Thesis Ref. No. _____

MVSC THESIS

EPIDEMIOLOGY OF PESTE DES PETITS RUMINANTS IN SMALL RUMINANTS OF BORENA ZONE, ETHIOPIA

BY

ADEM KUMBE FENTA

JUNE, 2023

BISHOFTU, ETHIOPIA

EPIDEMIOLOGY OF PESTE DES PETITS RUMINANTS IN SMALL RUMINANTS OF BORENA ZONE, ETHIOPIA

A Thesis submitted to College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfilment of the requirements for the degree of Master of Veterinary Science in Veterinary Epidemiology

By

Adem Kumbe Fenta

June, 2023

Bishoftu, Ethiopia

Addis Ababa University
College of Veterinary Medicine and Agriculture
Department of Clinical Studies

EPIDEMIOLOGY OF PESTE DES PETITS RUMINANTS IN SMALL RUMINANTS OF BORENA ZONE, ETHIOPIA

Submitted by: Adem Kumbe Fenta _____ 16/6/2023
Signature Date

Approved *for submittal* to athesis assessment committee

Haileleul Negussie (DVM, MSc, PhD, Assoc. Prof.)	_____	16/6/2023
Major Advisor	Signature	Date
Yitbarek Getachew(DVM, MSc, PhD, Assoc. Prof.)	_____	16/6/2023
Co- Advisor	Signature	Date
Samson Leta (DVM, MSc, Assoc. Prof.)	_____	16/6/2023
Co- Advisor	Signature	Date
Gezahegn Alemayehu(DVM, MSc, PhD)	_____	16/6/2023
Co- Advisor	Signature	Date
Haileleul Negussie (DVM, MSc, PhD, Assoc. Prof.)	_____	16/6/2023
Department chairperson	Signature	Date

Addis Ababa University

College of Veterinary Medicine and Agriculture

Department of Clinical Studies

As members of the Examining Board of the final MSc open defense, we certify that we have read and evaluated the Thesis prepared by: **Adem Kumbe** entitled: **Epidemiology of Peste Des Petits Ruminants in small ruminants of Borena Zone, Ethiopia** and recommend that it be accepted as fulfilling the thesis requirement for the degree of: Masters of Science in Veterinary Epidemiology.

_____	_____	_____
Chairman	Signature	Date
_____	_____	_____
External Examiner	Signature	Date
_____	_____	_____
Internal Examiner	Signature	Date

I hereby certify that I have read the revised version of this thesis prepared under my direction and recommend that it be accepted as fulfilling the thesis requirement.

Haileleul Negussie(DVM, MSc, PhD, Assoc. Prof.)	_____	_____
Major Advisor and Department chairperson	Signature	Date

DEDICATION

I dedicate my MVSc thesis to the pastoralists and agro pastoralists in the Borena Zone who lost their animals as a result of droughts.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my *bonafide* work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for an advanced (MVSc) degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however permission must be obtained from the author.

Name: **Adem Kumbe Fenta** Signature_____

College of Veterinary Medicine and Agriculture, Bishoftu

Date of Submission: _____

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

ACKNOWLEDGEMENTS

Special heartfelt thanks go to Dr. Haileul Negussie, my major advisor and department head of the Veterinary Clinical Studies, for sharing his extensive knowledge with me during the study and instructions. I am grateful for all of his recommendations, guidance, and assistance throughout this endeavour. His perseverance, inspiration, evaluates and continual assistance aided me in my research field and laboratory work, thesis writing and defence. He spent a significant amount of time editing the thesis, and giving me excellent feedback that helped me prepare the work more effectively, which is highly appreciated.

I want to extend my sincere gratitude and appreciation to my co-advisor, Dr. Yitbarek Getachew, for his incomparable and valuable support as well as for devoting his significant time to leading, reading and editing this article. Dr. Yitbarek Getachew made valuable contributions through a variety of helpful comment and great recommendations especially at time of thesis proposal preparations. I also want to express sincere thanks to Dr. Samson Leta, my co-advisor. He taught me how to handle and analyze geospatial data, create maps, and use geographic information systems. He offers a variety of helpful advice and ideas on laboratory work especially during molecular laboratory sessions, research write ups, assistance and regular follow-up on the progress of the research, all of which are really appreciated.

My co-advisor from the International Livestock Research Institute (ILRI), Dr. Gezahagn Alemayehu, deserves special acknowledgement for his suggestions, direction and advice on the research effort and data analysis. I would like to thank Epidemiology and Control of Peste des Petits Ruminants (ECo-PPR) project for provision of c-ELISA kits and different lab materials, including equipment for taking blood samples for study. I also want to thank Dr. Biruk Alemu for his help with this study project.

My heartfelt thanks and appreciation go to Yabelo Pastoral and Dryland Agriculture Research Center, Oromia Agriculture Research Institute, for enabling me to take a study leave and for helping to fortify this thesis by assigning a budget and a car to my fieldwork

program. My heartfelt thanks go to Dr. Dereje Teshome, the centre director; Mr. Beshir Hussein, Mr. Muhammed Luko, Mr. Dambala Garbole, and Mr. Galgalo Liban in particular for their unflinching cooperation with the field work. It would not have been easy to collect serum samples and swabs from small ruminants and conduct questionnaire surveys in several villages throughout the study area without you. You provided invaluable support, labor, and time during sample and survey data collection.

I am happy that the highly regarded Ministry of Agriculture (MOA) epidemiology unit that provided me the PPR retrospective data that I used in this study. For their patience and help in providing retrospective data for retrospective analysis, I especially like to thank Dr. Wubishet Zewdie and Gashaw Beyene of the Ministry of Agriculture epidemiology section.

I am especially grateful to the Animal Health Institute (AHI) for providing research materials and permission for laboratory facilities for this work. I would want to offer my heartfelt gratitude to Mr. Demeke for his outstanding hospitality and assistance. All his helpful recommendations, encouragement, hospitality and time spent to me were highly appreciated. This is also an excellent occasion for me to convey my heartfelt gratitude to Mr. Kemal and Mr. Kebede for their unwavering assistance during the laboratory work. It is great that they were so eager to share the laboratory skills they had gained through years of practice.

I want to thank Dr. Golo Dabasa, the director of Yabelo Regional Laboratory and his teams for their generous help with different input materials.

Last but not least, I would like to thank my friend Asrat Areke for supporting idea on this research, as well as my family, particularly my mother Asha Gemeda, my wife Fatuma Jula, and my son Amin Adem. Throughout my study time and my thesis work, these people inspired me with their genuine advice, moral encouragement, prayers, and support.

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXES

LIST OF ABBREVIATIONS

AGID	Agar Gel Immuno-Diffusion
AHI	Animal Health Institute
CAHWs	Community Animal Health Workers
c-DNA	Complementary Deoxyribonucleic Acid
c-ELISA	Competitive Enzyme Linked Immunosorbent Assay
CPE	Cytopathic Effect
DIVA	Differentiation of Infected from Vaccinated Animals
ELISA	Enzyme Linked Immunosorbent Assay
ESGPIP	Ethiopia Sheep and Goat Productivity Improvement Program
FAO	Food and Agricultural Organization
Ic-ELISA	Immune Capture Elisa
LAMP	Loop-Mediated Isothermal Amplification
MV	Measles Virus
NP	Nucleoprotein
OD	Optical Density
OR	Odd Ratio
PCR	Polymerase Chain Reaction
PPR	Peste Des Petits Ruminants
PPRV	Peste Des Petits Ruminants Virus
RNA	Ribonucleic Acid
RPV	Rinderpest Virus
RT-PCR	Reverse Transcription Polymerase Chain Reaction
SD	Standard Deviations
s-ELISA	Sandwich Enzyme Linked Immunosorbent Assay
SLAM	Signaling Lymphocytic Activation Molecules
TMB	Tetramethylbenzidine
VTM	Viral Transport Medium
WOAH	World Organization for Animal Health

ABSTRACT

A *peste des petits ruminants* (PPR) *is* a major economic threat to sustainable small ruminant production in the developing world, including Ethiopia. A cross-sectional study was conducted from December 2022 to March 2023 to estimate the epidemiological status of PPR in the small ruminants of the Borena Zone. Moreover, a questionnaire survey and retrospective outbreak data analysis were conducted to complement laboratory and field data. In the present study, districts and households were selected purposively based on small ruminant population, and individual animals were selected randomly. A total of 384 serum samples were collected from sheep and goats and subjected to serological analysis using c-ELISA. In this study, the seroprevalence in nonvaccinated animal was 32.1% (95% CI: 26.3–38.3). Multivariable logistic analysis revealed a statistically significant association of PPRV seropositivity to older age (60%, OR = 7.3, 95%CI = 2.7–19.4; P = 0.000), animals of market origin (62.9%, OR = 4, 95%CI = 1.4–11.3; P = 0.00), animals given as gifts (56.3%, OR = 8.3, 95%CI = 2.1-32.6; P = 0.003), poor veterinary service (43.5%, OR = 2.6, 95%CI = 1.2–5.7; P = 0.019), and medium flock size (74.2%, OR = 15.4, 95%CI: 3.1–77.3; P = 0.001). In retrospective data from 2018 to 2022, 554 outbreaks and 114,924 deaths of small ruminants were reported in Ethiopia, with 9.6% outbreaks and 0.6% deaths reported from Borena Zone. A total of 81 household heads were interviewed in three districts. The disease was known to locals as "Marareba". Respondents reported that the virus had a detrimental effect by causing mortality in goats (12.3%) and sheep (7.4%), and abortions in goats (22.2%) and sheep (11.1%). However, most respondents (81.5%) lack knowledge about disease transmission, sources and practices facilitating factors including small ruminant sales, cultural festivals, dry seasons, and traditional remedies. The study highlighted the presence of PPR among the sheep and goats in Borena Zone. Lack of awareness on means of transmission, and different social activities might have contributed toa higher presence of the disease in the study population. Therefore, continuing the vaccination effort and community education are recommended to minimize the socioeconomic impact of PPR among the Borena pastoral community.

Keywords*:Borena Zone, Epidemiology, ELISA,Peste Des Petits Ruminants*

1. INTRODUCTION

A *Peste des petits ruminant* (PPR)is a viral disease that causes pyrexia, nasal and ocular discharge, ulcers, necrosis, and erosive changes in the mucosal membrane of the gastrointestinal tract. As it progresses, it causes pneumonia, severe diarrhea, and abortion (Alemu et al., 2019). It is caused by the peste des petits ruminants virus (PPRV). The virus belongs to the Paramyxoviridae family and the Morbillivirus genus, which contains Rinderpest Virus (RPV), Canine Distemper Virus (CD), and Phocine Distemper Virus (PDV), which plague cattle, dogs, and seals, respectively (Khalafalla *et al*., 2010).

PPRV is an RNA virus with six genes that encode contagious, non-overlapping proteins (Mahapatra *et al*., 2015). PPR was initially reported in Cote d'Ivoire but has since spread to other parts of Africa and Asia. Outbreaks have been reported in Ethiopia, Sudan, Kenya, and Somalia (Kwiatek *et al*., 2011; Kihu *et al*., 2015; Jemberu *et al*., 2022; Mohammed *et al*., 2022). The first clinical PPR suspect was found in Ethiopia in 1977 and proved in 1991 (Roeder *et al*., 1994). At this juncture, PPR is a major economic threat to sustainable small ruminant production in the developing world. As the disease is endemic in most of Africa, including Ethiopia, a significant effort is being expended to eradicate it (OIE, 2015; Dundon *et al*., 2020). In Asia, the disease is prevalent in India, Bangladesh, Nepal, Pakistan, Afghanistan, Mongolia, Tajikistan, Kazakhstan, and China (Ullah *et al*., 2022).

PPR is a disease that affects goats, sheep, other domestic animals, and wild species (Wang *et al*., 2009). It causes immunosuppression, and secondary bacterial infections aggravate the condition of affected animals (Schulz *et al*., 2019). Clinical signs include lacrimation, nasal discharge, breathing difficulties, and fever. In the naive population, the disease has a different range of morbidity and mortality (Saravanan *et al*., 2010). Morbidity up to 100% and mortality ranging from 50% to 80% have been reported (Abubakar *et al*., 2016; Dubie *et al*., 2022). PPRV infection results in a major loss of small ruminants through morbidity and mortality. It also negatively affects the national economy by impeding the movement of small ruminants towards foreign markets (Silva *et al*., 2014; Mamo, 2019).

The diagnosis of PPR is based on clinical findings, epidemiology, post-mortem lesions, and laboratory tests (Singh *et al*., 2009). Conventional tests are labor-intensive, time-consuming, and less sensitive, making them unsuitable for primary diagnosis (Wang *et al.,* 2009). The PPRV antigen and antibodies can be detected and identified using a variety of molecular assays and serological tests. Serological tests include indirect ELISA, the agar gel immunodiffusion test (AGID), and counter-immunoelectrophoresis (OIE, 2015). Moreover, serological methods such as competitive ELISA (c-ELISA) and blocking ELISA (b-ELISA) are highly accurate and reliable (Singh *et al*., 2004).

Immunization of susceptible animals at the appropriate times is key for the control and prevention of PPR (Singh *et al*., 2009). Prior to the creation of the PPRV vaccine, the rinderpest vaccine guaranteed PPR protection for small ruminants. Recently, live attenuated PPR vaccines for small ruminants can establish lifetime immunity against all lineages (Schulz *et al*., 2019). However, the majority of live attenuated vaccines are used in tropical endemic regions, which impacts the vaccine's heat tolerance. In 2014, improvements in vaccine heat tolerance were made by the National Veterinary Institute, which now produces lyophilized vaccines (Silva *et al.,* 2014; Cosseddu *et al.,* 2016).

However, besides vaccination, in-depth understandings of the epidemiology, community appraisal, and use of accurate diagnostics are instrumental for effective control of endemic PPR. In this regard, local and international researchers have tried to reveal the epidemiology of PPR in Ethiopia. Various studies have confirmed the abundance of the disease in small ruminant production systems. For instance, surveillance in 1999 reported 5.7% in sheep and goats, with an overall prevalence of 9% and 13%, respectively (Abraham *et al.*, 2005; Waret-Szkuta *et al*., 2008). Megersa *et al.* (2011) reported a seroprevalence of 30.9% in small ruminants managed under pastoral and agro-pastoral systems. Alemu *et al*. (2019) reported that in the Amhara region, the seroprevalence of PPR virus was 28.1% in the unvaccinated, 64.5% in the vaccinated, and 56.5% in those with unknown vaccination status. Gelana *et al*. (2020) reported 5.7% (sheep) and 4.53% (goats) from the Ambo area. Waret-Szkuta *et al*. (2008) found that the seroprevalence of PPR was higher in the lowlands of pastoral systems

than in the highlands of Ethiopia. However, little epidemiological information has been drawn from the Borena zone about the disease.

Borena Zone is located in the southern part of Ethiopia and is well known for its pastoral livestock production. Potentially higher numbers of small ruminants support the livelihood of the pastoralists and contribute to food security in the area. As a result, any outbreak of livestock disease, including PPR, would have a high impact on the social fabric of the community. Serological evidence of PPR in sheep of the Borena zone was reported in 2005 (Abraham *et al.* 2005). Additionally, the risk of disease transmission is considered high due to seasonal animal movement within the area and toward central Ethiopia for market and export abattoirs (Alemayehu *et al*., 2015). The Borena zone also covers a long boundary with Kenya, and seasonal movement of livestock towards the Kenyan border can contribute to disease spread. A vaccination campaign is ongoing in the region. Nevertheless, limited vaccine coverage, uncontrolled animal movement, drought, and feed shortages might be facilitating the spread of the PPR virus in the animal population. Therefore, it is important to assess the recent distribution of the PPRV in the study area. The present study was initiated to produce epidemiological information pertinent to the effective control of PPR in the Borena Zone. The objectives of the study were:

Objectives

General objective

- To estimate the epidemiology of PPR in sheep and goats in the Borena zone, Oromia regional state, Ethiopia.

Specific objectives

- To determine the seroprevalence of PPR and its associated risk factors in goats and sheep in the study area.
- To compare the spatiotemporal distribution of PPR in the Borena Zone and other regions from retrospective data.
- To assess the community's awareness of PPR and associated risk factors.

2. LITERATURE REVIEW ON PPR

2.1. PPR

PPR often referred to as Kata, pseudorinderpest, pneumo enteritis complex, or stomatitis-pneumo enteritis syndrome, is a severe and contagious viral illness that affects small ruminants. Acute cases mostly occurred in small ruminants, which resemble Rinderpest in cattle. Symptoms in PPR affected animals include a rapid rise in body temperature, oral, ocular, and nasal discharges, necrotic stomatitis, severe pneumonia, dyspnea, coughing, enteritis, severe diarrhea, and death (Elzein *et al*., 2004; Mantip *et al.,* 2019). In severe cases, it causes severe morbidity and mortality (Banyard *et al*., 2010). Infection rates increase with age, and the severity is highly fatal in young animals (Jones *et al*., 2021).

A subclinical case can be considered in cattle, but those with poor body condition can develop clinical signs. In other animals like buffaloes and camels, PPRV was isolated from a rinderpest-like disease in buffaloes in India and Ethiopia in 1995–1996. As well as clinical cases, these were reported in wildlife and gazelles in captivity (Elzein *et al*., 2004).

2.2. Etiological cause of PPR

PPR is caused by a virus belonging to the Order *Mononegavirales*family*, Paramoxyviridae*, Morbillivirus genus and PPR virus species (Zakian *et al*., 2016). A PPR virus is enclosed by pleomorphic particles that possess single-strand RNA. The RNA genome is wrapped up by different structural proteins. PPRV is delicate and cannot endure prolonged survival outside the host, but it can survive for a long time in cold or frozen tissues. Heat, lipid solvents, non-ionic detergents, formaldehyde, and oxidizing chemicals all cause the virus to become extremely fragile (Diallo, 2006).

2.2.1. PPR Virus structure and its role

PPR virus has pleomorphic particles with a diameter of 150-700mm and has genomic sequence of 15948 nucleotides. The ribo-nucleoprotein is 14-23 nm thick and the envelope is 8-15 nm thick with 8.5-14.5 nm long (Dou *et al*., 2020). The structural proteins encompasses F (fusion protein), P (phosphoprotein), N (nucleocapsid protein), M (matrix protein), HN (haemagglutinin aminidase protein) and L (large/polymerase protein)(Figure 1). The other two C and V proteins are non-structural viral proteins(Zakian *et al*., 2016).

Nucleoprotein (N) is the main viral protein used in the development of diagnostic tests and is responsible for forming nucleocapsids. It is the most immunogenic and abundant protein but does not trigger a protective immune response (Abubakar *et al*., 2016). Haemagglutination enables the virus to bind to the cell receptor, while M protein is essential for nucleocapsids to be incorporated into virions during the viral budding process. Both F and H proteins are essential for activating a protective host immune response against the virus. In all strains of morbillivirus, the polymerase-associated (P) phosphoprotein is necessary for the development of an active transcription complex (Diallo, 2006).

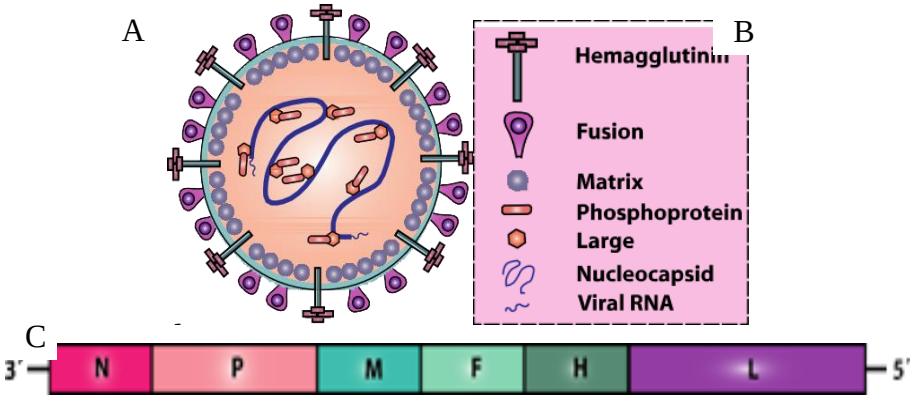

Figure 1: A schematic illustration of the PPR virus structure.

The arrangement of the viralproteins(A).Thenamesoftheviralproteinsinthevirusstructure(B).Theviralgenomeare shown(C).

Source: Munir *et al*.(2013)

2.3. Pathogenesis and clinical signs

PPRV has a strong affinity for lymphocytes and epithelial cells in the oropharyngeal lymph nodes, which leads to severe lesions in organ systems rich in lymphoid and epithelial tissues (Gulyaz and Ozkul, 2005). Suppression in lymphatic systems causes a reduction in immunity in infected animals, leading to secondary bacterial and parasitic infection. PPRV multiplies in the tonsils, pharyngeal, and mandibular lymph nodes after entering through the respiratory pathway. As it begins to develop in cells, apoptosis starts in infected cells (Munir *et al*., 2013).

