseases, which hinders commercial scale production and value to meet up with the growing meat demand (Awa et al., 2007; Rumosa et al., 2008; ILRI, 2011). With the growing incidence of PPR, it's difficult for farmers to make the most out of these animals. Since most animals are not really kept for profit (business), ability to scale it up has become extremely difficult (Obidike et al., 2006). Sheep and goats are unequally distributed across the region with higher numbers in the drier northern areas compared to the southern rain forest areas. The nature of small ruminant production in the region varies from extensive, low-input systems based on free grazing and village scavenging to more intensive cut-and-carry feeding of confined animals and commercial grazing of sheep flocks which predisposes to contagious and infectious diseases such as PPR (CAADP, 2010). To achieve maximum productivity and prevent diseases occurrence, management practices need to change to enable high productivity and alleviate poverty.

Disease occurrence and distribution

PPRV is currently believed to be endemic across much of West Africa since its first report. However, poor disease reporting systems and farm practices are considered major reasons of increasing rates of disease outbreaks (Couacy-Hymann et al., 2007; Parida et al., 2015). The West Africa region is made up of 16 countries most of which had reported outbreaks. Lineages I circulating in Burkina Faso (Munir et al., 2012), II in Ghana (Dundon et al., 2014), I and IV reported in Nigeria (Luka et al., 2011b; Woma et al., 2014), II in Niger (Libeau et al., 2014), I in Sierra Leone (Munir et al., 2013) and Lineage I and II in Senegal (Salami et al., 2010). PPRV strains from both Lineages I, II and IV are currently circulating across West Africa although undoubtedly many outbreaks are not characterized at the molecular level (Parida et al., 2015). Detection of PPR and mortality's in camels in Ethiopia and Egypt (Khalafalla et al., 2010; Rogers et al., 2001) and their possible role in long-distance transmission due to trade with the region (Awa et al., 2002) can thereby complicate the epidemiology of the disease. Previous reports by Daneji et al. (1997) reported 4% prevalence from 250 camels slaughtered at the Sokoto abattoir northwest Nigeria, however, subsequent report by Ibu et al. (2008) failed to detect the presence of antibodies or antigen by competitive and immune-capture ELISA from camels in Borno and Kano states northeast and northwest Nigeria, respectively. Further studies with increased sample size over a wider geographical area were suggested to draw up a conclusion.

Improved veterinary infrastructure for prevention and control

There are several central veterinary centres in the entire region responsible for the diagnosis of PPR and various reference laboratories outside the region for confirmation of the disease. However, personnel knowledge on disease reporting and monitory is de-

ficient (Tsoho, 2010). Effective data collection and networking among stakeholders will enable rapid assessment of certain profiles such as: vaccination status of a region, herd immunity and epidemiological data, target flock, movement and tracking of animals (Singh et al., 2010; Parida et al., 2015).

Most borders in Africa are porous and free movement of animals contribute to rapid spread of transboundary animal diseases. Therefore, for an effective control and eradication programme to succeed there will be need for coordination and cooperation at the regional level given the lack of variability of the virus and a vaccine that confers immunity across all virus lineages. Stem (1993) estimated a US$24 million return on investment of US$2 million on PPR control (vaccine) in Niger for over a period of 5 years while Awa et al. (2000) in a separate study in Cameroon indicated benefit-to-cost ratios of 2.26 to 4.23 for a PPR vaccination and strategic anthelminthic programme. A sufficient understanding on the benefits of any government investment in this sector (Stem, 1993) and the satisfactory financial support from the Economic Community of West African States (ECOWAS) will be crucial for any foreseeable success in controlling and eradicating the disease. However, relevant technical and financial support from international development partners such as FAO, United Nations Development Programme (UNDP), European Union and the Word Bank will also be required to drive a successful control programme.