As the virus circulates in the bloodstream, it spreads to internal organs, visceral lymph nodes, and the mucosa of the gastrointestinal system (Abubakar *et al*., 2012). In two to three days of infection, the circulating white blood cells decrease (leucopoenia). On concurrent days, necrotic lesions and congestion start in the gums and inside the lower lip (Gulyaz and Ozkul, 2005).

Studies have showed that the apoptosis of infected cells seems to play an important role in the pathogenesis of PPRV in goats and sheep. Virus spread to oral lesions has been reported in several studies (Gulyaz and Ozkul, 2005). (Ezeibe *et al*., 2008) demonstrated the presence of viral antigen in papules around the oral cavity, which is an indication of the predilection site for viral replication and tropism like the measles virus, a skin lesion causing virus in humans (Abubakar *et al*., 2012). Although this prediction is helpful to understand the pathogenesis of the disease, further studies are required to confirm that this is not due to other concurrent infections (Munir *et al*., 2013).

Clinical symptoms range from sub-acute in sheep to acute in goats, with a fever lasting 5-8 days (Ezeibe *et al*., 2008). In the beginning, nasal discharge is clear. However, as the nose is clogged by crust, it turns dark and sticky, which causes inflammation in the mucous membrane as well as respiratory distress. Involvement of the conjunctiva results in severe catarrhal conjunctivitis and matting of the eyelids. Infections in pregnant animals cause

abortion. The disease usually lasts longer than two weeks, with mortality rates ranging from 50 to 100% (Alemu *et al*., 2019).

In acute PPR infection, animals experience severe respiratory condition with terrible prognosis that often results in the death and incubation period last for 3-6 days (Radostitis *et al*., 2006). Symptoms in acute case include sudden fever (40-41.3°C), sneezing, lacrimation and nasal secretions. In 1–2 days necrotic lesions are seen in the oral and nasal cavities. Animals with such conditions exhibit mucopurulent secretions and a dry muzzle. Abortions and deaths can happen 7 days after a fever first appears (Kahn, 2005).

Clinical sigh with the sub-acute type of PPR often affects sheep. Sign of necrotizing ulcers in oral cavity seen and death is not common (Abubakar *et al*., 2017). Cattle may also have clinical signs that resemble rinderpest. Serologically, for example test of serum on competitive ELISA from cow populations in the Sudan shows a higher seroprevalence (42%) of PPRV (Ali *et al*., 2019). However, cattle are not likely to act as a reservoir host, maintenance host. In such case they cannot spread the disease and act as dead-end hosts (Sen *et al*., 2014).

The peracute PPR infection in camels was reported by Ismail (1990) from Egypt. Similarly, in 2004, a different outbreak occurred in eastern Sudan, which later spread to Somalia and Kenya (Khalafalla *et al*., 2010). The Peracute cases cause a high mortality rate and are characterized by sudden death, abortion, and diarrhea. Later, the molecular test confirmed PPRV lineages III and IV (Kwiatek *et al*., 2011).

2.4. Pathologic lesion

The pathologic lesion starts to develop in the mouth and may resolve in 48 hours or increase to other parts of the gastrointestinal tract. In severe cases, the large intestine is congested and forms zebra stripes (Ezeibe *et al*., 2008). In serious cases, erosion involves the vulva and vaginal mucosa. The formation of pus in the lung and enlargement of the lymph nodes and spleen may be seen. Diseased animals were crusted with secretions on their faces. Animals

become emaciated, and stomatitis is typically discovered at a late stage of the disease (Chowdhury *et al*., 2014).

PPR-specific histopathological lesions were found in the intestines, lymphoid organs, and lungs. Curtailing and dampening of villi in the GI tract and enteritis are developed. Lymphoid organs displayed partial to total loss of lymphoid follicles (Khan *et al*., 2018). Erosions and hemorrhages can be found in the abomasum, while erosions are less frequently seen in the initial part of the small intestine. Scattered bleeding along the large intestine's mucosal fold causes a stripe of congestion and a zebra-like appearance. The large intestine is more seriously impacted. The carcass emits a foul smell (Radostitis *et al*., 2006).

The respiratory tract is characterized by signs of bronchopneumonia, necrotic foci, tracheal obstruction, fibrinous deposits, serous and mucopurulent discharges, lymphadenopathy, and nodular, cystic, pneumonic, and engorged lungs. Histopathological lesions such as fibrinous pneumonia, bronchointerstitial pneumonia, bronchopneumonia, and interstitial pneumonia can be seen in the respiratory tract. Alveoli may be filled with oedematous fluid, macrophages, mononuclear cells, enlarged interalveolar septa, and intranuclear eosinophilia inclusion bodies (Khan *et al*., 2018).

2.5. Differential Diagnosis

Small-ruminant plague can be recognized by the presence of diarrhea and copious nasal discharge that emerge at the beginning of the rainy season. A tentative diagnosis is frequently made on the basis of clinical symptoms. Due to the similarity of clinical symptoms of PPRV with different diseases, the infection in sheep and goats can be confused with a number of diseases and conditions (Mondal *et al*., 2009). This may include rinderpest, pneumonia, bluetongue, contagious ecthyma, capripox, foot and mouth disease (FMD), and contagious caprine pleuropneumonia. Accordingly, those differential diagnoses need to be confirmed by laboratory diagnostic techniques (Radostitis *et al*., 2007).

Rinderpest is a viral disease caused by a Morbillivirus of the family *Paramyxoviridae* that affects sheep and goats when they have had close contact with infected cattle (Mondal *et al*.,

2009). PPR has clinical signs of rinderpest, and a laboratory test is needed to establish the diagnosis. Besides, Rinderpest was declared eradicated from the world in 2011 (WOAH, 2018).Pneumonic pasteurellosis and contagious caprine pleuropneumonia can be distinguished by a respiratory illness. Contagious caprine pleuropneumonia is a bacterial disease caused by Mycoplasma. It affects goats and is characterized by fever, difficulty breathing, and coughing. Diarrhoea and oral lesions are not commonly associated with the infection. Pneumonic pasteurellosis is a bacterial disease caused by Mannheimia hemolytica. It affects both sheep and goats and causes only respiratory signs associated with pneumonia (Khalafalla *et al*., 2010).

Foot and mouth disease (FMD) is a viral disease caused by an Apthovirus of the family *Picornaviridae* that affects all cloven-hooved animals. Clinical signs include lameness, lesions in the oral cavity. Respiratory signs and diarrhoea are not associated with the disease (Radostits *et al*., 2007). Bluetongue viral infections are caused by an Orbivirus, most commonly in sheep. They can manifest as reproductive illness and vascular disease, but do not cause diarrhoea and Sheep are most affected animals (Radostits *et al*., 2007).

Contagious ecthyma (Orf) is caused by a poxvirus and is characterized by vesicle and pustule formation on the lips, nostrils, face, eyelids, feet, and udders. It can be distinguished from Capripox by the absence of necrotic stomatitis and pock lesions. Nevertheless, differential diagnosis is not always achievable due to PPR-infected animals failing to exhibit all of the clinical symptoms (OIE, 2015).

It is necessary to undergo laboratory confirmation of PPR for a firm diagnosis in mixed and secondary bacterial infections. There are many laboratory techniques used to detect the PPV virus and virus antibodies (Malik *et al*., 2011). Comprehensive evaluations of the effects of vaccination campaigns with sero-surveillance, a history of the recent introduction of fresh stock, and the clinical as well as post-mortem signs of stomatitis can help the diagnosis (Albina *et al*., 2013).

2.6. Epidemiology of PPR

2.6.1. Geographic Distribution of PPR

PPR was first reported in the Ivory Coast in 1942 and then detected in various regions of Africa, the Middle East, and Asia. In West Africa, PPR is identified in Burkina Faso (2008), Ghana (2010), Nigeria (2007), and Senegal (2010) with the presence of viral nucleic acids or viral antibodies (Banyard *et al*., 2010; Libeau *et al*., 2014; OIE, 2015). According to El-Yuguda *et al*. (2010), PPRV infections in Nigerian sheep, goat, and camel populations have also been documented. It has been observed that the north of Burkina Faso has 28.5% antibody prevalence for PPRV (Sow *et al*., 2021).

PPRV is endemic in East Africa, where serological reports and molecularly lineage III and IV viruses have been identified in Kenya (1999 and 2009), Uganda (2005 and 2007), Ethiopia (1996), Sudan (2000), Uganda (2007), and Tanzania (2008 and 2010) (Swai *et al*., 2009; Osman *et al*., 2009; Khalafalla *et al*., 2010; Saeed *et al*., 2018).

In central Africa, on the basis of phylogenetic analysis, the virus was discovered in the Central African Republic (in 1999, 2005, and 2006), the Democratic Republic of the Congo (DRC), Rwanda (2006), Chad (1999 and 2006), Cameroon (2009), Gabon (2007), Chad (2007), and Burundi with the lineage IV virus (Banyard *et al*., 2010). In North Africa, PPRV was discovered in Egypt in 1987 and 1990 (El-Hakim, 2006). The molecular characterization of a new PPRV discovery in Egypt has revealed Lineage IV. Various outbreaks have been reported in Morocco, Algeria, and Tunisia (Baazizi *et al*., 2017).

In the Arabian Peninsula and the Middle East, an outbreak with a case mortality rate of 100% was reported in sheep and goats in 2002 (Housawi *et al*., 2004). Various serological surveys and outbreaks have been reported in Pakistan, North Jordan, Lebanon, Yemen, Oman, Qatar, and the United Arab Emirates in the Arabian Peninsula. Molecularly, the disease is categorized into Lineages III and IV (Kinne *et al*., 2010; Benfield *et al*., 2023). In China,

outbreaks in ibex (*Capra ibex sibirica*), argali sheep (*Ovis ammon*), and goitered gazelle (*Gazella subgutturosa*) occurred (Xia *et al*., 2016).

PPR is the most reported disease of small ruminants in India, with the highest reported outbreaks in goats showing various percentages of mortality and morbidity (Balamurugan *et al*., 2021). PPRV outbreaks are most frequently recorded in Iraq and Iran and are classified as lineage IV (Alidadi *et al*., 2021).PPR has spread over 70 countries across Asia, Africa, and the Middle East, reaching Europe in 2016 (Georgia). As of May 2022, the disease had been eradicated from 59 nations (WOAH, 2022) (Figure 2).

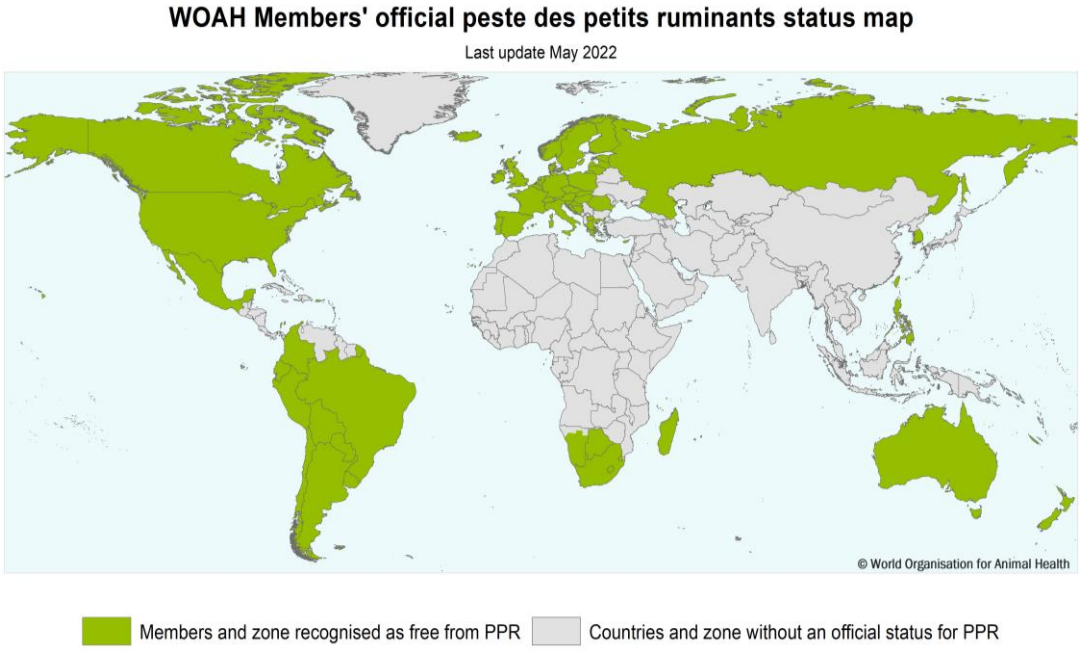

Figure 2: Official PPR status map of WOAH members countries

Source: WOAH (2022)

Madagascar, Lesotho, Mauritius, Eswatini, and South Africa are currently disease-free countries in Africa; Namibia is the only country with zonal PPR-free status (seven free zones) (Figure 3).

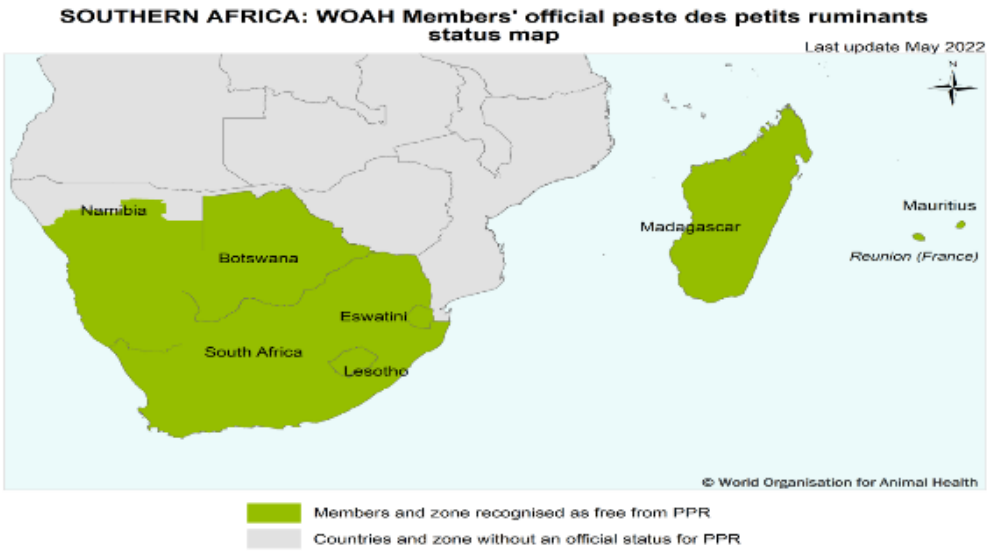

Figure 3: Official PPR free map of WOAH members African countries

Source: WOAH (2022)

2.6.2. Seasonal occurrence of PPR

There is a considerable seasonal difference in PPR occurrences in different geographical areas (Abraham *et al*., 2005). PPR is more common during the winter season due to the related cold in subtropical places and the dry season in tropical countries, when nutritional access is limited. This causes stress in animals, which increases the likelihood of PPRV infection. In addition to husbandry conditions and the ability of the small ruminant owner to raise the animals, the illness outbreak reoccurred due to weather-related factors (Abubakar *et al*., 2016; Balamurugan *et al*., 2021; Govindaraj *et al*., 2023).

PPRV may circulate silently without causing mortality, but as the host's immunity drops, the availability of younger animals and the confinement of newborns with older animals increase sporadic epidemics. A serum assessment in Ethiopia revealed that the presence of PPR antibodies in young aged 4–24 months suggests the virus is maintained in the young population. This suggests that an increase in the number of young small ruminants in the flocks during the associated kidding season might increase the virus activity and its virulence in the susceptible population (Waret-Szkuta *et al*., 2008).

Seasonal movement of animals within the same country or across borders is a factor in disease transmission. Animals typically travel large distances in search of feed and water during the dry season. In humid areas, PPR reveals itself as an epizootic disease with substantial morbidity and mortality. PPR is frequently fatal and appears as a subclinical condition in dry and semi-arid regions (Diallo, 2006). Because of a decline in natural immunity (maternal antibodies), young animals between the ages of three and four months are more susceptible to PPRV (Saliki, 2022).

Factors such as seasonal problems associated with the cold and rainy seasons, the introduction of new animals, flocks returned from markets, and confinement or limited movement owing to nutritional difficulties contribute to PPR outbreaks in the flocks (Radostits *et al*., 2007). In sub-tropical areas, disease is common during the winter season (Kwiatek *et al*., 2011). According to the FAO report (2015), PPR is associated with increased animal movement for commercial and trade purposes and nomadic movement in search of food and water.

PPR outbreaks are reduced during the rainy season due to decreased animal movement, which increases fodder availability and improves nutritional and health status. In the dry and dusty season, disease spreads and cases increase due to poor nutrition and stress. In Pakistan, most instances of PPR appear with the start of the summer season, peak between April and July, and subsequently decline (Abubakar *et al*., 2011). In India, the disease occurs throughout the year, with the maximum outbreaks occurring during the winter season prior to the onset of the rainy season (Govindaraj *et al*., 2023). In Ethiopia, PPR outbreaks were more common during the dry season (Abraham *et al*., 2005; Alemu, 2014; Senbeto, 2022).

2.6.3. PPR host range and its transmissions

PPR primarily affects goats and sheep. The disease can also affect camels, cattle, and pigs, although pigs and cattle are unable to excrete the virus. Infection of wild animals such as gazelles, impalas, bushbucks, and springbucks was also reported in different areas (Banyard

et al., 2010; Balamurugan *et al*., 2012). PPR can expand geographically where wild and domestic small ruminants share their shelter and rangelands (Mahapatra *et al*., 2015).

PPRV infection has been documented in cattle and buffaloes, with varying serological frequency. Calves infected with PPRV developed subclinical symptoms and specific anti-PPRV antibodies. Cattle, being a dead-end host for PPRV, are unlikely to operate as a PPRV reservoir or play a role in PPRV maintenance and transmission. The virus was not discovered in swabs; therefore, cattle are unlikely to pose a risk of transmitting PPRV to other species (Khan *et al*., 2008; Sen *et al*., 2014; Ali *et al*., 2019).

There have been several cases of camels infected with PPRV. A serological examination of the camel population in Ethiopia discovered PPRV antibodies, indicating the presence of PPRV infection in camels (Roger *et al*., 2001). An outbreak of PPRV in Ethiopian camels was observed, resulting in a highly contagious disease marked by pneumonia, lacrimation, and respiratory distress with a low mortality rate (Roger *et al*., 2001). PPRV antibodies were also reported from serological surveys in Nigeria (Woma *et al*., 2015), Sudan (Intisar *et al*., 2017), and Iran (Zakian *et al*., 2016).

Khalafalla *et al*. (2010) found that PPR in camels was clinically marked by abrupt mortality of apparently healthy animals, yellowish and later bloody diarrhea, and abortion. In other cases, moderate indications of subcutaneous edema and submandibular enlargement, chest pain and infrequent coughing, decreased milk production and weight loss, and increased water consumption developed and lasted 10–14 days. The mortality rate varied depending on the location, and all age groups, genders, and breed groups were affected (Khalafalla *et al*., 2010).

As shown in Figure 4, PPRV infection in wild animals has been documented in African nations (Gur and Albayrak, 2010; Jones *et al*., 2021). Serological evidence has been observed in Tanzanian African buffalo (*Syncerus caffer caffer*), blue wildebeest (*Connochaetes taurinus*), impala (*Aepyceros melampus*), common tsessebe (*Damaliscus lunatus*), and Grant gazelle (*Nanger granti*) (Jones *et al.*, 2021).

According to Omani *et al*. (2019), a virus was found in Sudan's Dorcas gazelles (*Gazella dorcas*). Clinical cases have been seen in domestic yaks (*Bos grunniens*) and free-ranging Sindh ibex (*Capra aegagrus*) in Pakistan (Abubakar *et al*., 2016; Omani *et al*., 2019). Wild goats (*Capra aegagrus)* have been affected in Iraq (Hoffmann *et al*., 2012), whereas wild goats and wild sheep (*Orientalis vignei*) have been frequently infected in Iran as a result of disease outbreaks (Marashi *et al*., 2017).

PPRV is transmitted through direct contact or through contaminated objects between healthy and sick animals. It is more likely to occur in groups of susceptible animals or congregations of flocks and can be excreted in the feces approximately 10 days after the onset of fever. Large amounts of the virus are found in loose feces, eye, nose, and mouth secretions, and other bodily fluids. Oronasal discharge promotes the transmission of viruses. The disease is more likely to occur in groups of susceptible animals or congregations of flocks (Abubakar *et al*., 2012; Munir *et al*., 2013; Biruk, 2014; Saeed *et al*., 2022).

The disease can be spread indirectly by licking bedding, water, and feed troughs, as well as the milk of sick dams. Heavy outbreaks in endemic countries are associated with free animal movements and infected migratory animals in search of feed and water. Trans-boundary movements allow the disease to spread across borders, infecting nearby nations that share similar markets around the border. The risk of infection and clinical signs in affected animals are elaborated by age, species, and season (Biruk, 2014; Zakian *et al*., 2016; Munibullah *et al.,* 2021).