East Africa

Husbandry and ownership of small ruminants

The situation in East Africa is not very different in terms of husbandry, movement and management practices, and other production characteristics that enable the persistence of PPR and poor small ruminant's production in the region. Geographically, it is used generally and specifically to refer to the area now comprising the countries of Kenya, Tanzania and Uganda but sometimes includes Somalia, Djibouti, Ethiopia and Eritrea (Banyard et al., 2010).

Disease occurrence and distribution

PPR is endemic in all countries in this region. Detection of antibodies against PPRV from archival samples by Wamwayi et al. (1995) in border districts of Kenya and Uganda suggested that the virus might probably been circulating in both countries long before it was initially confirmed. Genetically, two lineages (III and IV) at various times were subsequently reported to be circulating in the region. Moreover, both lineages have been reported in Asia. Recently, PPRV has been confirmed to be endemic across East Africa following the detection of antibodies in Kenya (1995 and 2009) (Wamwayi et al., 1995; Kihu et al., 2015) and Uganda (2005 and 2007) (Luka et al., 2012). The use of molecular tools for the characterization of available and appropriate samples from Sudan, Uganda, and Tanzania revealed that the viruses belonged to lineage III (Diallo, 1988; Banyard et al., 2010; Parida et al., 2015). Co-circulation with lineage IV viruses in the region has also been reported in Sudan and Uganda (Khalafalla et al., 2010; Luka et al., 2011a). Recent outbreak of PPR in Kenya (Kihu et al., 2015) in the Turkana districtrapidly spread to 16 districts with associated socioeconomic impact on food security and livelihood of the populace due to movement and management practices.

Improved veterinary infrastructure for prevention and control

With adequate infrastructure, manpower and timely vaccination, the Kenyan government would have save 5 million animals across 16 districts. Financially, annual losses due to PPR in 2010 were estimated in excess of US$15 million (Anonymous, 2008). Eventually, vaccination and quarantine were used to halt the spread of the disease. As a result of depleting funds, limited vaccines, shortage of trained staff for coordination, tribal clashes, rustling, drought and movement of pastoralist complicated and compromised the control programme (Anonymous, 2008). In 2006, the disease spread to neighbouring Somalia with high mortalities in the central region of the country. The spread was stopped due to unfavourable topography to support the spread to the entire country coupled with a successful ring-vaccination that was implemented in 2009 and further curtail the spread (Nyamweya et al., 2009). In a study in Uganda assessing vaccination antibodies by Luka et al., (2011a) suggested the need for a repeat vaccination to achieve herd immunity (75-80%) as suggested in the case of Rinderpest by Rossiter and James, (1989) giving the resource limiting situation of the continent. The East African Community (EAC) recognizes PPR as one of the transboundary animal diseases that serves as a major hindrance to animal production within the region (EAC, 2015).

Central Africa

Husbandry and ownership of small ruminants

This region comprises countries namely: Burundi, the Central African Republic (CAR), Angola, Cameroon, Chad, Gabon, Democratic Republic of Congo (DRC) and Rwanda. About 57% of ruminant populations in sub-Saharan African are located in both arid and semi-arid zones and Central Africa is made up of 54% of the total land area (Winrock Int'l, 1992). Most farmers within the region generally do not have any form of education, and traditional pastoralist in Africa never gives true values of their wealth information especially to strangers (Awa et al., 2002). In Rwanda, however, 43% of household leaders are women, widows and children. Small ruminants' husbandry across the region is similar to what is obtain in West Africa where animals are small scaled and graze freely as scavenger with free grazing restricted in Rwanda as a government policy (Lukuyu et al., 2009; Manzi et al., 2013). Small ruminants are kept as savings, insurance and/or diversification of asset and 50% of farmers keep breeding records in Rwanda. A high number of farmers borrow or hire bucks for breeding from other farmers for a better productivity. Organised breeding is more preferred over natural breeding in the country (Manzi et al., 2013). The practice of purchase of animals from open market, borrowing or hiring of animals is a big risk especially in an enzootic area for the spread of a disease.