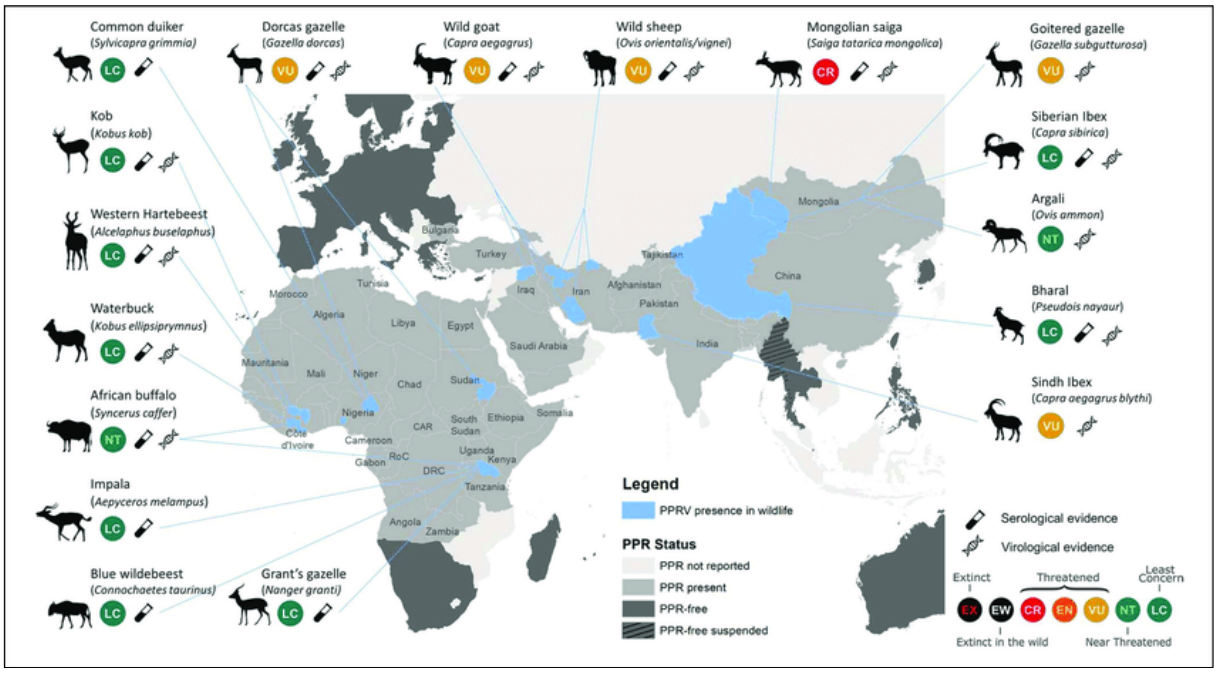

Figure 4: Map illustrating reports of PPR virus detection in free-ranging wildlife species. CR=Critically Endangered; EN=Endangered; VU=Vulnerable.

Source: Fine *et al*. (2020)

2.7. Diagnosis of PPR

Observations, symptoms, and laboratory confirmation utilizing various serological and molecular approaches all contribute to the diagnosis of PPR. Regular laboratory diagnoses are virus isolation, AGID, nucleic acid hybridization, hemagglutination, immunochemical detection, virus neutralization, and ELISA. Vero dog cell lines and African monkey kidney cell lines are used to isolate the PPR virus (Megersa *et al*., 2011; OIE, 2015; Mahapatra *et al*., 2015).

Immune capture ELISA (Ic-ELISA) is used to detect antigens in animals, and competitive ELISA (c-ELISA) and the viral neutralization test (VNT) are used to detect antibodies against PPR (Munir *et al*., 2013). PPRV molecules are identified using loop-mediated isothermal amplification techniques and a real-time polymerase chain reaction (RT-PCR) assay based on the sequence of the N protein gene (Ezeibe *et al*., 2008). The RT-PCR assay based on the

sequence of the N protein gene is the most rapid method for viral nucleic acid sequencing (Afera *et al*., 2014).

2.7.1. Serological detection of PPR

For the detection or confirmation of PPRV, a variety of serological tests are currently available. Competitive ELISA (c-ELISA) and the viral neutralization test are laboratory methods used to determine the presence of antibodies against the virus (Baron *et al*., 2011). The competitive PPRV-specific anti-H monoclonal-based ELISA (cH-ELISA) and virus neutralization assays are now recommended by the OIE for the identification of PPRV antibodies (OIE, 2019).

There are two types of competitive ELISAs (c-ELISA) based on mAbs that recognize virus proteins. The mAb recognizes the N protein, which uses recombinant N protein produced as the antigen. The other is a PPRV (vaccine strain) antigen made of a pure or partially purified viral attachment protein H-specific mAb. All of the tests are based on the idea that PPRV antibodies in test sera can prevent the mAb from adhering to the antigen. A competition ELISA based on a monoclonal antibody targeted against the virus nucleoprotein is the most accurate and efficient technique for antibody detection (OIE, 2015; Chukwudi *et al*., 2022).

The virus neutralization test (VNT) requires cell and virus cultures and takes several days to produce a response (Albina *et al*., 2013). Utilization of a polyclonal antibody is used to capture antibodies in the first Ic-ELISA for the purpose of discovering PPRV. The standard neutralization test is carried out on 96-well microtiter plates. Roller tubes are used on vero cells as well as primary lamb kidneys for cultures. There will not be any CPE for the serum titration in wells where the serum has successfully neutralized the virus during the test. Any level of CPE means that the virus has not been neutralized by serum. The neutralizing titer is the dilution of serum that neutralizes the virus in half the wells. A neutralizing titer of greater than 10 is positive (OIE, 2019).

2.7.2. Detection of PPR antigen by using ELISA

A sandwich enzyme-linked immunosorbent assay (s-ELISA) based on a monoclonal antibody specific to PPR allows for the effective identification of antigen in the tissues and secretions of infected small ruminants. A PPR-specific monoclonal antibody (clone 4G6) to an epitope of nucleocapsid protein is used in a sELISA test that has been created. Polyclonal sera are used in the test to isolate the antigen from clinical samples (tissues and swabs). PPR-specific monoclonal antibodies are used to identify captured antigens from clinical samples (Singh *et al*., 2009; Prajapati *et al*., 2020).

An alternative form of antigen ELISA that has been used more commonly is immunocapture ELISA (Abraham *et al*. 2005). It delivers a trustworthy result in two hours with no more than a 50% reduction in response on pre-coated plates and samples stored at room temperature for seven days. Because PPR and RP viruses can affect the same animal species and have similar geographic distributions, the immunocapture ELISA's fast differential identification of PPR and RP viruses is essential. The simplicity, robustness, speed, and specificity of this test are its main advantages. It is appropriate to regularly diagnose PPR and RP using field samples such as ocular and nasal swabs (OIE, 2019; Logozzi *et al*., 2020).

2.7.3. Isolation of PPR virus

For PPRV isolation, primary lamb kidney, ovine skin tissues, and vero cells are the most frequently used cell culture methods. To increase the sensitivity of PPRV isolation, the virus can develop in lamb's or goat's kidney cells (OIE, 2019). Other continuous cell lines were also modified to promote the proliferation of the peste des petits ruminants virus, including the Madin-Darby bovine kidney epithelial cell line and the baby hamster kidney 21 fibroblast cell line (MDBK and BHK-21) (Diallo, 2006).

A Vero cell derived from African green monkey kidney is the most commonly utilized cell line for PPRV. The SLAM is used preferentially by wild-type morbilliviruses to bind to the host after the identification of a protein receptor on the cell surface of morbillivirus-

susceptible hosts. However, it has been shown that morbillivirus can infect and replicate in epithelial cells of other tissues besides lymphoid tissues, which are the main sites of morbillivirus replication (Baron *et al*., 2011).

PPRV has been isolated and maintained using primary cultures of lung, kidney, and goat cells. However, the adoption of cell lines for PPRV isolation has been encouraged due to the limitations of primary cell cultures, particularly the African green monkey kidney (Vero) cell line. Vero cells expressing SLAM proteins have been used as a highly effective method of isolation and propagation as the primary receptor used by MV, CDV, and RPV wild-type strains (Diallo, 2006; Banyard *et al*., 2010; Mohammed *et al*., 2022).

A cell line stably expressing the goat SLAM protein was created for the isolation of PPRV in response to the identification of SLAM as a potential protein for the isolation and dissemination of PPRV (Adombi *et al*., 2011). Using clinical samples of sick sheep and goats with probable PPR specimens obtained in 2008 and 2009 from various areas in Nigeria and Cote d'Ivoire, respectively, initial testing revealed a high sensitivity for separating PPRV from pathological samples, indicating that SLAM has recently been used in place of earlier techniques for PPRV isolation and propagation (Adombi *et al*., 2011).

2.7.4. Molecular epidemiology using RT-PCR

In the PPRV outbreaks, genetic characterizations of the virus have been done through epidemiological assessment of lineages based on technological improvements, increasing awareness, and the availability of molecular tools. As a result, there have been claims that a dominant lineage of PPRV has appeared in new areas (Kwiatek *et al*., 2011). Undoubtedly, the discovery of PPR in new areas is a significant obstacle to the expansion of sustainable agriculture across Africa (Banyard *et al*., 2010).

On a molecular basis, the PCR approach has proven to be the most popular and effective way to detect PPRV. It is a good option to detect virus on deteriorated tissue samples, which makes the polymerase chain reaction (PCR) crucial for the analysis of poorly preserved field

materials. The test involves cycles of DNA denaturation, primer annealing, and extension of a DNA polymerase by reverse transcription polymerase chain reaction (RT-PCR), which transforms RNA into DNA (Niyokwishimira *et al*., 2019).

Loop-mediated isothermal amplification (LAMP) is an isothermal, autocycling, strand displacement DNA amplification technique that can be performed at a constant temperature. In the case of PPRV, a reverse transcriptase LAMP assay based the process on the M-protein and N-protein genes (Ashraf *et al*., 2016). The lineage classification of PPRV is based on the sequence analysis of the F and N genes (Couacy-Hymann *et al.,* 2019). Both are well-conserved genes, with 10% mean variability between the most distantly related sequences (Kwiatek *et al.,* 2011). Couacy-Hymann *et al*. (2019) present RT-PCR employing primer sets specific to the fusion protein gene (F) and phosphoprotein (P) universal primer to detect and distinguish between PPR and RP.

According to molecular analysis, the PPRV genome can be divided into four lineages (I–IV) based on nucleoprotein genes (Kwiatek *et al*., 2011; Couacy-Hymann *et al*., 2019). Only one serotype of the virus has been identified among its four recognized lineages. The assessment of lineage distribution is used for effective vaccination in the targeted area (Munir *et al*., 2013).

The development of technology for creating sequences from samples allows for easy sequencing techniques. This allows the assessment of the genomic region of the virus from the sample (Banyard *et al*., 2010). Based on this, Bayesian analysis of the virus's whole genome indicates the emergency of PPRV in the early 20th century (Couacy-Hymann *et al*., 2019). Accordingly, the first PPRV lineage to split from a parent virus was lineage III PPRV, according to a Bayesian phylogenetic study of all PPRV lineages. Occurrences of the PPRV estimations indicate that Senegal is the lineage I root, Nigeria or Ghana is the lineage II, Sudan is the lineage III, and India is the lineage IV root location (Muniraju *et al*., 2014).

2.8. Prevention and control of PPR

Control of the PPR is important both in terms of reducing disease incidence and the long-term goal of disease control. To control PPRV occurrences in different areas, understanding the disease epidemiology, vaccinating on time, and linking the epidemiology with laboratory tests are necessary for controlling PPR (Singh *et al*., 2009). As part of traditional PPR management of disease, pastoralists isolate affected animals from other flocks and employ hot stones, locally accessible therapeutic plants, and antibiotic capsules (Kihu *et al*., 2015). The target in the control and eradication program aims to reduce disease intensity through targeted vaccination and the implementation of mass vaccination campaigns with high levels of vaccination coverage (OIE, 2019).

During PPR outbreaks, controlling animals' movements and administering ring vaccination to susceptible animals is helpful. However, controlling infectious diseases in wild ruminants through restriction of the movement of free-ranging wildlife is inefficient. Burying the contact fomites and carcasses, as well as sterilizing items, is necessary during outbreaks (Abraham *et al*., 2005). Vaccinating free-ranging wildlife is necessary in order to build up herd immunity. Vaccinating vulnerable captive animals is helpful to control PPRV in domestic animals (OIE, 2019).

Globally, Pan-Africa is targeted to control and eradicate PPR by 2030. Based on this, all regions and nations employ a four-stage strategy with well-coordinated actions. The phase is comprised of four distinct stages that combine prevention and control with diminishing levels of epidemiological risk. In the control of the disease, the epidemiological setting within local socioeconomic contexts is beneficial for its distribution among the various farming systems. In order to prevent the spread of the PPR virus, control measures include mass vaccination at probable sources of virus propagation. After eradication from the national flock, there should be no clinical outbreaks, and diagnostic testing would show that there is no virus circulation in the populations of domestic animals and wildlife (FAO, 2021).

The inactivated vaccine is utilized in non-endemic areas, whereas live attenuated vaccination is used in endemic areas (Cosseddu *et al*., 2016). Sheep and goats that have received the live attenuated PPR vaccine and those recovered from the infection exhibit active, lifelong immunity (Chen *et al*., 2010). Utilizing a homologous vaccine during pregnancy is both safe and effective (Saravanan *et al*., 2010).

2.9. PPR in Ethiopia

In Ethiopia, the first clinically suspected PPR was identified in 1977 in a goat herd in the Afar region. In 1991, the finding of a PPR cDNA probe in the lymph nodes and spleen samples obtained from outbreaks at a holding facility close to Addis Abeba provided conclusive evidence of the virus' existence in Ethiopia (Roeder *et al*., 1994; Abraham *et al*., 2005; Munir *et al*., 2013). Since then, the locally circulating virus has been genetically clustered within lineage III (Banyard *et al*., 2010).

Mass immunizations are currently the preferred method of PPR vaccination to prevent the virus from spreading. Losses of small ruminants are anticipated to be reduced by the intervention of control. The federal government offers the vaccination in collaboration with the FAO and numerous NGOs. To meet vaccination programs, the National Veterinary Institute (NVI) is producing doses of live attenuated tissue culture homologous PPR vaccine (PPR 75/1 Vero 76, attenuated, freeze dried) as part of a progressive control campaign based on repeated vaccination of all susceptible small ruminants (Biruk, 2014).

The major challenge in controlling PPR in the region is the lack of adequate information on the dynamics of the disease and the inefficiency of early detection. Additionally, several agro-ecological conditions, the seasonal occurrence of the disease, the movement of infective small ruminants within the country and cross-border, and a seasonal movement in search of pasture and water in pastoral areas are also challenges to controlling this widely spreading disease (Alemayehu *et al*., 2015).

The National Veterinary Institute (NVI) of Ethiopia produces lyophilized PPR virus strain vaccine cultured on vero cells and freeze-dried vaccine. The vaccine is available in 5 ml or 20ml vials of 100 doses and should be stored at a temperature of -20^{o}C before use. The PPR vaccine is reconstituted and diluted in 100 ml of cool and sterile saline water, and 1 ml of the diluted vaccine is injected subcutaneously for all goats and sheep above 6 months of age. Annual vaccination is recommended for apparently healthy animals, and immunity develops eight days after vaccination and lasts for three years (https://www.nvi.com.et/). In general, seroprevalence studies on PPR in small ruminants from different parts of Ethiopia are summarized as shown in Table 1.

Table 1: Some seroprevalence studies on PPR of small ruminants in different areas

Authors and year	**Study area**	**Prevalence (%)**
Mohammed*et al*. (2022)	South Ethiopia	54
Megersa *et al*. (2011)	Afar	38.3
	Gambela	35.1
Faris *et al*. (2012)	Afar	1.7
Waret-Szkuta *et al*. (2008)	Afar	15.3
	Amhara	4.6
	Benishangul Gumuz	8.0
	Oromia	1.7
	SNNPR	1.8
	Somali	21.3
	Tigray	15.3
Agga *et al*. (2019)	Amhara	28.4
Gelana *et al*. (2020)	Oromia	5.71
Mebrahtu *et al*. (2018)	South Omo	30.8
Gari *et al*. (2017)	Oromia	48.43
Yalew *et al*. (2019)	Benishangul gumuz	85.12

2.10. Research Gaps

The effective use of PPR live attenuated vaccines can cross-protect against all four PPRV lineages and produce lifelong protective immunity in sheep and goats that have received the vaccination. The currently available attenuated vaccines are widely utilized, despite their inability to distinguish between diseased and vaccinated animals (DIVA) (Hodgson *et al*., 2018). To facilitate the general application of PPR vaccinations and to aid in the distinction between vaccinated and naturally infected animals, DIVA vaccines must be produced.

Field exploration of epidemiological aspects is another area of research that should be supported to more accurately determine the possible epidemiological impact of other domestic animals or wildlife species. Studies on the socioeconomics of PPR, the effects of the disease, and the cost-benefit analysis of control and eradication should be conducted. In general, a report of PPR from different areas in each year and vaccination strategies that were applied during the implementation of the global strategy would yield a significant amount of information for the general improvement of small ruminant health and intervention strategies for other diseases and should be properly reviewed.

3. MATERIALS AND METHODS

3.1. Study area

This study was conducted in three districts of the Borena zone, namely Dubuluk, Elweye, and Yabelo. The Borena Zone is located in the southern portion of Oromia Regional State (Figure 5) at 3º 26' - 6º 32' N latitude to 36º 43' - 40º 46' E longitude. In relation to its surroundings, the zone is located north of Kenya, southeast of the Southern Nations, Nationalities, and Peoples Regional State (SNNP), southwest of the West Guji Zone, and northwest of the Somali Regional State. Yabelo town is the capital city of the Borena zone (BZAO, 2022).

The majority of the Borena Zone is situated below 1500 meters above mean sea level and receives bimodal rainfall, namely, long and short rainfall seasons. Short rains are anticipated between September and November, while the long rainy season occurs between March and May. In the area, available livestock breeds include cattle, sheep, goats, and camels. Estimated hosts are 1,494,437 sheep, 2,306,672 goats, 2,338,998 cattle, and 355,837 camels (BZAO, 2022).

Yabelo was one of the selected districts for the present study. The district is situated 575km south of Addis Ababa. The elevation spans from 943 to 2400 m.a.s.l. An environment that is semi-arid is produced by inconsistent rain that falls throughout two seasons with fluctuating quality and distribution. The annual temperature is between 19°C and 42°C. The district hosts approximately 192,746 cattle, 125,180 sheep, 198,935 goats, and 7,955 donkeys (BZAO, 2022).

The second district included in the study area was Dubuluk district. It is about 638 kilometers to the south of Addis Ababa in the Borena zone and located at 4° 22' 0" N latitude and 38° 17' 59" E longitude at an altitude of 1480 meters above sea level. The district has about 134,244 sheep, 154,542 cattle, 187,459 goats, and 18,103 camels (BZAO, 2022).

The other was Elweye district, which was 30km southwest of Yabelo town. The district has 129,555 cattle, 104,281 sheep, 136,559 goats, and 21,354 camels. Small ruminants make up the majority of the livestock in the area (BZAO, 2022).

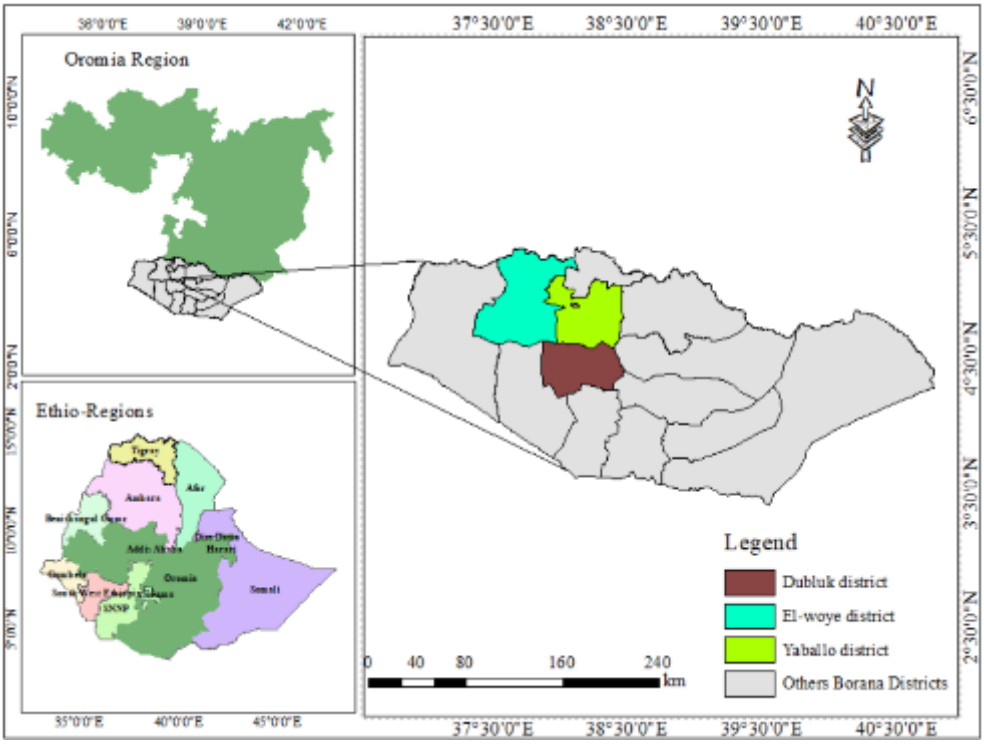

Figure 5: Map of study areas

3.2. Study population

In the present study, sheep and goats were used in the serological examination found in the Borena zone. Sheep and goat in the study area were reared with pastoral production system which are local breeds. The animal browse on local pastures and uses communal public water sources. Animal owners and attendants were involved in the questionnaire survey.

3.3. Sample size determination

The sample size required for the study of seroprevalence was computed according to Thrusfield (2005).

$$n = 1.96^2 \frac{Pexp(1 - Pexp)}{d^2}$$

Where: n is = sample size, Pexp= expected prevalence, d= Desired absolute precision at 95% confidence interval, 50% expected prevalence considered in this at a 95% confidence interval and 5% of absolute precision. The computed sample size was 384 small ruminants blood samples.

3.4. Sampling strategies

3.4.1. Herd size and study unit profiling

The flocks were categorized as small size (less than 40 animals), medium size (40–75 animals), and large size (> 75 animals), as mentioned by Negash and Dubie (2021). The age of the study animals was determined by using dentition according to ESGPIP 2009 (Annex 3) and categorized into young (1 year), adult (1-3 years), and old (>3) (Husen *et al*., 2018). The body condition of the animals was recorded (Annex 4) and categorized as poor, medium, or good (ESGPIP, 2009; Yasin *et al*., 2017).

The districts were selected purposively based on the small ruminant populations, transport access and information on security problems (Table 2). The lists of village administrations (*Kebeles*) found within the districts were obtained from each district agricultural office, and two *Kebeles* were randomly selected from each, which encompasses six *Kebeles* in total. Simple random was applied to the select Peasant Associations (locally known as *Olla*) while household that have small ruminants been purposively selected. Sample random sampling was employed to pick up small ruminants, and a blood sample was collected.

Table 2: Number of sampled small ruminants and interviewed population

District	Small ruminants population (2021/22)		No. of sampled animals	*Kebele*	No. of Interviewed respondents
	Sheep	Goats			
Yabelo	125,180	198,935	128	Dida Yabelo	13
				Dololo Hola	14
Elweye	104,281	136,559	128	Elweye Golba	12
				Hidi Ale	15
Dubuluk	134,244	187,459	128	Lafto	14
				Goro Dada	13
Total sample size			384		81

3.4.2. Sampling for questionnaire survey

Owners of all households from which sampling was done were automatically considered for the questionnaire survey. Accordingly, a total of 81 pastoralists were interviewed.

3.5. Study design

This study used both retrospective and cross-sectional study designs. A cross-sectional study design was employed from December 2022 to June 2023 to collect epidemiological data of questionnaires and blood samples for serological analysis. The five-years retrospective (2018–2022) PPR outbreak data collected using DOVAR II, which is part of routine passive surveillance were obtained from the Ministry of Agriculture to analyze the outbreak that occurred in the country as well as in the study area. DOVAR-II is a real-time and web-based disease reporting mechanism in which information is collected and filled out by animal health workers (DOVAR-II focal personnel) in the districts. Thus, it is aimed at supporting the declaration of disease status for the purpose of finalizing eradication programs. This retrospective report includes different outbreak data arranged in months, years, regional

states, zones, and wereda, as well as the number of cases, deaths due to PPR, and the vaccine dose used.

3.6. Data collection

3.6.1. Sample collection and transportation for serological analysis

Animals were carefully restrained, and blood samples were collected for serological analysis. A total of 384 blood samples were collected from small ruminants. The serum samples were collected using a plain vacutainer tube from the jugular vein of sheep and goats. During blood collections, data were collected related to potential risk factors such as animal body condition, species, age, sex of animal, herd size, introduction of new animals, water sources, and access to markets, shortage of veterinary services, and vaccine status of the animal (Annex 1).

The vaccination status of small ruminants was gathered from different sources, including the owner and their relevant district agricultural offices. In addition to this, the five-year (2018–2022) PPR vaccination record was also collected from the Ministry of Agriculture, which confirms that 10,000 PPR vaccine doses were utilized in the Borena zone. Even though the results of c-ELISA could not differentiate the antibodies due to vaccines or natural infections, the results were categorized based on the animal's history of vaccinations.

Other information related to districts, kebele (village name), and sample codes was recorded and labeled properly. The blood samples were kept in a slanted position overnight for serum separation. Then, the serum was decanted and aliquoted into 2 ml of cryovials at the Yabelo Pastoral and Dryland Agriculture Research Center before transportation and stored at -20^{o}C.

Finally, the collected serum samples were transported to the AHI using an ice box containing ice packs for serological analysis.

3.6.2. Serological test

Antibodies against PPRV were detected using competitive ELISA kit (manufacture of IDvet, 310, rue Louis Pasteur-Grabels, FRANCE; ID Screen® PPR Competition; Sensitivity= 94.5, Specificity=99.4%) as recommended by Libeau *et al*., 1995.This diagnostic kit is designed to detect antibodies directed against the nucleoprotein of the PPR virus. It can be used with sheep, goat and swine serum or plasma. While the sample to be tested and controls were added to microwells, which are coated with purified recombinant PPR nucleoprotein (NP), the anti-NP antibodies, if present, form an antibody-antigen complex. Subsequently, an anti-NP-peroxidase conjugate was added to fix the remaining free NP epitopes, forming an antigen-conjugate-HRP complex. After being washed, substrate solution and stop solution were subsequently added, and the color formed depended on the quantity of specific antibodies present in the sample. As a result, in the presences of antibody no coloration was formed while yellow color indicates no antibodies against PPR. The obtained result was read by the microplate at 450nm (Libeau *et al*., 1995).

To perform the c-ELISA test it began by adding the sample and control to the ELISA wells. Next, the microwells were filled with an anti-NP-peroxidase (HRP) conjugate and incubated, then washed with a wash solution after incubation to remove any extra conjugate. Then, a substrate solution was added, and the quantity of particular antibodies present in the sample was determined based on the coloration. A stop solution was added to each well to stop further reactions. The optical densities (ODs) were measured with an ELx800BIOTIC ELISA Reader on a microplate photometer at a wavelength of 450nm, and the findings were expressed as the sample positivity percentage (S/N%). Samples with the S/N% was less than 50% regarded as positive and negative those greater than 60% or uncertain that shows between 50% and 60%.

The OD (optical density) values of each sample converted to S/N % by using the following formula:

S/N % = [OD sample / OD NC] X 100

3.6.3. Collection of retrospective epidemiological data on PPR outbreaks

The retrospective data on the PPR outbreaks recorded from 2018 to 2022 through national surveillance systems were used for the present study. And, this data source was the Ministry of Agriculture, Ethiopia.

3.6.4. Questionnaire survey

Structured questionnaires were prepared to perform the survey (Annex 2). Each interview was made face-to-face during the time of house-to-house visit. Enumerators use Afan Oromo for all communications with respondents. Participants were interviewed for information related to their socio-cultural activities as well as to elicit data on the herd size, age, and sex of the flock, health conditions, grazing management, introduction of new animals, accessibility to veterinary services, clinical signs associated with PPR infection, and the number of sick and dead animals.

3.7. Data management and analysis

Collected data from the field sites, retrospective data, and laboratory data were stored in Microsoft Excel 2010 and coded for analysis. Data collected from household surveys with closed-ended questions was coded and entered into an Excel spreadsheet. The responses to open-ended questions were categorized based on similarities and coded. All data analyses were performed using STATA statistical software (Version 14.0, STATA Corp., College Station, Texas, 77845, USA). Univariable logistic regression was used to assess the association of the risk factors with the disease, and the significant associations (P-value < 0.05) were further tested by a multivariable logistic regression model. The spatial distribution of the disease in the various regions of Ethiopia was examined, and maps were produced using QGIS version 3.22.6. In this study, a computed P-value less than 0.05 at the 95% confidence interval and a 5% degree of precision were considered statistically significant.

3.8. Ethics statement

The study was carried out in accordance with the Animal Research Ethics Review Committee of the College of Veterinary Medicine and Agriculture of Addis Ababa University and ethical approval for the study was ensured by the approval certificate with reference number VM/ERC/04/15/2022indicated in Annex 7. The owners were informed about the purpose of the study and consent was sought. The samples for this investigation were carefully gathered without causing any harm to the animals and in accordance with all ethical standards for sample collection and sampling methods.

4. RESULTS

4.1. Serological study of PPR

4.1.1. Prevalence

The overall seroprevalence of PPR virus antibody in nonvaccinated small ruminants was 32.1%, while the seroprevalence in small ruminants with an unknown history of vaccination was 45.5%. However, the seroconversions in small ruminants with a history of vaccinations against PPR were 68.8% (Table 3).

Table 3: Seroprevalence of PPR in sheep and goats based on vaccination status

Districts	**Vaccination status**	**Sheep**		**Goat**		**Overall**	
		No. tested	Positive (%)	No. tested	Positive (%)	No. tested	Positive (%)
Yabelo	Nonvaccinated	25	13(52)	86	32(37.2)	111	45(40.5)
	Unknown	-	-	17	8(47.1)	17	8(47.1)
Dubuluk	Nonvaccinated	62	14(22.6)	61	16(26.2)	123	30(24.4)
	Unknown	5	2(40)	-	-	5	2(40)
Elweye	Vaccinated	24	11(45.8)	104	77(74)	128	88(68.8)
Total nonvaccinated		87	27(31)	147	48(32.7)	234	75(32.1)
Total unknown status		5	2(40)	17	8(47.1)	22	10(45.5)
Total vaccinated		24	11(45.8)	104	77(74)	128	88(68.8)

4.1.2. Risk factors of PPR seroprevalence in nonvaccinated populations

A univariable logistic regression was run to identify the possible individual risk factors for seropositivity to the PPRV antibody. Accordingly, the districts, shortages of vet services, animal origin, old age, and medium sized flocks were statistically significant risk factors with a p-value < 0.05 (Table 4).

Table 4: Univariable logistic analysis of risk factors for PPR positivity in nonvaccinated populations

Risk factors	Category	Number of sampled	Number of Positive (%)	OD (95% CI)	P value
Districts	Dubuluk	123	30(24.4)	Ref.	
	Yabelo	111	45(40.5)	2.1(1.2-3.7)	0.009
Species	Ovine	87	27(31)	Ref.	
	Caprine	147	48(32.7)	1.07(0.65-1.9)	0.798
Sex	Female	209	69(33)	Ref.	
	Male	25	6(24)	0.6(0.2-1.7)	0.364
Body conditions	Good	12	3(25)	Ref.	
	Medium	106	32(30.2)	1.3(0.3-5.1)	0.710
	Poor	116	40(34.5)	1.6(0.4-6.2)	0.511
Age	Young	54	16(29.6)	Ref.	
	Adult	135	32(23.7)	0.7(0.4-1.5)	0.399
	Old	45	27(60)	3.6(1.5-8.2)	0.003
Flock Size	Small	153	22(14.4)	Ref.	
	Medium	66	49(74.2)	17.9 (8.4-35.1)	0.000
	Large	15	4(26.7)	2.2 (0.6-7.4)	0.218
Animal origin	Born	183	44(24)	Ref.	
	Bought	35	22(62.9)	4 (1.4-11.5)	0.009
	Gift	16	9(56.3)	5.3(2.5-11.5)	0.000
Shortages of vet services	No	149	38(25.5)	Ref.	
	Yes	85	37(43.5)	2.3 (1.3-3.9)	0.005

The statistically significant risk factors with univariable logistic analysis (P-value < 0.05) were further analysed by the multivariable logistic regression model for the potential risk factor. As a result, animal origin, old age, medium-sized flock, and shortage of veterinary services were statistically significant potential risk factors for PPRV seroprevalence (P < 0.05).

Accordingly, the odd of being seropositive for PPRV infection was 7.3 times higher in older animals (OR: 7.3; 95%CI: 2.7-19.4; P =0.000) compared to adult ones. When compared to inborn small ruminants, the odd of being seropositive for PPRV antibodies was 4 times higher in bought (OR:4; 95%CI: 1.4-11.3; P =0.008) and 8.3 times higher in gifted small ruminants (OR:8.3; 95%CI: 2.1-32.6; P =0.003). Sheep and goats raised in medium flock sizes were more likely to be PPRV seropositive (OR= 15.4, 95%CI: 3.1-77.3; P = 0.001). The odd of being seropositive to PPRV was 2.6 times higher in small ruminants raised in the area that have a shortage of veterinary services (OR:2.6; 95%CI: 1.2-5.7; P =0.019) when compared to those with access to veterinary services (Table 5).

Table 5: Multivariable logistic regression analysis of risk factors associated with PPR positivity in nonvaccinated population.

Risk factors	Category	Odd ratio (95% CI)	Coefficients	P-value
Districts	Dubuluk	Ref.		
	Yabelo	0.6(0.3-1.5)	-0.5	0.307
Age	Young	Ref		
	Adult	0.7(0.2-1.7)	1.5	0.448
	Old	7.3(2.7-19.4)	1.9	0.000
Flock Size	Small	Ref.		
	Medium	15.4(3.1-77.3)	2.7	0.001
	Large	1.5(0.4-6.3)		0.551
Animal origin	Born	Ref.		
	Bought	4(1.4-11.3)	1.4	0.008
	Gift	8.3(2.1-32.6)	2.1	0.003
Shortage of vet services	No	Ref.		
	Yes	2.6(1.2-5.7)	0.9	0.019

4.1.3. Seroconversion and risk factors of PPR antibody

Out of 128 small ruminants that had a history of vaccinations, the overall seroprevalence was 68.75%. On descriptive statistics, the association of seroconversion against PPRV were

revealed statistically significant (P< 0.05) with species, sex, age and body conditions in vaccinated small ruminants (Table 6).

Table 6: Univariable logistic analysis of seroconversion of vaccinated sheep and goats

Risk factors	Category	No. sampled	Seropositive (%)	OD (95% CI)	P-value
Species	Sheep	24	11(45.8)	Ref.	
	Goat	104	77(74)	3.4(1.4-8.4)	0.009
Sex	Female	106	81(76.4)	Ref.	
	Male	22	7(31.8)	0.1(0.05-0.4)	0.000
Age	Young	22	5(22.7)	Ref.	
	Adult	29	19(65.5)	6.4(1.8-22.7)	
	Old	77	64(83.1)	2.5(0.9-6.8)	0.05
Body conditions	Good	11	3(27.3)	Ref.	
	Poor	83	64(77.1)	8.9(2.2-37.2)	0.002
	Medium	34	21(61.8)	4.3(0.9-19.2)	0.05

Further analysis by a multivariable logistic regression model revealed that species and animals with poor body conditions had statistically significant on the seroconversion of PPRV (Table 7). Accordingly, the likelihood of seroconversion in PPRV-vaccinated goats was 3.1 times higher (74%; OR: 31; 95% CI: 1–8.9; P =0.041) compared to vaccinated sheep. When compared to animals with good body condition, the likelihood of being seropositive for PPRV antibodies was 5.5 times higher in poor animals (OR: 5.5; 95% CI: 1.1–28.7; P =0.043).

Table 7: Multivariable logistic regression analysis of factors in PPR positivity in the vaccinated population

Variables	Category	Odds Ratio	95% Conf. Interval	P value
Species	Sheep (ref)			
	Goat	3.1	1.1-8.9	0.041
Body conditions	Good (ref)			
	Poor	5.5	1.1-28.7	0.043
	Medium	3.8	0.7-22.2	0.136
Age	Young (ref.)			
	Adult	0.3	0.1-1.4	0.128
	Old	2.2	0.8-6.3	0.130
Sex	Female (ref.)			
	Male	0.3	0.1-1.1	0.067

4.2. A retrospective epidemiological analysis of PPR outbreaks

4.2.1. Spatial distributions of PPR disease outbreaks

From the retrospective data, PPR outbreaks were reported from Borena zone, in Dhas, Arero, Dillo, Dirre, Dubuluk, Elwaye, Gomole, Guchi, Moyale and Yabello districts (Figure 6). The highest number of outbreaks was recorded in Arero (n = 21; 39.6%), followed by Dhas district (n = 11; 20.8%).

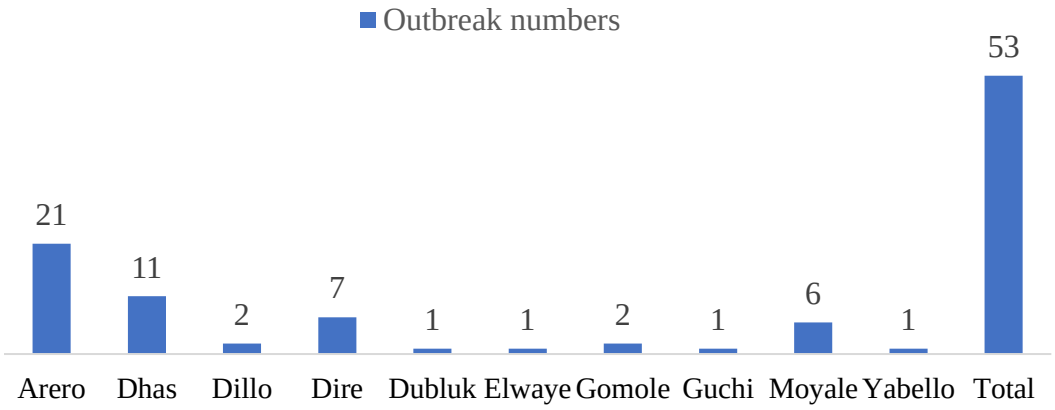

Figure 6: distribution of PPR outbreaks in the districts of Borena zone from 2018 to 2022

4.2.2. Temporal distributions of PPR outbreaks in Borena zone

In the Borena Zone, a total of 53 outbreaks were recorded from the year 2018 -2022, which covers 9.6% of PPR outbreaks that occurred in the country and 34.4% that occurred in the Oromia Regional state. A total of 692 small ruminants' death reported in the study area, which accounts for 0.6% of death reported in the country. Furthermore, the highest outbreaks were reported in 2019 in the zone (Figure 7).

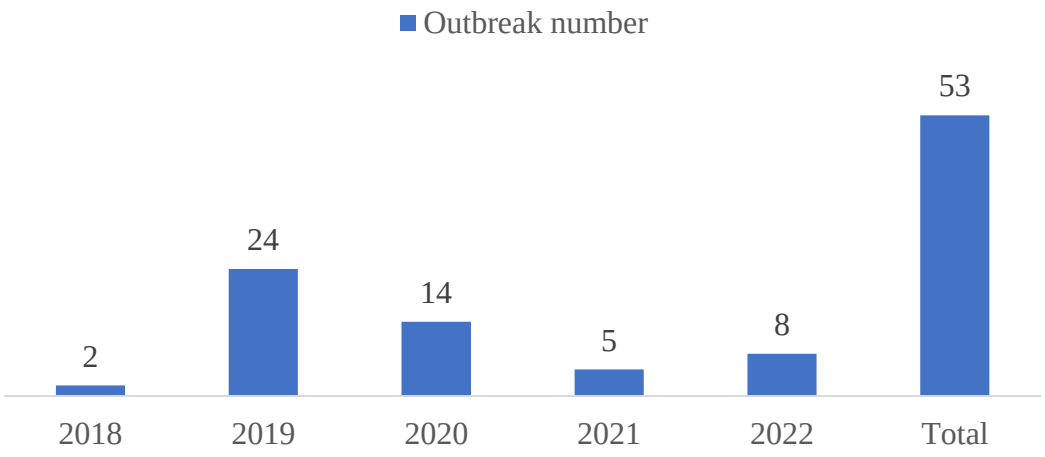

Figure 7: Map showing yearly distribution of PPR outbreak in the zone

A monthly variation was observed in the frequency of outbreaks, with peak outbreaks recorded in January (20.8%) followed by December (Figure 8). In October and May, there were 1.9% fewer outbreaks than in any other months.