Demand for animal protein as a result of growing population is encouraging movement of animals across markets. National or regional conflict is also aiding the movement and spread of diseases such as PPR to disease free areas. Trade information revealed that Cameroon and Central African Republic serve as transit route for Chadian animals while Nigeria serve as trade destination for animals from Cameroon, CAR and Chad (Koussou et al., 2001).

Disease occurrence and distribution

Historically, serological and molecular techniques have identified PPRV in a number of regions; the CAR (1999, 2005 and 2006), DRC (2006), Chad (1999 and 2006), Cameroon (2009) (Awa et al., 2000) and Gabon (2007) (Maganga et al., 2013). So far, lineage II and IV has been demonstrated to be circulating in the region (Bidjeh et al., 1995; Banyard et al., 2010; Parida et al., 2015). Uncontrolled movement of animals in search of feed due to the general extensive farming system has been a major factor in the spread of the disease in the region. Transboundary trade are very common, borders are difficult to control and the enzootic disease situation make easier for the PPRV to spread south towards southern African countries (Libeau et al., 2014).

Improved veterinary infrastructure for prevention and control

Veterinary infrastructures are minimal generally within the region and service coverage is equally inadequate or lacking in Cameroon. Some aspect of veterinary services are emerging but limited by government legislation which does not favour effective functioning of private veterinary services. Farmers in CAR are better organised under livestock initiatives which makes it easier to access services and vaccinations for large ruminants. However, small ruminant's vaccination in CAR is absent (Awa et al., 2002). Helminthosis is a major health problem in Chad, Cameroon and CAR where it is the major cause of diarrhoea and death (Cardinale et al., 1996; Awa et al., 2000). PPR is common with attending mortalities reaching up to 80% in Cameroon (Awa and Ngo Tama, 1997).

Southern Africa

Husbandry and ownership of small ruminants

This region, based on United Nation's geographical demarcation, is said to comprise of 5 countries namely: Botswana, Lesotho, Namibia, South Africa and Swaziland. However, to enhance regional and economic cooperation, the Southern African Development Community (SADC) was established in 1980, which eventually comprises PPR infected and non-infected states. With common trade and movement of human and animal resources, an enabling environment was created for transmission of the disease (SADC, 2012). Over 60% of the regions is suitable for livestock farming and thereby guaranteeing food security for the region. Supportively, the region has a rich and diverse livestock population estimated at 64 million cattle, 39 million sheep, 38 million goats, 1 million horses and 380 million poultry. Majority of the livestock (75%) are kept under smallholder traditional farming systems with more women keeping goats compared to men in the ration of 3:1 (Oladele and Monkhei, 2008; SADC, 2012). Averagely, most farmers are above 50 year in age, married and without formal education (Mabe et al., 2010). Majority (90%) of goats within the region are indigenous and

information on them is scanty with traditional management as the major practice. Major constraints to production include high disease and parasite prevalence, low management and poor marketing strategies (Rumosa et al., 2009).

Disease occurrence and distribution

Two member countries of the community (Angola, DCR and Tanzania) are infected with PPR and thereby tagged as infected area. Initially, Tanzania and DRC were the only infected while neighbouring of Angola, Zambia, Malawi and Mozambique were considered to be at high risk of contracting the disease. Consequently, the disease has been reported to be present in Angola and Zambia (SADC, 2012; AU-IBAR, 2013) thereby increasing the number of infected countries within the region to five countries. Genetic characterization confirmed that II and IV lineages are circulating in Tanzania while lineages IV in Angola and DRC (Misinzo et al., 2014; Parida et al., 2015).

Improved veterinary infrastructure for prevention and control

Movement of animals has been identified as one of the major cause of spread of the disease. Regionally, some control options were recommended. Targeted vaccination on critical control point such as livestock market and transport route use by traders and pastoralist was recommended for controlling spread. However, stamping out was included in the SADC-PPR strategic plan especially where the infected population is defined and small in size couple with government compensation policy in place. The disadvantage of this method is the monetary involvement in and most governments are reluctant to join. Initially SADC was divided into zones with infected, high risk areas and disease free areas for ease of observing biosecurity and biosafety measures. The strategic plan for the regions recommended stiffer penalties for movement across zones. Movement of live animals should be restricted (SADC, 2013). Personnel will be required for any effective control policies in place, therefore, the need for training and capacity building in various duties on control and eradication of the disease.