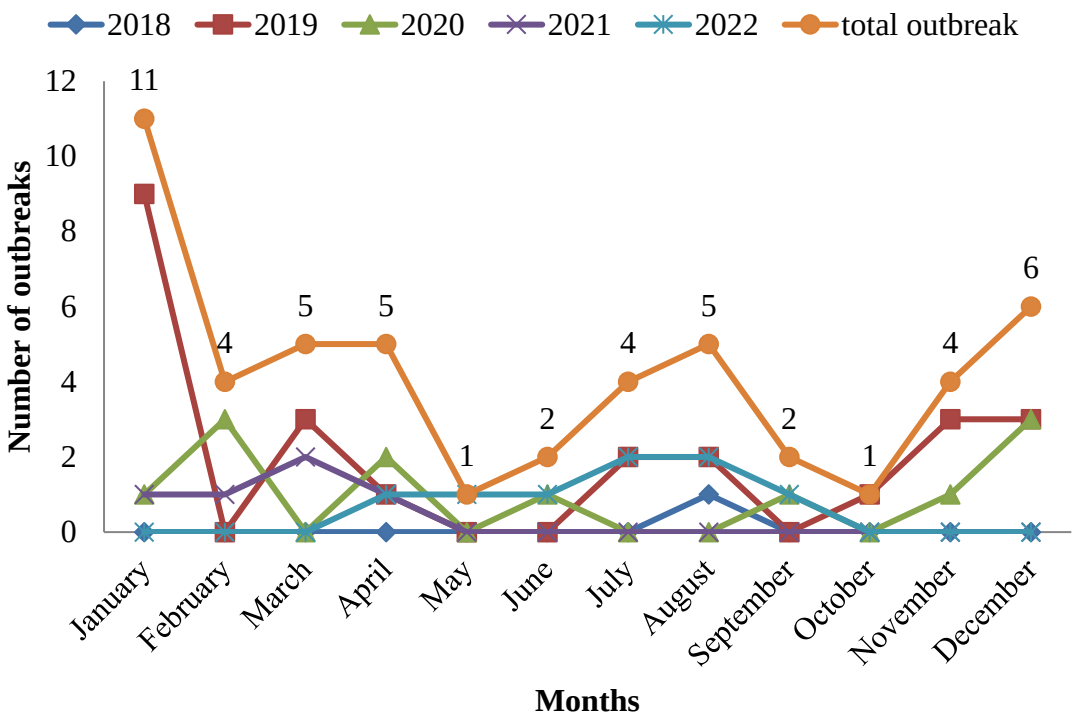

Figure 8: Monthly distribution of PPR from 2018 to 2022

4.2.3. Different disease frequency measures

During the five-year PPR outbreak reports, different numbers of cases with different morbidity and mortality rates were reported from different parts of Ethiopia. The highest case fatality (46.7%) was reported in the Yabelo district. The highest morbidity (3%) and mortality rate (0.9%) were reported in Dilo district. The lowest morbidity rate was observed in Gomole (0.01%), while the lowest mortality (0.005%) and case fatality (5%) occurred in Dubuluk (Figure 9).

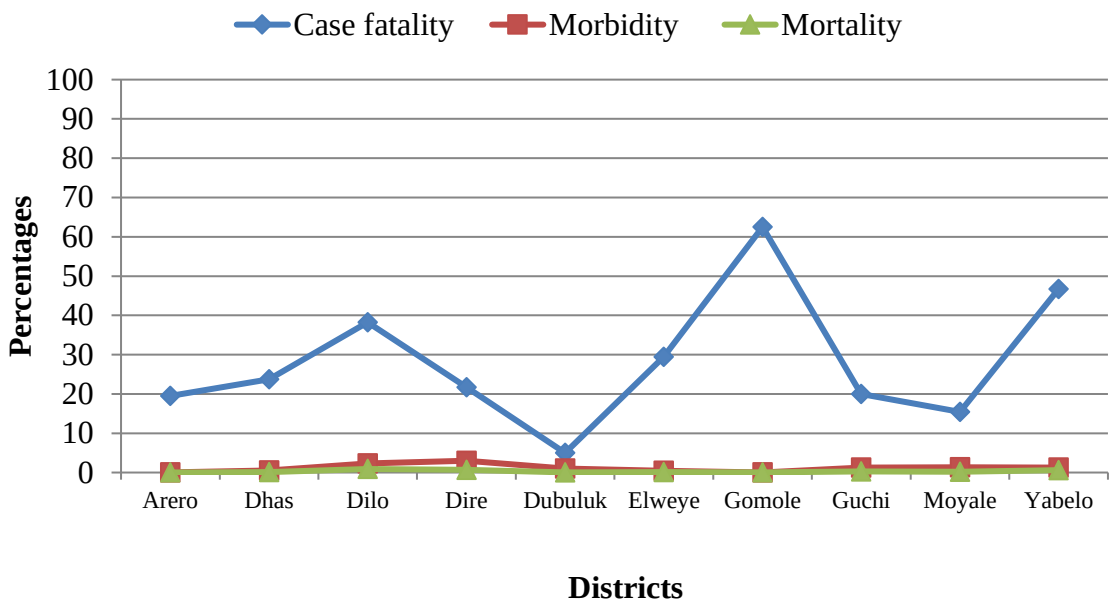

Figure 9: Morbidity, mortality, and case fatality of PPR in different Districts of Borena Zone

4.2.4. Reports of vaccinations during PPR outbreaks (2018–2022)

In Borena Zone, 10,000 vaccine doses were used to control PPRV during the outbreak reports. During outbreaks the reported animals at risk were 397,189. Intervention for the vaccination in the Zone is 0.7% of the vaccine dose used in the country. Even though outbreaks occurred in the area is higher than outbreaks that occurred in Afar region, Benishangul Gumuz region and Southwest Ethiopia region and Dire Dawa city administration, the vaccines used were lower compared to them. However, it is higher than the vaccine dose used in Somali regional state (0.2%).

4.3. Questionnaires Survey analysis

4.3.1. Demographic characteristics of interviewed participants

During the study period, flock owners who had offered their small ruminants for PPR serological study were asked about their animals' conditions. A total of 81 small ruminant owners participated in the interviews from six *Kebeles* in three districts of the Borena zone.

These participants were 74.07% male, 98.7% married, and 96.3% had no formal education. Of the respondents, 55.6% were solely dependent on the production of livestock, and 70.37% of owners had a small flock size (Table 8).

Table 8: Demographic characteristics of interviewed participants (N= 81)

Variables	**Subdivisions**	**Districts**			**Total (%)**
		Dubuluk Freq. (%)	Elweye Freq. (%)	Yabelo Freq. (%)	
Sex	Female	5(6.2)	7(8.6)	9(11.1)	21(25.9)
	Male	22(27.2)	20(24.7)	18(22.2)	60 (7)
Education level	Nonformal education	26(32.1)	25 (30.9)	27(33.3)	78 (96.3)
	Primary	1 (1.2)	2 (2.5)	-	3 (3.7)
Marital status	Married	26 (32.1)	27 (33.3)	27 (33.3)	80 (98.7)
	Single	1 (1.23)	-	-	1 (1.23)
Age	18- 29	2 (2.5)	3 (3.7)	-	5 (6.2)
	30- 44	7(8.6)	10(12.3)	8(9.9)	25(30.9)
	45 -59	9(11.1)	5(6.2)	9(11.1)	23(28.4)
	60^{+}	9(11.1)	9(11.1)	10(12.3)	28(34.6)
Role of respondent	Household head	21 (25.9)	20 (24.7)	18 (22.2)	59 (72.8)
	Son	1 (1.2)	-	-	1 (1.2)
	Spouse	5(6.2)	7 (8.6)	9(11.1)	21 (25.9)
Productions systems	Agro-pastoralists	-	9 (11.1)	27(33.3)	36(44.4)
	Pastoralists	27(33.3)	18(22.2)	-	45(55.6)
Herd size owned	Small	22(27.2)	16(19.8)	19 (23.5)	57 (70.4)
	Medium	5(6.2)	4(4.9)	6(7.4)	15(18.5)
	Large	-	7(8.6)	2 (2.5)	9 (11.1)

4.3.2. Major socioeconomic practice and the risk factors of PPR

Small ruminants were common in the study area, with the mean number of sheep (12.8±9.5SD) and goats (33.3±30.8SD) reared per household higher when compared to the mean number of cattle (1.8±2.6SD), donkeys (0.8+0.8SD), and camels (0.4±1.2SD). Respondents showed a mean experience of 34.9±14.7 SD years in keeping small ruminants. Rearing flocks was for the purpose of producing milk and meat, creating cash income as an indication of wealth status, replacing kids and lambs, and improving the social standing of the households (Table 10). However, a decrease in the number of sheep and goats can occur due to different diseases, including PPR (Table 9).

Table 9: Number of small ruminants owned and dead per households in the last one year(N=81)

Parameters	**Mean ± SD**	**Range**	**Sum**
Number of cattle owned	1.8 ± 2.59	0-13	146
Number of goats owned	33.2 ± 30.82	6-120	2694
Number of camels owned	0.39 ± 1.19	0-8	32
Number of donkeys owned	0.78 ± 0.84	0-6	63
Number of female goats	29.8 ± 28.4	5-111	2413
Number of male goats	3.47 ± 3.42	0-20	281
Number of dead goats	0.21 ± 0.67	0-4	17
Number of sheep owned	12.8 ± 9.46	5-66	1037
Number of female sheep	11.59 ± 8.15	4-60	939
Number of male sheep	1.21 ±1.82	0-10	98
Number of dead sheep	0.07 ± 0.26	0-1	6
Number of aborted sheep	0.26 ± 0.5	0-2	10
Number of aborted goats	0.31 ± 0.68	0-3	25
Household size	5.77 ± 1.95	1-13	-
Experience in shoat rearing (years)	34.93 ± 14.68	8-60	-

Communal grazing was common, mixing small ruminants with other livestock populations (58.02%) during the daytime, while all respondents attest, they built an open yard locally as a "Dhoqoba", made a wooden barn, and separated kids in a small cage at night (Annex 6). Besides communal grazing, movements of animals to the market were common, as 60.5% of respondents visited the livestock markets twice a week for selling or buying animals and the other 24.7% received new animals as gifts (Table 10).

Table 10: The management methods of small ruminants in study area

Interview category	Response category	Frequency	Percents
Communal grazing season	All season	81	100
	Cool dry season (Adolessa)	5	6.2
Lambing/kidding season	All season	24	29.6
	Short rainy season (Hagaya)	4	4.9
	Long rainy season (Ganna)	48	59.3
Housing type	Open Yard (dhoqoba)	81	100.00
Ways of herding sheep and goat	Herding with other livestock	47	58.02
	Sheep and goat together only	34	41.98
Shoat market access	Once a week (one market)	32	39.5
	Twice a week (two markets)	49	60.5
Introduced new shoat	No	61	75.31
	Yes	20	24.7
Bought new shoats	No	64	79.1
	Yes	17	20.9

The use of small ruminants for different purposes was common at different cultural events in the study area. Specifically, with local names, Gubisa, Moggaati, Nyaachisa, Gadamoojjii, Dhibayyuu, and Buufata were the names of the most important cultural events commonly celebrated in the dry season (71.6%) (Table 11).

Table 11: Sociocultural factors increase small ruminants' susceptibility to infection

Interview category	Response category	Frequency	Percents
Cultural ceremonies	Gubbisa	81	100
	Marriage	77	95.1
	Mogatii	62	76.5
	Eid Alfatir and Eid Aldah	1	1.2
	Nyaachisa	9	11.1
	Gadamoojjii	9	11.1
	Buufata	2	2.5
	Celebration when son born	2	2.5
	Dhibaayyu	3	3.7
	Huluqoo	1	1.2
Major period of cultural ceremony in year	Dry season (Bona)	58	71.6
	Cool dry season (Adolessa)	23	28.4
Contribution of small ruminants to household	Milk and Money	81	100.0
	Meat	50	61.7
	Wealth status	35	43.2
	Replacement	21	25.9
	Social standing	17	21.0
	Hide and skin for home use	5	6.2
	Manure	1	1.2

Participants mentioned that decreases in flock size as well as in sheep and goat production were caused by different factors. PPR, along with other diseases, causes the deaths (93.8%) of their flocks in the study area (Table 13). However, respondents used a variety of strategies to maintain a large flock size in the study area. Surprisingly, to maintain large flock sizes, 21% of respondents prepare cultural events to get donations of small ruminants from neighbors and relatives, while about 85.2% prefer to buy female shoats and keep them in the flock for years. Additionally, 2.5% borrow male small ruminants from neighbors for breeding purposes (Table 12).

Table 12: Factors affect the flock size in the study area

Interview category	Response category	Frequency	Percent
Method of increasing flocks size	Sell male only	24	29.6
	Buy and keep female for years	69	85.2
	Gift (Busa-Gonofa) from others	17	21.0
	Keep two or more male together	2	2.5
	Share male from neighbors	2	2.5
Ways sheep and goat leave flocks	Sell	69	85.2
	Gift	56	69.1
	Death	76	93.8
	Affected by predators	70	86.4
	Loss	51	63.0
	Stolen by thief	8	9.9
feed shortage season	All season	28	34.6
	Bona	53	65.4

All respondents could recognize and identify the PPR as "*Marareba*" locally. Infection in small ruminants has been noted, as well as disease transmissions such as getting PPR from other sick sheep or goats (7.4%) or when an outbreak arises in the region (4.9%). However, most respondents (81.5%) were unable to identify the source and transmissions of PPRV between hosts (Table 14). Respondents noted that PPRV infection causes mortality (12.3% in goats; 7.4% in sheep) and abortions (22.2% in goats; 11.1% in sheep), with an associated dry season (64.4%), feed shortages (65.4%), and major cultural activities as obstacles in sheep and goat production in the last one year. To minimize the loss of their small ruminants due to this disease, the respondents used traditional treatment and different veterinary drugs to help their animals. As a result, 69.1% of respondents treated the animals as they wished without consulting veterinary professionals. Only 18.5% went to a veterinary clinic and consulted animal health officials, while 12.3% of respondents could consult Community Animal Health Workers (CAHWs) in their villages (Table 13).

The respondent utilized various traditional treatment options for various animal diseases. Traditionally, "*Walda*," a tree believed to be medicine for various diseases when crushed and mixed with water,*Dodonaea angustifolia* for internal problems, *Capsicum annum* for diarrhoea, local salt for mouth lesion, and butter with alcohol or Omo soap for retained placenta and abortion were used in small ruminants (Table 13).

Table 13: Response on PPRV related infections in the study area

Interview category	Response category	Frequency	Percents
Identifying PPR infection	Yes	81	100.0
Information on PPR infection in the area	Yes	27	33.3
	No	54	66.7
Had a PPR related infection in goats	Yes	26	32.1
	No	55	67.9
Had a PPR related infection in sheep	Yes	10	12.3
	No	71	87.7
Had a PPR related deaths in goat	Yes	10	12.3
	No	71	87.7
Had PPR related deaths in sheep	Yes	6	7.4
	No	75	92.6
Had an abortion on your in sheep	Yes	9	11.1
	No	72	88.9
Had an abortion on your goat	Yes	18	22.2
	No	63	77.8
Measure taken on PPR infection	Treat by themselves	56	69.1
	Ask CAHWs	10	12.3
	Consult veterinary officials	15	18.5
Any traditional treatment option of PPR	Dodonaea Angustifolia (Dhitacha)	5	6.2
	Walda	46	56.8
	Capsicum annum (Barbare)	14	17.3
	Nicotiana tabacum L. (Tambo borandade)	2	2.5
	local salt (Soodda Kula)	11	13.6
	Swallowing butteralcohol omo soap	3	3.7
Do you vaccinate your goat	Yes	27	33.3
	No	54	66.7

5. DISCUSSION

The study found a seroprevalence of 32.1% in the study area, which is inconsistent with previous studies in different pastoral areas, Oromia, South Omo, and northern Ethiopia, which found 30.9%, 30.2%, 30.8%, and 32.5%, respectively (Megersa *et al*., 2011; Michael *et al*., 2017; Mebrahtu *et al*., 2018; Abesha *et al*., 2022). In India, Balamurugan *et al.* (2012) reported 32.8%, which is consistent with current findings. In contrast, the findings of Yalew *et al*. (2019) (75.7%), Dubie *et al*. (2022) (60.15%), and Senbeto (2022) (65.4%) in the Awi and Metekel Zones had a higher prevalence than the current findings in different parts of Ethiopia. Khalafalla *et al*. (2010) (62.8%), Osman *et al.* (2018) (80.9%), and Kihu *et al.* (2015) (40%) all found a higher prevalence. The current prevalence was higher than the reports of Nigusu and Fantie (2012) (26.3%), Alemu (2014) (28.1%), and Gebre *et al*. (2018) (2.1%) in Ethiopia, and the findings of Kgotlele *et al*. (2013) (27.1%) in Tanzania, and Shyaka *et al.* (2021) (14.8%) in Rwanda. The difference in seroprevalence might be due to varied geographical locations, seasonal and uncontrolled movement of animals, small ruminant population density, management strategies, and migration of animals within and between countries.

The seroprevalence of PPRV showed a statistically significant association with old ages of the study animals (P = 0.003), with the highest prevalence recorded in old (60%) followed by young (29.6%) and adult (23.7%) small ruminants. Similar to the current finding, Saeed *et al*. (2018) revealed that the prevalence is higher in older (65.5%) animals than in adults in Sudan. In contrast, the findings of Dubie *et al*. (2022) in the Afar region of Ethiopia revealed that the highest seroprevalence was reported in young animals (72.97%). The difference in prevalence between ages might be due to the development of the immune system, which indicates older small ruminants' immune responses could be stronger than those of other age groups (Saeed *et al*., 2018). It might also be due to the fact that newborn animals become susceptible to PPRV infection based on the severity of PPRV as well as probability of exposure might be increase with age (Singh *et al*., 2004).

The statistically significant associations between flock sizes and seroprevalence of PPR were recorded, with the highest seroprevalence in medium (74.2%) flock size, followed by large (26.7%) flock size. Similar to the current findings, Gelana *et al*. (2020), Senbeto (2022), and Ozkul *et al*. (2002) found significantly higher seroprevalence with 70.8%, 70.8%, and 72% in medium flock sizes, respectively. Studies carried out by Al-Majali *et al*. (2008), Alemu (2014), and Dejene (2016) indicated higher seroprevalence in medium flock sizes without statistically significant differences. The higher seroprevalence in medium flock size may associated might be due to low number of animals sampled from large flock size. Given that PPRV is contagious, the higher prevalence in medium size flock might be related to an increase in the number of small ruminants, which might have enhanced the virus's spread.

In the present study, small ruminants bought from the market had a higher seroprevalence (62.9%), followed by those owned through gifts (56.3%). Those born in the flock had a lower seroprevalence (24%). The association was statistically significant ($P<0.005$). In agreement with this study, the findings of Alemu (2014), Saeed *et al*. (2018), and Gelana *et al*. (2020) showed a higher seroprevalence of PPRV in animals brought from the markets. Similar findings were made by Abubakar *et al*. (2009), Abesha *et al*. (2022), and Rahman *et al*. (2023) that found small ruminants purchased from the market had a significantly higher seroprevalence of PPRV. This might be associated with the animals from the market having a higher risk of exposure to infection due to the intermixing of animals.

The current findings reported a relatively similar profile of seroprevalence in PPRV in goats (32.7%) and sheep (31%), with no statistically significant association with the seropositivity of PPRV. This study was in agreement with the findings of Alemu (2014), who found a similar profile of seroprevalence in goats (28.6%) and sheep (27%), as well as Megersa *et al*. (2011), who found a comparable prevalence in sheep (29.5%) and goats (31.3%). Similarly, Gari *et al*. (2017) reported that in the East Shewa and Arsi zones, the seroprevalence in sheep (46.68%) was approximately the same as that of goats (50.85%), and a similar observation was also reported with a seroprevalence of 9% in goats and 13% in sheep in the pastoral production system of Ethiopia due to equal exposure (Abraham *et al*., 2005). As well, Kivaria *et al.* (2013) found no association between animal species and seropositivity for PPRV. The

non-significant difference could be attributed to an equal chance of exposure to disease risk factors in the free movement of sheep and goats around the grazing area and animals sharing common housing at night.

The multivariable logistic regression analysis revealed that animal origin, old age, medium-sized flock, and shortage of veterinary services were identified as statistically significant potential risk factors for PPRV seropositivity ($P < 0.05$). The likelihood of being seropositive for PPRV infection in older animals was 7.3 times higher when compared to adult small ruminants. Similar findings were undertaken by Waret-Szkuta *et al*. (2008), Abubaker *et al*. (2009), Alemu (2014), Saeed e*t al*. (2018), Yalew *et al*. (2019), Rume et al. (2020), Senbeto (2022), and Akwongo *et al*. (2022), who identified age as a potential risk factor for PPRV seropositivity. In contrast, Shuaib *et al*. (2014) found a non-significant association between age and positivity for serum levels of PPRV, which might be due to the immunogenic nature of PPRV, long-term seropositivity, and high mortality rate of highly susceptible animals.

In the present study, the likelihood of being seropositive for PPRV was 4 times higher in animals purchased from the market and 8.3 times higher in gifted small ruminants when compared to small ruminants born in the flocks. In agreement with the present findings, Abesha *et al*. (2023) recorded that animal brought from other places had a 2.7 times higher chance of being positive compared to animals born in the flocks. Additionally, Singh *et al*. (2004), Alemu (2014), and Hailegebreal (2018) revealed that new animals bought from marketplaces or from other places have been attributed as the origins of the disease. In the present study, sheep and goats raised in medium flock sizes were more likely to be PPRV antibody seropositive (OR = 15.4, P = 0.001). In agreement with this, flock size was mentioned as statistically significant (Al-Majali *et al*., 2008; Alemu, 2014; Hailegebreal, 2018; Abesha *et al*., 2023).

Herd immunity was tested in 128 small ruminants that had vaccination histories, and the level of protection recorded against PPR was 68.75%. Herd immunity in the present study was similar profiles with the findings of Faris *et al*. (2012), Delil *et al*. (2012), and Alemu (2014), who found herd immunity of 61%, 61.13%, and 64.5% in vaccinated small ruminants of the

Awash Fentale district of the Afar Region and the eastern Amhara region bordering the Afar region of Ethiopia, respectively. The increase in herd immunity in small ruminants over different study periods might be associated with the increased intervention of mass vaccination by the Ethiopian government to eradicate the disease.

The findings of Hammami *et al*. (2016) in Morocco indicate somewhat comparable (70%) results to the current study, while Luka *et al*. (2011) observed a lower seroconversion rate of 55.3% for PPRV antibodies among small ruminants in the Karamoja region of Uganda. As a result, the findings of Faris *et al*. (2012), Delil *et al*. (2012), Alemu (2014), and Hammami *et al*. (2016), as well as the current investigation, fall below the FAO-OIE (2015) recommended threshold herd immunity of 80%. The lower seroconversions might be due to factors related to vaccine handling and storage, which could be vaccine transportation, faulty use of the cold chain and vaccination protocols, inappropriate vaccination, and low awareness creation during vaccination campaigns, resulting in insufficient population protection.

In contrast to the current findings, Yirga *et al*. (2020) found 93.9% herd immunity in the Metema districts in northwest Ethiopia. Another study revealed 96% and 100% herd immunity in Pakistan and Bangladesh, respectively (Rajput *et al*., 2016; Kabir *et al*., 2016). These findings might be attributed to improved cold chain preservation, better follow-up of post-vaccination and better use of vaccination protocols.

On multivariable logistic regression analyses, the antibody level of PPRV in vaccinated animals was significantly higher in goats than sheep, as well as in animals with poor body conditions. When compared to the analysis of nonvaccinated animals, poor animal response was associated with a higher percentage of seroprevalence of PPR infection. As a result, antibodies generated in response to natural PPR infection and additional vaccination might trigger a considerably stronger immunologic response in the target species.

The current retrospective data analysis found 554 outbreak reports. It is found to be lower than the outbreak numbers reported in Ethiopia by Alemu (2014), Dejene (2016), and Senbeto (2022), which were 832 (2009–2013) years, 1282 (2006–2015) years, and 632

(2016–2021) years, respectively. Similarly, the present finding is lower than the 756 outbreaks that occurred in India during the 2016–2019 years (Balamurugan *et al*., 2021) and higher than the 62 outbreaks that occurred in Pakistan during the 2005–2007 years (Abubakar *et al*., 2009). The decrease in the number of PPR outbreaks in the present study might be due to the intervention of effective control and prevention measures with strategic vaccinations and the efforts of the animal health expert in controlling the disease with effective surveillance systems.

In this study, the highest outbreaks were recorded in 2019 (244 outbreaks), and the lowest were reported in 2018 (25 outbreaks). Similar to the present study, Senbeto (2022) reported a low outbreak in 2018. The low number of outbreaks in 2018 might be due to low awareness of detecting and reporting the disease on the available systems. In contrast, the highest number of outbreaks reported in 2019 might be due to increased awareness of disease surveillance systems, detection, and reporting system improvement through training for target groups.

The retrospective data analysis shows that PPR was present throughout the year. The higher reports were recorded in dry season which starts to increase in December and gradually peak in January. This suggests that the majority of outbreaks took place during the dry season. In February, Senbeto (2022) reported larger outbreaks, which is consistent with the current findings. Alemu (2014), on the other hand, reported more outbreaks in dry seasons. Similarly, Abraham (2005) reported a disease increase in the dry season, and Govindaraj *et al*. (2023) from India reported that the disease occurs round the year, with the maximum outbreaks reported during the winter season prior to the onset of the rainy season. The occurrences of disease in the dry season might be associated with unrestricted movements of animals in search of feed and water that increase disease transmission, and a shortage of animal feed may reduce animal disease resistance.

According to spatial analysis, PPR outbreaks were reported from Borena zone in different districts. The highest number of outbreaks was recorded in Arero (n = 21; 39.6%), followed by Dhas district (n = 11; 20.8%). In line with the current findings, Senbeto (2022) reported

the different outbreaks in different districts of the country. The high number of outbreaks in areas might be due to the high potential of the sheep and goat populations in the regions as well as lack of reporting from other regions

The majority of participants were pastoralists with no formal education and household heads. Though respondents had an average of 35 years' experience rearing small ruminants, their low formal education level created low perceptions about the identification of potential risks of infections in their flocks, transmissions of the disease, and control options. Different findings from different pastoral areas reported a high percentage of no formal education. This might influence knowledge of disease detection, transmission, and diagnosis (Alhaji and Kabir, 2016; Alhaji *et al*., 2018).

In this study, the livestock owners present for the serological study of PPR were asked about their animals and revealed that they mostly raise small ruminants, with a high proportion of females (89.8%) and goats (72.2%; mean, 33.2±30.8; range, 6-120), as well as various age collections. Similarly, different scholars reported that pastoral and agro-pastoral settings had a higher proportion of goats than sheep (Hassen and Tesfaye, 2014; Fenetahun and Fentahun, 2020; Sow *et al*., 2021; Jemberu *et al*., 2022). The usage of female and numerous goats might be related to a greater pastoral requirement for milk production, the need for replacement, and a preference to have a larger number of small ruminants as social indicators.

According to the respondents, infection of small ruminants with PPR could occur, and all the respondents could recognize it by different signs, which were locally known as "Marareba". Similarly, studies undergone by Dejene (2016) in the Somali pastoral area, Alemu (2014), and Senbeto (2022) in the Amhara region reveal the easy recognition of PPR by the owners with different local names. In PPR-infected animals, comparable detection knowledge among small ruminants' owners has been reported by Wohlsein and Saliki (2006), Banyard *et al*. (2010), and Fathelrahman *et al*. (2021). Detection of PPR in the study area might be associated with different social and cultural activities that increase the vulnerability of small ruminants to infection and increased awareness with experience developed during repeated occurrences of PPR outbreaks.

PPRV is a contagious disease whose spread and transmission are facilitated by the uncontrolled movements of infected animals (Banyard *et al*., 2010). In the study area, about 2.4% of respondents share male sheep and goats for breeding, and 18.5% exchange animals as gifts (Busa-Gonofa). Similarly, the practice of sharing animals for breeding was practiced in the pastoralist area of Afar. Denying rams for breeding to neighbors in the Afar Region is traditionally prohibited (Haile *et al*., 2013). In agreement with the present findings, a study from India indicates male breeding animals are used communally (Lanari *et al*., 2005). According to Alhaji *et al*. (2018), cultures of borrowing and giving out small ruminants as gifts greatly increase disease occurrence in animal populations. The habits of sharing animals for different purposes increase animal movements from different areas to new places, which might spread the highly infectious and contagious PPRV.

Different cultural events were practiced mainly in the dry season (71.6%). Duressa (2022) noted comparable cultural festival finds in the Borena Zone. According to Fenetahun and Fentahun (2020), during religious festivals and cultural celebrations, a high livestock market trade chain was involved in Dubuluk market, Yabelo market, Haro-Bake market, and Elweye market, which were similar market areas to the current finding. The occurrence of disease during cultural events might be related to the high demand for animals, which promotes the trade of infected sheep and goats and spreads infection to other animals (Saliki, 2022).

In the dry season, about 65.4% of respondents explained that a feed shortage occurred. Similarly, the present retrospective analysis indicates most cases of PPR occurred in the dry season. The occurrence of disease in the dry season might be associated with the depletion of immunity in small ruminants in relation to feed shortages and sociocultural practices.

In the current study, 20.9% (17/81) of respondents encountered PPR-related infections in small ruminants in the last one year. The present PPR-related infection was lower than the 89.7% reported in Awi and Metekel zones and the 64% in the Somali region that were reported by Senbeto (2022) and Dejene (2016), respectively. The lower occurrence of PPR in the study area might be associated with the government's participation in the control strategies of mass vaccinations of small ruminants in Ethiopia compared to previous attempts. Only 18.5% of respondents had hints for the ways in which the disease is

transmitted between infected and susceptible animals. This might be associated with less active participation of the community, animal health experts, and nongovernment organizations in creating awareness about the spread of the disease in the flocks.

Respondents used a selection of different treatment options for their PPR-related diseased sheep and goats. Around 69.1% of respondents treat their animals by themselves, purchase drugs from markets, and store them at home for further use. Similar to the present finding, Gemeda *et al*. (2020) and Dejene (2016) reported that 74% and 34% of pastoralists bought veterinary drugs depending on their own judgments about the kind of drug to use, dose, and treatment duration in the Borena Zone and in the Somali region, respectively. Similar to the current findings, Turkana pastoralists in Kenya, Cameroon, and the Maasai tribe purchase drugs and self-treat sick animals (Bett *et al*., 2008; Vougat *et al*., 2017; Mangesho *et al*., 2021; Makau *et al*., 2022). Only 18.5% of respondents consulted veterinary officials. According to Dejene (2016), 21% of pastoralists in the Somali regional state were able to take their animals to a nearby clinic when they suspected PPR disease. The self-judgment about the health and treatment of the animals by the pastoralists might be related to a lack of readily available veterinary services, animal health professionals, adequate awareness, and an adequate medicine supply in the area.

The respondents used different traditional PPR treatment methods. About 56.8% of respondents used "Walda" (the local name for a traditional medicine that is supposed to be medicine for several animal diseases when it is crushed, mixed with water, and swallowed by the animals) for treatment of any animal diseases, including PPR. According to Amenu *et al*. (2017), "walda" were used by Borena pastoralists in various traditional treatments known as "Qorsa Borena" (meaning Borena medicine). Similarly, 18.5% of respondents used *Dodonaea angustifolia* (the vernacular name is "Dhitacha") for internal problems and fattening, and 17.3% used *Capsicum annum* (the vernacular name is "Barbare") to stop diarrhea in small ruminants. In agreement with the present finding, Sori *et al*. (2004) identified *Accacia busei* (Hallo) and *Capsicum annum* ("Barbare") as being used for diarrheal animals in the Borena zone. Drummond and Moll (2002) mentioned that a hot infusion of the roots of selected plants was used to cure diarrhea.

In agreement with the present findings, the most common traditional remedies used for retained placenta are salty water (19.05%), soap detergent solution (19.05%), and different plant species in different pastoral areas of Ethiopia, Kenya, South Africa, and Tanzania (Sori *et al*., 2004; Okoli *et al*., 2010; Moreki *et al*., 2012). The scarcity of nearby veterinary clinics, the prohibitive distance between veterinary centers and rural areas, and the potential affordability and accessibility of traditional healers in rural areas might contribute to the use of traditional medicine.

6. CONCLUSION AND RECOMMENDATIONS

Small ruminants were the most common livestock population in the study area. In the current study, the seroprevalence of 32.1% and 68.8% of PPRV antibodies-positive small ruminants were recorded in unvaccinated and vaccinated small ruminants, respectively. The seroprevalence of PPR in the study animals showed a statistically significant difference with age, herd size, animal origin and shortage of veterinary services. Herd immunity in small ruminants that have a vaccination history against PPR was below the threshold herd immunity level recommended by the OIE. Different PPR outbreaks were recorded in different parts of Ethiopia from the year 2018 to 2022 with most outbreaks peaking during the dry season including Borena Zone. Interviewed respondents practice different cultural and socio-economic activities that facilitate, spread and allow transmissions of PPR between small ruminants in the area. The study highlighted the presence of PPRV among the sheep and goat of the selected Borena districts. The local community can recognize the disease and its impact. Lack of awareness on PPR means of transmission, free animal movement and communal grazing might have contributed for higher presence of the PPR virus in the study population. Additionally, the use of veterinary drugs to treat PPRV infected animals without consulting veterinary professionals was common.

Based on the above conclusion the following recommendations were forwarded:

- Continuing vaccination and further extensive serosurveillance for PPRV should be undertaken to evaluate the effectiveness of PPR control program in the study areas.
- Awareness creation should give to the pastoralists on means of transmission, free animal movement, communal grazing, and improper utilization of veterinary drugs to minimize the socioeconomic impact of PPRV among the Borena pastoral community.

7. REFERENCES

Abesha, H., Teshome, Y., Alemu, Y. F., Dejene, H., Tarekegn, Z. S. and Assefa, A. (2023). Seroepidemiology of peste des petits ruminants virus in small ruminants in selected districts in Northwest Ethiopia. *Veterinary Medicine and Science*, **9:** 884–890

Abraham, G., Sintayehu, A., Libeau, G., Albina, E., Roger, F., Laekemariam, Y., Abayneh, D. and Awoke, K.M. (2005). Antibody seroprevalences against peste des petits ruminants (PPR) virus in camels, cattle, goats and sheep in Ethiopia.*Preventive veterinary medicine*, **70**(1-2): 51-57.

Abubakar, M., Arshed, M. J., Zahur, A. B., Ali, Q. and Banyard, A. C. (2012). Natural infection with peste des petits ruminants virus: a pre and post vaccinal assessment following an outbreak scenario. *Virus research*, **167**(1): 43-47.

Abubakar, M., Jamal, S. M., Arshed, M. J., Hussain, M. and Ali, Q. (2009). Peste des petits ruminants virus (PPRV) infection; its association with species, seasonal variations and geography. *Tropical animal health and production*, **41**(7): 1197.

Abubakar, M., Khan, H.A., Arshed, M. J., Hussain, M. and Ali, Q. (2011). Peste des petits ruminants (PPR): Disease appraisal with global and Pakistan perspective. *Small Ruminant Research*, **96**(1): 1-10.

Abubakar, M., Manzoor, S., Wensman, J.J., Torsson, E., Qurban, A. and Munir, M. (2016). Molecular and epidemiological features of Peste des petits ruminants outbreak during endemic situation. *Hosts and Viruses*, **3**(4): 123.

Abubakar, M., Mahapatra, M., Muniraju, M., Arshed, M. J., Khan, E. U. H., Banyard, A. C., Ali, Q. and Parida, S. (2017). Serological detection of antibodies to peste des petits ruminants virus in large ruminants. *Transboundary and Emerging Diseases*, **64**(2): 513-519.

Adombi, C. M., Lelenta, M., Lamien, C. E., Shamaki, D., Koffi, Y. M., Traoré, A., Silber, R., Couacy-Hymann, E., Bodjo, S.C., Djaman, J.A. and Luckins, A.G. (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. *Journal of virological methods*, **173**(2): 306-313.

Afera, B., Hussien, D. and Amsalu, K. (2014).Seroprevalence of Peste des petits ruminants in goats of southern parts of Tigray region.*Global Veterinaria*, **12**(4): 512-516.

Agga, G. E., Raboisson, D., Walch, L., Alemayehu, F., Semu, D. T., Bahiru, G., Woube, Y. A., Belihu, K., Tekola, B. G., Bekana, M. and Roger, F. L. (2019). Epidemiological survey of peste des petits ruminants in Ethiopia: Cattle as potential sentinel for surveillance. *Frontiers in Veterinary Science*, **6**: 302.

Albina, E., Kwiatek, O., Minet, C., Lancelot, R., de Almeida, R. S. and Libeau, G. (2013). Peste des petits ruminants, the next eradicated animal disease?. *Veterinary microbiology*, **165**(1-2): 38-44.

Alemayehu, G., Hailu, B. and Seid, N. (2015). Participatory assessment of major animal health constraints to sheep export from Afar Pastoral Production System. *Global Veterinaria,* **15**(1): 48-56.

Alemu, B. (2014). Epidemiology and identification of peste des petits ruminants (PPR) virus circulating in small ruminants of eastern Amhara region bordering Afar, Ethiopia. *MSc Thesis. Addis Ababa University, Bishoftu, Ethiopia*, **112**.

Alemu, B., Gari, G., Libeau, G., Kwiatek, O., Kidane, M., Belayneh, R., Siraw, B., Wieland, B., Asfaw, W. and Abdi, R.D. (2019). Molecular detection and phylogenetic analysis of Peste des petits ruminants virus circulating in small ruminants in eastern Amhara region, Ethiopia. *BMC veterinary research*, **15**(1): 1-9.

Alhaji, N. B., and Kabir, J. (2016). Influence of Pastoralists' Sociocultural Activities on Tsetse–Trypanosome–Cattle Reservoir Interface: The Risk of Human African Trypanosomiasis in North-Central Nigeria. *Zoonoses and Public Health*, **63**(4): 271-280.

Alhaji, N. B., Babalobi, O. O. and Isola, T. O. (2018). A quantitative exploration of nomadic pastoralists' knowledge and practices towards Rift Valley fever in Niger State, North-central Nigeria: The associated socio-cultural drivers. *One Health*, **6**: 16-22.

Ali, W. H., Osman, N. A., Asil, R. M., Mohamed, B. A., Abdelgadir, S. O., Mutwakil, S. M. and Mohamed, N. E. (2019). Serological investigations of peste des petits ruminants among cattle in the Sudan.*Tropical animal health and production*, **51**(3): 655-659.

Alidadi, N., Aghaeean, L., ZiafatiKafi, Z., Hamedi, M. and Ghalyanchilangeroudi, A. (2021). Detection and Phylogenetic Study of Peste des Petits Ruminants in Iran, 2019: Updated Data. *Archives of Razi Institute*, **76**(1): 161.

Al-Majali, A.M., Hussain, N.O., Amarin, N. M. and Majok, A. A. (20080.Seroprevalence of, and risk factors for, peste des petits ruminants in sheep and goats in Northern Jordan. *Preventive veterinary medicine*, **85**(1-2): 1-8.

Amenu, K., Szonyi, B., Grace, D. and Wieland, B. (2017). Important knowledge gaps among pastoralists on causes and treatment of udder health problems in livestock in southern Ethiopia: results of qualitative investigation. *BMC veterinary research*, **13**: 1-13.

Ashraf, W., Unger, H., Haris, S., Mobeen, A., Farooq, M., Asif, M., and Khan, Q. M. (2016). Genetic detection of peste des petits ruminants virus under field conditions: a step forward towards disease eradication. *BMC veterinary research*, **13**: 1-13.

Baazizi, R., Mahapatra, M., Clarke, B. D., Ait-Oudhia, K., Khelef, D. and Parida, S. (2017). Peste des petits ruminants (PPR): A neglected tropical disease in Maghreb region of North Africa and its threat to Europe. *PloS one*, **12**(4): 0175-461.

Balamurugan, V., Sen, A., Venkatesan, G., Bhanot, V., Yadav, V., Bhanuprakash, V. and Singh, R.K. (2012). Peste des petits ruminants virus detected in tissues from an Asiatic lion (Panthera leo persica) belongs to Asian lineage IV. *Journal of veterinary science*, **13**(2): 203-206.

Balamurugan, V., Varghese, B., Kumar, K.V., Muthuchelvan, D., Dheeraj, R., Govindaraj, G., Suresh, K.P., Hemadri, D. and Roy, P. (2020). Seroprevalence study of peste des petits ruminants in sheep and goats in the northern region of India. *Veterinary World*, **13**(8): 1573.

Balamurugan, V., Vinod Kumar, K., Dheeraj, R., Kurli, R., Suresh, K.P., Govindaraj, G., Shome, B.R. and Roy, P. (2021). Temporal and spatial epidemiological analysis of Peste des petits ruminants outbreaks from the past 25 years in sheep and goats and its control in India. *Viruses*, **13**(3): 480.

Banyard, A. C., Parida, S., Batten, C., Oura, C., Kwiatek, O. and Libeau, G. (2010). Global distribution of peste des petits ruminants virus and prospects for improved diagnosis and control. *Journal of general virology*, **91**(12): 2885-2897.

Baron, M. D., Parida, S. and Oura, C. A. L. (2011). Peste des petits ruminants: a suitable candidate for eradication?. *Veterinary Record*, **169**(1): 16-21.

Benfield, C. T., Legnardi, M., Mayen, F., Almajali, A., Cinardi, G., Wisser, D., Chaka, H. and Njeumi, F. (2023). Peste Des Petits Ruminants in the Middle East: Epidemiological Situation and Status of Control and Eradication Activities after the First Phase of the PPR Global Eradication Program (2017–2021). *Animals*, **13**(7): 1196.

Bett, B. K., Jost, C. and Mariner, J. C. (2008). Participatory investigation of important animal health problems amongst the Turkana pastoralists: Relative incidence, impact on livelihoods and suggested interventions. *ILRI Targeting and Innovation Discussion Paper*.

BZAO (2022).Borena Zone Agriculture Office

Chen, W., Hu, S., Qu, L., Hu, Q., Zhang, Q., Zhi, H., Huang, K. and Bu, Z. (2010). A goat poxvirus-vectored peste-des-petits-ruminants vaccine induces long-lasting neutralization antibody to high levels in goats and sheep. *Vaccine*, **28**(30): 4742-4750.