Countermeasures for the Control and Prevention of PPR in Africa

For an effective control programme, a variety of technical, financial and logistic reasons have to be put in place (Thomson, 2009). Firstly, a high level of total standstill of livestock movements across zones should be encouraged. Banning of markets may be effective if enforceable and short lasting in duration, since the incubation period is short. However, legitimate market should be allowed and point vaccinations at markets to control spread should be encouraged (Taylor et al., 1990; SADC, 2013). The practice of an effective quarantine of affected and in-contact animals for one month after the recovery of the last clinically affected case has been recommended (Rossiter and Taylor, 1993). Transboundary and illegal movement encourages contact and possible sharing of water points is a risk in the transmission of the virus (Couacy-Hymann et al., 2007; Ezeibe et al., 2008). However, ban on livestock movements accompanied by a slaughter policy of animals on infected and in-contact premises to achieve rapid eradication (Diallo et al., 2007; Sen et al., 2010). Measures that negatively affect livelihoods will be unpopular and difficult to enforce unless accompanied by incentives, and have rarely been implemented by authorities (CAADP, 2010; SADC, 2013). Therefore, stakeholder orientation and adequate government policies will have to be considered to be successful.

Effective control and possible eradication of PPR is possible with an adequate, and potent vaccine that at the moment is very much available but requires cold chain. The Nig/75 vaccine and the Indian strains have proven to be effective and but require high titre for inoculation (Singh et al., 2009). Maintenance of cold chain against high ambient temperatures is a pre-requisite for optimum titre and adequate serological response (Baba et al., 2007; El-Yuguda et al., 2014). This vaccine has been used in Morocco, Uganda, Kenya, Ethiopia and other states within the region for prevention and control of the disease. The major challenge with the vaccination is coverage and the ability to achieve the minimum 75-80% herd immunity that is required for rinderpest control (Rossiter and James, 1989). A well-coordinated mass vaccination at both national and regional levels will ensure wider coverage and possible eradication of the disease. A reduction in the mortality of 24% was reported in Nigeria compared to controls, for a combined vaccination and dipping programme (Reynolds and Francis, 1988) and a higher return on investment for 5 years in Niger (Stem, 1993). However, the biggest challenge in sub Saharan Africa is the production, delivery and storage. An efficient, well-planned animal health service is a

pre-requisite for increasing small ruminant production in tropical Africa. It must be stressed, however, that any improvement in animal health services interns if disease surveillance, diagnosis, control and eradication of diseases must be visible with improvement in production outputs (SADC, 2013). There is need for training and retraining of manpower as a countermeasure strategy because the knowledge of what is required of everyone involved and the skills required carrying out the task is something that will need to be horn periodically. Trained personnel without a functional surveillance and laboratory will be waste of resources. Diagnostic laboratory either mobile or stationary at regional and national level will be key in early and rapid disease diagnosis and control (Singh et al., 2009).

Appropriate coordination and networking will enhance an early warning system among regional states during disease occurrence. In the same way, regulatory bodies should be informed to facilitate the institution of control strategies to forestall further spread across borders. The OIE publishes recommendations for zoo-sanitary conditions and certification of trade in animals and livestock products from countries which are not recognized as having freedom from PPR disease to discourage further spread. The Animal Health Code of the OIE considers: in case of disease, the recommendations of the Animal Health Code backed by veterinary certifications should be a requirement (OIE and FAO, 2015). Generally, across Africa, animal health services (AHS) are provided free of charge without cost recovery. However, AHS is for the benefit of all members of the society. However, sometimes there is disconnect between research output and the need of the farmers or sometimes never gets to the farmers. Therefore to drive disease control and prevention, farmers, government and animal healthcare provider will have to work together to enhance farm output (ILRI, 2011).

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