Chowdhury, E. H., Bhuiyan, A. R., Rahman, M. M., Siddique, M. S. A. and Islam, M. R. (2014). Natural peste des petits ruminants virus infection in Black Bengal goats: virological, pathological and immunohistochemical investigation. *BMC Veterinary Research*, **10**(1): 1-10.

Chukwudi, I. C., Ogbu, K. I., Ugwu, G. N., Ugochukwu, E. I. and Chah, K. F. (2022). Serological screening of Peste des petits ruminants, comparative haemodynamic changes and serum biochemical profiles in symptomatic and asymptomatic sheep and goats in Enugu State. *Nigerian Journal of Animal Science*, **24**(3): 60-70.

Cosseddu, G. M., Polci, A., Pinoni, C., Capobianco Dondona, A., Iapaolo, F., Orsini, G., Izzo, F., Bortone, G., Ronchi, F.G., Di Ventura, M. and El Harrak, M. (2016). Evaluation of humoral response and protective efficacy of an inactivated vaccine against peste des petits ruminants virus in goats. *Transboundary and emerging diseases*, **63**(5): 447- 452.

Couacy-Hymann, E., Koffi, M. Y., Kouadio, V. K., Mossoum, A., Kouadio, L., Kouassi, A., Assemian, K., Godji, P. H. and Nana, P. (2019). Experimental infection of cattle with

wild type peste-des-petits-ruminants virus–their role in its maintenance and spread.*Research in veterinary science*, **124**:118-122.

Delil, F., Asfaw, Y. and Gebreegziabher, B. (2012). Prevalence of antibodies to peste des petits ruminants virus before and during outbreaks of the disease in Awash Fentale district, Afar, Ethiopia. *Tropical animal health and production*, **44**: 1329-1330.

Diallo, A. (2006). Control of peste des petits ruminants and poverty alleviation.*Journal of Veterinary Medicine, Series B*, **53**: 11-13.

Dou, Y., Liang, Z., Prajapati, M., Zhang, R., Li, Y. and Zhang, Z. (2020). Expanding diversity of susceptible hosts in peste des petits ruminants virus infection and its potential mechanism beyond. *Frontiers in veterinary science*, **7**:66.

Drummond, R. B. and Moll, E. J. (2002). Keith Coates Palgrave trees of Southern Africa. Struik Publishers, Cape Town, South Africa, **225**: 345-667.

Dubie, T., Dagnew, B., Gelo, E., Negash, W., Hussein, F. and Woldehana, M. (2022).Seroprevalence and associated risk factors of peste des petits ruminants among ovine and caprine in selected districts of Afar region, Ethiopia.*BMC Veterinary Research*, **18**(1): 429.

Dundon, W. G., Diallo, A. and Cattoli, G. (2020). Peste des petits ruminants in Africa: a review of currently available molecular epidemiological data, *Archives of Virology*, **165**(10): 2147-2163

Duressa, G. (2022). Dhibaayyuu: An indigenous thanks giving ritual among the Borena Oromo, Southern Ethiopia. *Cogent Social Sciences*, **8**(1): 2011540.

El-Hakim, O. (2006). An outbreak of peste des petits ruminants (PPR) at Aswan Province, Egypt evaluation of some novel tools for diagnosis of PPR. *Assiut Veterinary Medical Journal*, **52**(110): 146-157.

El-Yuguda, A., Chabiri, L., Adamu, F. and Baba, S. S. (2010). Peste des petits ruminants virus (PPRV) infection among small ruminants slaughtered at the central abattoir, Maiduguri, Nigeria. *Sahel Journal of Veterinary Science*, **8**(2): 93-96.

Elzein, E. A., Housawi, F. M. T., Bashareek, Y., Gameel, A. A., Al-Afaleq, A. I. and Anderson, E. C. E. C. (2004). Severe PPR Infection in Gazelles kept under semi-free range conditions. *Journal of Veterinary Medicine, Series B*, **51**(2): 68-71.

ESGPIP (2009).Body condition scoring of sheep and goats. Technical Bulletin 8, Ethiopia.

ESGPIP (2009). Estimation of the weight and age of sheep and goats. Technical Bulletin 23, Ethiopia

Ezeibe, M. C. O., Okoroafor, O. N., Ngene, A. A., Eze, J. I., Eze, I. C. and Ugonabo, J. A. C. (2008). Persistent detection of peste de petits ruminants antigen in the faeces of recovered goats. *Tropical animal health and production*, **40**(7): 517-519.

Faris, D., Yilkal, A., Berhe, G. and Kelay, B. (2012).Seroprevalence and sero-conversion after vaccination against Peste des Petits Ruminants in sheep and goats from Awash Fentale District, Afar, Ethiopia.*Preventive veterinary medicine*, **103**(2-3): 157-162.

Fathelrahman, E. M., Reeves, A., Mohamed, M. S., Ali, Y. M. E., El Awad, A. I., Bensalah, O. K. and Abdalla, A. A. (2021). Epidemiology and Cost of Peste des Petits Ruminants (PPR) Eradication in Small Ruminants in the United Arab Emirates, Disease Spread and Control Strategies Simulations. *Animals*, **11**(9): 2649.

Fenetahun, Y. and Fentahun, T. (2020).Socio-economic profile of arid and semi-arid agropastoral region of Borena Rangeland Southern, Ethiopia.*MOJ Eco Environ Sci Rep*, **5**(3): 113-122.

Fine, A. E., Pruvot, M., Benfield, C. T., Caron, A., Cattoli, G., Chardonnet, P., Dioli, M., Dulu, T., Gilbert, M., Kock, R. and Lubroth, J. (2020). Eradication of peste des petits ruminants virus and the wildlife-livestock interface. *Frontiers in Veterinary Science*, **50**: 1-5.

Gari, G., Serda, B., Negesa, D., Lemma, F. and Asgedom, H. (2017).Serological investigation of peste des petits ruminants in east Shewa and Arsi Zones, Oromia Region, Ethiopia.*Veterinary medicine international*, **2017**.

Gebre, T., Deneke, Y. and Begna, F. (2018).Seroprevalence and Associated Risk Factors of Peste Des Petits Ruminants (PPR) in Sheep and Goats in Four Districts of Bench Maji and Kafa Zones, South West Ethiopia.*Global Veterinaria*, **20**(6): 260-270.

Gelana, M., Gebremedhin, E.Z. and Gizaw, D. (2020).Seroepidemiology of Peste des Petits ruminants in sheep and goats in the selected district of Horu Guduru Zone, Western Ethiopia.*Research in Veterinary Science*, **132**: 527-534.

Gemeda, B. A., Amenu, K., Magnusson, U., Dohoo, I., Hallenberg, G.S., Alemayehu, G., Desta, H. and Wieland, B. (2020). Antimicrobial use in extensive smallholder

livestock farming systems in Ethiopia: knowledge, attitudes, and practices of livestock keepers. *Frontiers in Veterinary Science*, **7**: 55.

Govindaraj, G.N., Balamurugan, V., Reddy, G.B.M., Yogisharadhya, R., Reddy, T.S., Naveenkumar, G.S., Kumar, K.V., Chaithra, H.R., Bi, A.Z., Parida, S. and Njeumi, F. (2023). Towards Eradication of PPR: Disease Status, Economic Cost and Perception of Veterinarians in Karnataka, India. *Animals*, **13**(5): 778.

Gulyaz, V. and Ozkul, A. (2005). Pathogenicity of a local peste des petits ruminants virus isolate in sheep in Turkey. Tropical animal health and production, **37**(7): 541.

Gur, S. and Albayrak, H. (2010).Seroprevalance of peste des petits ruminants (PPR) in goitered gazelle (Gazella subgutturosa subgutturosa) in Turkey.*Journal of wildlife diseases*, **46**(2): 673-677.

Haile, A., Mirkena, T., Duguma, G., Wurzinger, M., Rischkowsky, B., Tibbo, M., Okeyo, M. and Sölkner, J. (2013). Community based sheep breeding programs: Tapping into indigenous knowledge. *Livestock Research for Rural Development*, **25**(12): 219.

Hailegebreal, G. (2018). Seroprevalence of Peste Des Petits Ruminants in Selected Districts of Siltie and Gurage Zones, South Region, Ethiopia. *Journal of Veterinary Science andTechnology*, **9**(2): 529.

Hammami, P., Lancelot, R. and Lesnoff, M. (2016). Modelling the dynamics of post-vaccination immunity rate in a population of Sahelian sheep after a vaccination campaign against peste des petits ruminants virus. *PloS one*, **11**(9): e0161769.

Hassen, A. S. and Tesfaye, Y. (2014).Sheep and goat production objectives in pastoral and agro-pastoral production systems in Chifra district of Afar, Ethiopia. *Tropical animal health and production*, **46**: 1467-1474.

Hodgson, S., Moffat, K., Hill, H., Flannery, J. T., Graham, S. P., Baron, M. D. and Darpel, K. E. (2018). Comparison of the immunogenicities and cross-lineage efficacies of live attenuated peste des petits ruminants virus vaccines PPRV/Nigeria/75/1 and PPRV/Sungri/96. *Journal of virology*, **92**(24): 01471-18.

Hoffmann, B., Wiesner, H., Maltzan, J., Mustefa, R., Eschbaumer, M., Arif, F. A. and Beer, M. (2012). Fatalities in wild goats in Kurdistan associated with Peste des Petits Ruminants virus. *Transboundary and emerging diseases*, **59**(2): 173-176.

Housawi, F. M. T., EME, A. E., Mohamed, G. E., Gameel, A. A., Al Afaleq, A. I., Hegazi, A. and Al-Bishr, B. (2004). Emergence of Peste des petits ruminants in sheep and goats in Eastern Saudi Arabia. *Revue d'elevage et de Medecine Veterinaire des pays Tropicaux*, **57** (1-2).

Https://www.nvi.com.et/, National veterinary institute, Accessed in May 23, 2023

Husen, M., Aliyi, F., Damtew, S., Negassa, T. and Abebe, H. (2018).Prevalence of small ruminant helminthiasis in and around Tullo district in western Harerghe zone, eastern Ethiopia.*Austin J Vet Sci Anim Husb*, **5**:1038.

Intisar, K. S., Ali, Y. H., Haj, M. A., Sahar, M. A. T., Shaza, M. M., Baraa, A. M., Ishag, O. M., Nouri, Y. M., Taha, K. M., Nada, E. M. and Ahmed, A. M. (2017). Peste des petits ruminants infection in domestic ruminants in Sudan. *Tropical animal health and production*, **49**: 747-754.

Ismail, I. M. (1990).Evidence of identification of peste des petits ruminants from goats in Egypt.*Arch Exp Veterinarmed***44**: 471– 474.

Jemberu, W.T., Knight-Jones, T. J., Gebru, A., Mekonnen, S. A., Yirga, A., Sibhatu, D. and Rushton, J. (2022).Economic impact of a peste des petits ruminants outbreak and vaccination cost in northwest Ethiopia. *Transboundary and Emerging Diseases*, **69**(5): e2084-e2092.

Jones, B.A., Mahapatra, M., Mdetele, D., Keyyu, J., Gakuya, F., Eblate, E., Lekolool, I., Limo, C., Ndiwa, J. N., Hongo, P. and Wanda, J. S. (2021). Peste des petits ruminants virus infection at the wildlife–livestock interface in the greater Serengeti ecosystem, 2015–2019. *Viruses*, **13**(5):838.

Kabir, M. E., Hossain, M. M., Ershaduzzaman, M., Yousuf, M. A. and Islam, M. R. (2016).Sero-surveillance and sero-monitoring of locally produced PPR vaccine in the field and experimental level.*Asian Journal of Medical and Biological Research*, **2**(1): 33-37.

Kahn, C. M. (2005).The Merck Veterinary Manual. (9 edt) White House Station, New Jersey.

Kgotlele, T., Torsson, E., Kasanga, C., Wensman, J. J. and Misinzo, G. (2016). Seroprevalence of Peste Des Petits Ruminants virus from samples collected in different regions of Tanzania in 2013 and 2015.

Khalafalla, A. I., Saeed, I. K., Ali, Y. H., Abdurrahman, M. B., Kwiatek, O., Libeau, G., Obeida, A. A. and Abbas, Z. (2010). An outbreak of peste des petits ruminants (PPR) in camels in the Sudan.*Acta tropica*, **116**(2): 161-165.

Khan, A., Saleemi, M.K., Ali, F., Abubakar, M., Hussain, R., Abbas, R. Z. and Khan, I. A. (2018).Pathophysiology of peste des petits ruminants in sheep (Dorper&Kajli) and goats (Boer &Beetal).*Microbial pathogenesis*, **117**: 139-147

Khan, H. A., Siddique, M., Abubakar, M., Arshad, M. J. and Hussain, M. (2008). Prevalence and distribution of peste des petits ruminants virus infection in small ruminants. *Small Ruminant Research*, **79**(2-3): 152-157.

Kihu, S. M., Gachohi, J. M., Ndungu, E. K., Gitao, G.C., Bebora, L. C., John, N. M., Wairire, G. G., Maingi, N., Wahome, R. G. and Ireri, R. (2015). Sero-epidemiology of Peste des petits ruminants virus infection in Turkana County, Kenya. *BMC veterinary research*, **11**: 1-13.

Kinne, J., Kreutzer, R., Kreutzer, M., Wernery, U. and Wohlsein, P. (2010).Peste des petits ruminants in Arabian wildlife.*Epidemiology & Infection*, **138**(8): 1211-1214.

Kivaria, F. M., Kwiatek, O., Libeau, G., Kapaga, A.M., Gladson, J., Swai, E. S., Moshy, W. and Mbyuzi, A. O. (2013). The incursion, persistence and spread of peste des petits ruminants in Tanzania: Epidemiological patterns and predictions. *Onderstepoort Journal of Veterinary Research*, **80**(1): 1-10.

Kwiatek, O., Ali, Y. H., Saeed, I. K., Khalafalla, A. I., Mohamed, O. I., Obeida, A. A., Abdelrahman, M. B., Osman, H. M., Taha, K. M., Abbas, Z. and El Harrak, M. (2011). Asian lineage of peste des petits ruminants virus, Africa. Emerging infectious diseases, **17**(7): 1223.

Lanari, M., Domingo, E., Centeno, M. and Gallo, L. (2005). Pastoral community selection and the genetic structure of a local goat breed in Patagonia. *Animal Genetic Resources/Resources Génétiques Animales/Recursos Genéticos Animales*, **37**: 31-42.

Libeau, G., Diallo, A. and Parida, S. (2014). Evolutionary genetics underlying the spread of peste des petits ruminants virus. *Animal Frontiers*, **4**(1): 14-20.

Libeau, G., Préhaud, 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** (1):50-5.

Logozzi, M., Di Raimo, R., Mizzoni, D. and Fais, S. (2020). Immunocapture-based ELISA to characterize and quantify exosomes in both cell culture supernatants and body fluids.*Methods in enzymology*, **645**: 155-180.

Luka, P. D., Erume, J., Mwiine, F. N. and Ayebazibwe, C. (2011). Seroprevalence of peste des petits ruminants antibodies in sheep and goats after vaccination in Karamoja, Uganda: implication on control. *International Journal of Animal and Veterinary Advances*, **3**(1): 18-22.

Mahapatra, M., Sayalel, K., Muniraju, M., Eblate, E., Fyumagwa, R., Shilinde, S., MaulidMdaki, M., Keyyu, J., Parida, S. and Kock, R. (2015). Spillover of peste des petits ruminants virus from domestic to wild ruminants in the Serengeti ecosystem, Tanzania. *Emerging infectious diseases*, **21**(12): 2230.

Makau, D. N., Slizovskiy, I., Obanda, V., Noyes, N. R., Johnson, J. R., Oakes, M., Travis, D., VanderWaal, K. and Omondi, G. P. (2022). Factors influencing usage of antimicrobial drugs among pastoralists in Kenya.*Tropical Animal Health and Production*, **54**(5): 332.

Malik, Y. S., Singh, D., Chandrashekar, K. M., Shukla, S., Sharma, K., Vaid, N. and Chakravarti, S. (2011). Occurrence of dual infection of peste-des-petits-ruminants and goatpox in indigenous goats of central India.*Transboundary and Emerging Diseases*, **58**(3): 268-273.

Mamo, G.D. (2019). Assessment on impact of live animal export on meat export performance in Ethiopia; Policy implications.*Business and Management Studies*, **5**(3): 21-28.

Mangesho, P. E., Caudell, M. A., Mwakapeje, E. R., Ole-Neselle, M., Kabali, E., Obonyo, M., Dorado-Garcia, A., Valcarce, A., Kimani, T., Price, C. and Eckford, S. (2021). "We are doctors": Drivers of animal health practices among Maasai pastoralists and implications for antimicrobial use and antimicrobial resistance. *Preventive veterinary medicine*, **188**: 105266.

Mantip, S. E., Shamaki, D. and Farougou, S. (2019). Peste des petits ruminants in Africa: meta-analysis of the virus isolation in molecular epidemiology studies. *Onderstepoort Journal of Veterinary Research*, **86**(1): 1-15.

Marashi, M., Masoudi, S., Moghadam, M.K., Modirrousta, H., Marashi, M., Parvizifar, M., Dargi, M., Saljooghian, M., Homan, F., Hoffmann, B. and Schulz, C. (2017). Peste

des petits ruminants virus in vulnerable wild small ruminants, Iran, 2014–2016. *Emerging infectious diseases*, **23**(4): 704.

Mebrahtu, K., Getachew, S., Tesfaye, T., Sahlu, E. and Aragaw, K. (2018). Sero-epidemiological study of peste des petits ruminants (PPR) in sheep and goats under different production systems in South Omo, southern Ethiopia.*Small Ruminant Research*, **169**: 90-93.

Megersa, B., Biffa, D., Belina, T., Debela, E., Regassa, A., Abunna, F., Rufael, T., Stubsjøen, S.M. and Skjerve, E. (2011). Serological investigation of peste des petits ruminants (PPR) in small ruminants managed under pastoral and agro-pastoral systems in Ethiopia. *Small Ruminant Research*, **97**(1-3): 134-138.

Michael, H. G., Mulate, B. and Belayneh, R. (2017).Serological and molecular investigation of peste des petits ruminants in Adama district, eastern Shoa zone of Oromia, Ethiopia.*Bulletin of Animal Health and Production in Africa*, **65**(2): 349-358.

Mohammed, A. A., Chibssa, T. R., Terfa, W., Aklilu, F., Damena, D., Belayneh, R. and Kidane, M. (2022).Isolation and Molecular Characterization of Peste des Petits Ruminants Virus from Outbreaks in Southern Ethiopia, *Advances in Virology*, **2022**.

Mondal, B., Sen, A., Chand, K., Biswas, S. K., De, A., Rajak, K. K. and Chakravarti, S. (2009). Evidence of mixed infection of peste des petits ruminants virus and bluetongue virus in a flock of goats as confirmed by detection of antigen, antibody and nucleic acid of both the viruses. *Tropical animal health and production*, **41**(8): 1661-1667.

Moreki, J. C., Tshireletso, K. O. and koli, I. C. (2012). Potential use of ethnoveterinary medicine for retained placenta in cattle in Mogonono, Botswana. *J. Anim. Prod. Adv*., **2**(6): 303-309.

Munibullah, L.Y., Munib, K. and Zhang, Z. (2021).Regional epidemiology and associated risk factors of PPR in Asia-A Review.*Int J Vet Sci Res*, **7** (2): 178-190.

Munir, M., Zohari, S., Berg, M., Munir, M., Zohari, S. and Berg, M. (2013). Immunology and immunopathogenesis of peste des petits ruminants virus. *Molecular Biology and Pathogenesis of Peste des Petits Ruminants Virus*, **1**: 49-68.

Negash, W. and Dubie, T. (2021). Study on seroprevalence and associated factors of bovine brucellosis in selected districts of Afar National Regional State, Afar, Ethiopia. *Veterinary medicine international*, **2021**: 1.

Nigusu, K. and Fentie, T. (2012). Prevalence and causes of selected respiratory infections in indigenous Gumuz sheep in Metema District, Northwest Ethiopia. *International Journal of Sciences: Basic and Applied Research*, **5**(1): 14-20.

Niyokwishimira, A., de D Baziki, J., Dundon, W.G., Nwankpa, N., Njoroge, C., Boussini, H., Wamwayi, H., Jaw, B., Cattoli, G., Nkundwanayo, C. and Ntakirutimana, D. (2019).Detection and molecular characterization of Peste des Petits Ruminants virus from outbreaks in Burundi, December 2017–January 2018. *Transboundary and emerging diseases*, **66**(5): 2067-2073.

OIE.(2015). Peste des petits ruminants, *The OIE Terrestrial Manual*, May 2015.

OIE.(2019). Peste des petits ruminants, *The OIE Terrestrial Manual*, May 2019.

Okoli, I. C., Tamboura, H. H., Hounzangbe-Adote, S. M., Katerere, R. D. and Luseba, D. (2010).Ethnoveterinary medicine and sustainable livestock management in West Africa.*Ethnoveterinary Botanical Medicine: Herbal Medicines for Animal Health*, **14**: 321-344.

Omani, R. N., Gitao, G. C., Gachohi, J., Gathumbi, P. K., Bwihangane, B. A., Abbey, K. and Chemweno, V.J. (2019). Peste des petits ruminants (PPR) in dromedary camels and small ruminants in Mandera and Wajir Counties of Kenya. *Advances in virology*, **2019**.

Osman, N. A., Ali, A. S., A/Rahman, M. E. and Fadol, M. A. (2009).Antibody seroprevalences against Peste des Petits Ruminants (PPR) virus in sheep and goats in Sudan. *Tropical Animal Health and Production*, **41**:1449-1453.

Osman, N. A., Ibrahim, H. M., Osman, A. A., Alnour, R. M. and Gamal Eldin, O. A. (2018). Sero-prevalence of peste des petits ruminants virus antibodies in sheep and goats from the Sudan, 2016–2017. *VirusDisease*, **29**(4): 531-536.

Prajapati, M., Dou, Y., Zhu, X., Zhao, S., Alfred, N., Li, Y. and Zhang, Z. (2020). Development of an enzyme-linked immunosorbent assay based on CD150/SLAM for the detection of peste des petits ruminant virus. *Frontiers in Veterinary Science*, **7**: 196.

Radostits, O. M., Gay, C. C., Hinchcliff, K. W. and Constable, P. D. (2007).A textbook of the diseases of cattle, horses, sheep, pigs and goats. *Veterinary medicine*, **10**: 2045-2050.

Rahman, M. M., Sabuj, A. A. M., Islam, M. S., Islam, M. A., Alam, J., Ershaduzzaman, M. and Saha, S. (2023). Serological study and risk factor analysis on Peste des Petits Ruminants in sheep in Bangladesh. *Saudi Journal of Biological Sciences*, **30**(3): 103565.

Rajput, Z. I., Zahur, A. B., Soomro, N. A., Rajput, I. R., Lakho, S. A. and Leghari, A. (2016). PPR sero-prevalance and sero-monitoring after vaccination in field.*Sci. Int. Lahore (Lahore)*, **28**(6): 5259-5261.

Roeder, P. L., Abraham, G., Kenfe, G. and Barrett, T. (1994).Peste des petits ruminants in Ethiopian goats.*Tropical animal health and production*, **26**(2): 69-73.

Roger, F., Guebre Yesus, M., Libeau, G., Diallo, A., Yigezu, L.M. and 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*).

Rume, V. N., Dundon, W. G., Belay, G., Diakite, A., Paul, A., Tessema, Y. D., Nwankpa, N., Gizaw, D., Cattoli, G., Bodjo, S. C. and Tessema, T. S. (2019). Molecular epidemiological update of peste des petits ruminants virus (PPRV) in Ethiopia. *Veterinary microbiology*, **235**: 229-233.

Saeed, F. A., Abdel-Aziz, S. A. and Gumaa, M. M. (2018). Seroprevalence and associated risk factors of Peste des petits ruminants among sheep and goats in Kassala state, Sudan. *Open Journal of Animal Sciences*, **8**(04): 381.

Saeed, I. K., Haj, M. A., Alhassan, S. M., Mutwakil, S. M., Mohammed, B. A., Taha, K. M., Libeau, G., Diallo, A., Ali, Y.H. and Khalafalla, A. I. (2022). A study on transmission of Peste des petits ruminants virus between dromedary camels and small ruminants. *Journal of Infection in Developing Countries*, **16**(2):374-382.

Saliki J. T. (2022). Overview of Peste des Petits Ruminants, *Veterinary.Manual.*Accessed date, March 18, 2023.

Saravanan, P., Balamurugan, V., Sen, A., Sarkar, J., Sahay, B., Rajak, K.K., Hosamani, M., Yadav, M.P. and Singh, R.K. (2007).Mixed infection of peste des petits ruminants and orf on a goat farm in Shahjahanpur, India. *The Veterinary Record*, **160**(12): 410.

Schulz, C., Fast, C., Wernery, U., Kinne, J., Joseph, S., Schlottau, K., Jenckel, M., Höper, D., Patteril, N.A.G., Syriac, G. and Hoffmann, B. (2019). Camelids and cattle are dead-end hosts for peste-des-petits-ruminants virus. *Viruses*, **11**(12): 1133.

Sen, A., Saravanan, P., Balamurugan, V., Bhanuprakash, V., Venkatesan, G., Sarkar, J., Rajak, K. K., Ahuja, A., Yadav, V., Sudhakar, S. B. and Parida, S. (2014). Detection of subclinical peste des petits ruminants virus infection in experimental cattle. *Virus disease*, **25**: 408-411.

Senbeto, A. Y. (2022). Epidemiology of peste des petits ruminants, isolation and molecular detection of the virus in selected districts of awi and metekel zones, North West Ethiopia. MSc thesis Submitted to the College of Veterinary Medicine and Agriculture, Addis Ababa University.

Shyaka, A., Ugirabe, M. A. and Wensman, J. J. (2021). Serological Evidence of Exposure to Peste des Petits Ruminants in Small Ruminants in Rwanda. *Frontiers in Veterinary Science*, **8**: 651978.

Silva, A. C., Yami, M., Libeau, G., Carrondo, M. J. and Alves, P. M. (2014).Testing a new formulation for Peste des Petits Ruminants vaccine in Ethiopia. *Vaccine*, **32**(24): 2878-2881.

Singh, R. P., Sreenivasa, B. P., Dhar, P. and Bandyopadhyay, S. K. (2004).A sandwich-ELISA for the diagnosis of Peste des petits ruminants (PPR) infection in small ruminants using anti-nucleocapsid protein monoclonal antibody.*Archives of virology*, **149**:2155-2170.

Singh, R.K., Balamurugan, V., Bhanuprakash, V., Sen, A., Saravanan, P. and Yadav, M.P. (2009). Possible control and eradication of peste des petits ruminants from India: technical aspects. *Vet Ital*, **45**(3): 449-462.

Sori, T., Bekana, M., Adugna, G. and Kelbessa, E. (2004).Medicinal plants in the ethnoveterinary practices of Borena pastoralists, Southern Ethiopia. *Int J Appl Res Vet Med*, **2**(3): 220-5.

Sow, F., Camara, Y., Traore, E. H., Cabaraux, J. F., Missohou, A., Antoine-Moussiaux, N., Hornick, J. L. and Moula, N. (2021). Characterisation of smallholders' goat production systems in the Fatick area, Senegal.*Pastoralism*, **11**(1):1-11.

Swai, E. S., Kapaga, A., Kivaria, F., Tinuga, D., Joshua, G. and Sanka, P. (2009). Prevalence and distribution of Peste des petits ruminants virus antibodies in various districts of Tanzania. *Veterinary Research Communications*, **33**(8): 927.

Thrusfield, M., (2005).Veterinary epidemiology (3rd edn) Blackwell Science.*United Kingdom*, **158**.

Ullah, M., Li, Y., Munib, K. and Zhang, Z. (2022).Regional Epidemiology and Associated Risk Factors of PPR.*Authorea.*

Vougat, R. R. B., Tomdieu, T., Ziébé, R., Foyet, H. S., Moritz, M., Vondou, L., Schrunk, D. E., Imerman, P. M., Rumbeiha, W. K. and Garabed, R. B. (2017).Quality of veterinary pharmaceuticals and their use by pastoralists in the Far North Region of Cameroon.*Pastoralism*, **7**(1): 1-14.

Wang, Z., Bao, J., Wu, X., Liu, Y., Li, L., Liu, C., Suo, L., Xie, Z., Zhao, W., Zhang, W. and Yang, N. (2009). Peste des petits ruminants virus in Tibet, China. *Emerging infectious diseases*, **15**(2): 299.

Waret-Szkuta, A., Roger, F., Chavernac, D., Yigezu, L., Libeau, G., Pfeiffer, D. U. and Guitián, J. (2008). Peste des Petits Ruminants (PPR) in Ethiopia: Analysis of a national serological survey. *BMC Veterinary Research*, **4**: 1-10.

WOAH (2018).World Organization for Animal Health, https://www.woah.org/en/eradication-isnt-the-end-of-the-rinderpest/Accessed on April 28, 2023.

WOAH (2022).World Organization for Animal Health (WOAH), https://www.woah.org/en/what-we-do/animal-health-and-welfare/official-disease-status/.Accessed in April 28, 2023.

Wohlsein, P. and Saliki, J. (2006).Rinderpest and peste des petits ruminants. The diseases: Clinical signs and pathology. In Rinderpest and peste des petits ruminants.*Academic press.***68**: V.

Woma, T. Y., Kalla, D. J. U., Ekong, P. S., Ularamu, H. G., Chollom, S. C., Lamurde, I. I., Bajehson, D. B., Tom, N. D., Aaron, G. B., Shamaki, D. and Bailey, D. (2015).

Serological evidence of camel exposure to peste des petits ruminants virus (PPRV) in Nigeria. *Tropical animal health and production*, **47**: 603-606.

Xia, J., Zheng, X. G., Adili, G .Z., Wei, Y. R., Ma, W. G., Xue, X. M., Mi, X. Y., Yi, Z., Chen, S. J., Du, W. and Muhan, M. (2016). Sequence analysis of peste des petits ruminants virus from ibexes in Xinjiang, China. *Genet Mol Res*, **15**(2): 1-7.

Yalew, S., Woldemichal, G. and Mamo, M. (2019). Seroprevalence of Peste Des Petits Ruminant's Virus Antibody in Assosa Zone, Benishangulgumuz Region, Ethiopia. *ARC Journal of Animal and Veterinary Sciences*, **5**(3): 29-33.

Yasin, U., Wodajnew, B. and Tsehaineh, D. (2017). Study on the prevalence of GIT nematode infection of small ruminants in Kurmuk Woreda, Assosa Zone of Benishangul Gumuz Region, Western Ethiopia. *Rep Opin*, **9**(10): 48-59.

Zakian, A., Nouri, M., Kahroba, H., Mohammadian, B. and Mokhber-Dezfouli, M. R. (2016).The first report of peste des petits ruminants (PPR) in camels (Camelus dromedarius) in Iran. *Tropical animal health and production*, **48**: 1215-1219.

8. ANNEXES

Annex 1: Format for Sample Collections

No.	Sample ID	Districts	Kebele	Olla	Species(G,S}	Body	Sex(M,F)	Age	Origin (born, gift, buy)	Access to markets (Yes, No)	Introd. of new animals	Herd size (small, medium, large	Water source (publi, home)	Vaccine status (yes, no)	Access to vet service (yes, no)	cELISA results
	Sex: M=male, F=female Species; G=goat, S=sheep Body conditions: P=poor, M=medium, G=good															

Annex 2: Questionnaires on PPR

Date.....

ID No.....

I. General information about livestock owner

1. Region.....Zone.....District.....kebele .....Village/ollaa/.....
2. GPS reading: (a) Altitude …… (b) Longitude……(c) Latitude……
3. Name of respondent.....Sex: (a) Male (b) Female, Age.....
4. Educational level: (a) Non-formal education (years) (b) Primary education (c) Secondary school (d) Preparatory school
5. Marital status: (a) married (b) unmarried (c) widowed (d) divorced
6. Role of the respondent with livestock (multiple answers possible)

(a) Household (b) Marketing (c) keeper (d) None

7. Household size (number of people who share a meal in a house).....
8. How many years since you have been involved in keeping livestock? .....
9. Number of Livestock owned. What type of livestock do you have and tell us the number of each livestock you have?
    a. Cattle.....
    b. Sheep.....
    c. Goats.....
    d. Camels.....
    e. Equine (donkey....., Mule....., horse .....)
    f. Poultry.....
10. What are the main sources of food in the household? List the main sources of food in the household?.....

.....

11. What is the contribution of livestock to household food? .....
12. Does the lack of livestock owner affect one's social standing in the village? (a) Yes (c) No

13. How do you build your herds? List ways herds are accumulated and increase in sizes.....
.....
14. How do your sheep and goats leave the herd? List ways small stock leaves herds making your herd small?

.....

15. What are the age structures of sheep and goats? List of age sets of Sheep and goats.....
16. What period are major cultural ceremonies? .....
17. What cultural activities are you doing with small ruminants associated with the cultural ceremonies?.....

II. PPR-related disease occurrence

18. List the diseases of sheep and goats you have observed in last one years (local language).....
19. Do you have any dead sheep and goats? (a)yes (b) no
20. Please, mention symptoms that cause mortality to your shoat.....
21. Do you encounter in your sheep/goats that have eye and nose discharge, or stomatitis plague? (a) yes (b) no
22. Have you had PPR (Mararreeba (local name)) in your shoats? (a) yes (b) no
23. As you think, where does the disease originate from? .....
24. Have you seen PPR related outbreak in your area in the last one year? (a) yes (b) no
25. If yes, would you please provide the following information about the morbidity and mortality of the outbreak in your small ruminant herd?
    a. No. of affected species.....
    b. No. pregnant aborted.....
    c. No. died.....
    d. No. treated.....
26. How do the diseases get into your flocks?.....
27. How does the disease affect the flocks?.....

28. What signs are seen on sick sheep or goats?
    a. Nasal, oral, and ocular discharges and contagious.
    b. Diarrhea and nasal discharge and contagious
    c. Mouth lesions and diarrhea
29. When did the disease start in the area (Kebele)?

Season _____Mon____year____

30. What ages are affected by the diseases?.....
31. How frequent PPR reoccurs in the area? Don't Know __Every 1yr__ Every 2yrs__>3yrs__
32. How many animals had got sick and died due to PPR among the flock? _____

Categories	Species	Sex	sick	Died
< 4 month				
4 month -3 years				
>3 years				

33. What signs are seen on goats or sheep dead from the disease?.....

III. PPR risk factor-related issues

34. What is the common lambing/kidding season in which most of the animals born?
    (a) June – September (b) October – January (c) February – May
35. Did you encounter any critical season of feed shortages? (a) yes (b) no
36. If yes in which season .....
37. What period of the year are livestock raids common?
38. What period of the year do different flocks graze separately?
39. What period of the year do different herds graze together?
40. Do you move your shoats to another place for grazing or water search? (a) yes (b) no
41. If yes, when....., where ....., how long did you move them.....?
42. What is your watering point for your animal.....? And grazing system.....
43. How do you raise your sheep and goat?

a, Sheep and goat grazing separately (b) Sheep and goat grazing together (c) Sheep and goat grazing with other livestock (d) Other……...

44. Housing: Fenced stable …….; House barn…….
45. Have you bought new shoats or introduced new shoats before a month? (a) yes (b) no
46. If yes, the origin of the shoats, number, sex, and age? .....
47. What is your livestock market frequently used? Name……distance (km)…….....
48. How often are goats/sheep/sheep taken to the market and returned home? (a) never (b) sometimes (c) always
49. Do you cross into neighboring countries in such of pasture and water? (a) yes (b) no
50. If yes, when do you cross into neighboring countries with livestock?.....
51. Do you cross into neighboring countries to restock/buy flocks (raid)? (a) yes (b) no
52. If yes, when do you cross into neighboring countries to restock/buy flocks (month or season)?
53. Are there herds from other countries entering for grazing to your land? (a) yes (b) no
54. When do herds from other countries enter your land to share your water/feed sources?.....

IV. Community perception of PPR control methods

55. What does the community do when the animals get sick with PPR?.....
56. What are the traditional treatments/control options for small ruminants clinically signed with PPR-related disease? .....
57. What are the PPR treatment and control methods that your Village uses?.....
58. From whom do you get treatment and disease control support services? .....
59. What measures are taken to prevent PPR? (a)Traditional treatment (b) Modern treatment (c) Vaccination (d) No treatment (e) other.....
60. Did you vaccinate your shoats for PPR? (a) yes (b) no
61. If yes when? Before (a) 1 month (b) 1-2 months (c) > 3 months

62. How much are the costs of disease control components? (a) low (b) medium (c) costly

Annex 3: Small ruminant age estimation by dentitions

No. of permanent incisors	Estimated age range	
	Sheep	Goat
0 pair	Less than one year	Under one year
1 pair	1-1½ years	1-2 years
2 pairs	1½-2years	2-3 years
3 pairs	2½-3years	3-4 years
4 pairs	More than three years.	More than four years
Broken mouth	Aged	Aged

Source: ESGPIP, 2009

Annex 4: Body condition scoring method of sheep and goats

Condition	Score	Description
Starving	0	Extremely emaciated and on the point of death. It is not possible to detect any muscle or fatty tissue between the skin and the bone.
Very thin	1	The spinous process is prominent and sharp. The transverse processes are also sharp, the fingers pass easily under the ends, and it is possible to feel between each processes. The eye muscle areas are shallow with no fat cover.
Thin	2	The spinous process feels prominent but smooth, and individual processes can be felt only as fine corrugations. The transverse process is smooth and rounded, and it is possible to pass the fingers under the ends with a little pressure. The eye muscle area is of moderate depth, but has little fat cover
Moderate	3	The spinous process is detected only as a small elevation; it is smooth and rounded and individual bones can be felt only with pressure. The

		transverse process is smooth and well covered, and firm pressure is required to feel over the ends. The eye muscle area is full, and has a moderate degree of fat cover
Fat	4	The spinous processes can just be detected with pressure as a hard line between the fat covered eye muscle areas. The end of the transverse process cannot be felt. The eye muscle area is full, and has a thick covering of fat.
Very fat	5	The spinous process can't be detected even with firm pressure, and there is a depression between the layers of fat in the position where the spinous process would normally be felt. The transverse process cannot be detected. The eye muscle area is very full with thick fat cover. There may be large deposits of fat over the rump and tail.

Source: ESGPIP: 2009

Annex 5: Pictures indicating some serological and c-ELISA procedures




Annex 6: Pictures indicating some small ruminant production system in study area

Annex 7: Research Ethical Clearance Certificate

አዲስ አበባ ዩኒቨርሲቲ
የእንስሳት ሕክምናና
ግብርና ኮሌጅ
ቢሾፍቱ

ADDIS ABABA UNIVERSITY
College of Veterinary Medicine
and Agriculture
Bishoftu

Animal Research Ethics Review Committee

Ethical clearance certificate

Certificate Ref. No: VM/ERC/23/04/15/2023

Name of Applicant: Dr Samson Leta (MSc, Associate Professor)

Address: Department of Biomedical Sciences, College of Veterinary Medicine and Agriculture (Addis Ababa University)

Title of the project: *Advancing animal health through development of field-deployable diagnostic assay, bivalent vaccine and promotion of indigenous knowledge for peste des petits ruminants (PPR) and Sheep and Goat Pox (SGP): to promote early detection and progressive control of major small ruminant diseases – DABV-project*

Date of application:	**December, 2022**
Nature of the project:	**Field investigation and experimental vaccine trial**
Target animal species:	**Small ruminants**
Number of animals involved:	**2000**
Study area:	**Different parts of Ethiopia**

Minutes No. and date of review: **VM/ERC/04/15/022, 15/02/2023**

The Animal Research Ethical Review Committee of the College of Veterinary Medicine and Agriculture of Addis Ababa University has reviewed the above research project and unanimously approved the application of Dr Samson Leta.

Professor Getachew Terefe (DVM, PhD)
Chairman

Signature

Federal Democratic Republic of Ethiopia * Addis Ababa University College of Veterinary Medicine and Agriculture

መልሱን በሚጽፉልን ጊዜ አባክዎ የሮን ደብዳቤ ቁጥር ይጥቀሱልን
Please quote Our Ref. No. When replying

ፋክስ} Fax 251-11-4339933
ስልክ } Tel. +251 114338450
ፖ.ሣ.ቁ P.o.x. Box 34
ቢሾፍቱ፤ ኢትዮጵያ Bishoftu, Ethiopia

Annex 8: Status of plagiarism reports

EPIDEMIOLOGY OF PESTE DES PETITS RUMINANTS IN SMALL RUMINANTS OF BORENA ZONE, ETHIOPIA

by Adem Kumbe

Submission date: 15-Jun-2023 04:09PM (UTC+0300)
Submission ID: 2116625254
File name: Adem_msc_thesis_June__Final.docx (2.69M)
Word count: 22621
Character count: 128108

EPIDEMIOLOGY OF PESTE DES PETITS RUMINANTS IN SMALL RUMINANTS OF BORENA ZONE, ETHIOPIA

ORIGINALITY REPORT

14%	9%	10%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	repository.sustech.edu Internet Source	1%
2	repository.au-ibar.org Internet Source	1%
3	www.suaire.sua.ac.tz Internet Source	1%
4	Milkessa Gelana, Endrias Zewdu Gebremedhin, Daniel Gizaw. "Seroepidemiology of Peste des Petits ruminants in sheep and goats in the selected district of Horu Guduru Zone, Western Ethiopia", Research in Veterinary Science, 2020 Publication	<1%
5	www.oie.int Internet Source	<1%
6	www.frontiersin.org Internet Source	<1%
	www.hindawi.com	