Websites:
http://www.nbmedicine.org
http://www.sciencepub.net/nurse

Emails:
editor@sciencepub.net
nbmeditor@gmail.com

Biomedicine and Nursing

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Current Status Of Sheep And Goat Pox Diseases In Ethiopia: A Seminar Paper Presented For The Course: Current Topics In Veterinary Microbiology (MVMB-7252)

Tolessa Ebissa

Advisor: Hika Waktole (Bsc, Msc, Assist. Professor)
Department Of Veterinary Microbiology, Immunology And Public Health, Bishoftu, Ethiopia

Abstract: Ethiopia is endowed with large population of sheep and goats which supply milk, meat, and skin. Despite of these huge resource animal diseases is the major constraints that hinder the productivity. *Sheep and goat pox* disease is one of the major diseases caused by a genus of *Capripox virus* that cause detrimental effect on sheep and goat in many parts of the world. The objective of this review is to give insight on current status of the disease, its epidemiology, diagnosis, treatment, control and challenges of *sheep and goat pox* diseases. The diseases are most commonly transmitted through direct contact, indirect contact and mechanically by the vectors. Up on entry of virus into the host it replicates in local tissue and spread to different parts of the body as viremia causing pox lesions on skin (hair less area), lung, liver and kidney. Generally, in endemic areas the morbidity and mortality rate reaches 1-75% and 5-10% respectively. But, the disease is more sever in lambs, kids and exotic breed causing mortality rate up to 100%. In Ethiopia, the disease is distributed in all parts of the country causing significant economic losses in the form of decreased meat and milk yield, damage to skin, abortion, cause of death of animals, restriction of trade and genetic improvement of the animals. Diagnosis of the diseases is depends on clinical signs, laboratory confirmation and post mortem examinations. Since the disease has no effective treatment control measure depend on use of antibiotics for control of secondary bacterial complications, vaccination, limitation of animal movement and their products. But still control and eradication is challenging due to vaccine failure, nature of virus to undergo recombination and interspecies infection. Therefore awareness should be created on the husbandry and herd management to minimize interspecies infection and further study should be conducted at genetic level for detection of change in the genome and development of effective vaccine.

[Tolessa Ebissa. **Current Status Of Sheep And Goat Pox Diseases In Ethiopia: A Seminar Paper Presented For The Course: Current Topics In Veterinary Microbiology (MVMB-7252).** *Biomedicine and Nursing* 2021;7(2):
25-45]. ISSN 2379-8211 (print); ISSN2379-8203 (online). http://www.nbmedicine.org. 5.
doi:10.7537/marsbnj070221.05.

Keywords: *Capripox virus, Epidemiology, Ethiopia, Goat, Sheep, Sheep and goat pox and Vaccine*

TABLE OF CONTENTS
CONTENT……..…….PAGE

ACKNOWLEDGMENTS

First of all, my heartfelt thank goes to Almighty God and his Mother for giving me health, strength, patience and protection.

I am very much grateful to my advisor Mr. Hika Waktole for his encouragement, guidance, insight and professional assistance for the completion of this work.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBEREVATIONS

AU-IBAR	African Union Intera African Bureau for Animal Resources
AUSVETPLAN	Australian Veterinary Plan
CABI	Center for Agriculture and Biosciences International
CaPV	Capri Pox Virus
CCPP	Contagious Caprine Pluro Pneumonia
CFSPH	Center for Food Security Public Health
CSA	Central Statistical Agency
DNA	Deoxyribose Nucleic Acid
EFSA	European Food Safety Authority
ELISA	Enzyme Linked Immune Sorbent Assay
EM	Electron Microscope
ESGPIP	Ethiopian Sheep and Goats Productivity Improvement Program
FMD	Foot and Mouth Diseases
GGPV	Gorgan strain of Goat Pox Virus
GPCR	G-protein-coupled chemokine receptor
GTPV	Goat Pox Virus
H_2SO_4	Sulfuric Acid
HCL	Hydrochloric Acid
ILRI	International Livestock Research Institute

LIST OF ABBERVATIONS (CONTINUED)

ITR	Inverted Terminal Repeat
kbp	kilo base pair
kDa	kilo Dalton
KSGPV	Kenyan Sheep and Goat Pox Virus
LSD	Lumpy Skin Diseases
MAbs	Monoclonal Antibodies
MDBK	Madin Darby Bovine Kidney
NI	Neutralization Index
OIE	Organization of International Epizootics
ORF	Open Reading Frame
PCR	Polymerase Chain Reaction
PCR-RFLP	Polymerase Chain Reaction Restriction Fragment Length Polymorphism
PLK	Primary Lamb Kidney
PLT	Primary Lamb Testis
PPR	Peste dese Peptite Rumunants
REA	Restriction Enzyme Analysis
RPO30	RNA Polymerase subunit 30
RSPV	Romanian strain of Sheep Pox Virus
SGP	Sheep and Goat Pox

LIST OF ABBERVATIONS (CONTINUED)

SNT	Serum Neutralization Test
SPPV	Sheep Pox Virus
TCID50	Tissue Culture Infective Dose 50
USD	United State Dollar
VNT	Virus Neutralization Test
YSPV	Yugoslavian strain of Sheep Pox Virus

1. INTRODUCTION

Goat and sheep breeds are numerous which are found in a variety of livestock production systems and adapt to different agro ecology in many parts of the world. The majority can be found in extensive pastoralist and agro pastoralist areas by providing their owners with a vast range of products and services. Compared with large ruminants, they are cheaper to buy, their reproduction rate is relatively fast, they can easily be sold for cash or exchanged for other materials, provide milk, meat, skins and wool throughout the year. For farmers in cropping areas, they are also used as insurance against crop failure (Nottor, 2012; Abriham *et al*., 2018).

The greater Horn of Africa collectively exports several million live animals annually to the Arabian Peninsula (3 million in 2011) and in West Africa, goat meat and mutton account for about 25 percent of all meat produced in 2010 (FAO, 2013). Ethiopia is believed to have the largest livestock population in Africa with sheep and goat populations exceeding 50 million containing around 29.33 million of sheep and 29.11 million of goat, which make the country with the largest populations of small ruminants in Africa (CSA, 2014).

This huge amount of resource is providing 35% meat consumption and 14% of milk consumption in central highlands where mixed crop livestock production system is practiced. Small ruminants account for 40% of cash income and 19% of the household meat consumption**.** Hides and skins account for 12-16% of total value exports where the current utilization of hides and skins is estimated to be 48% for cattle hide, 75% for goat skin and 97% for sheep skin with the expected off take rate of 33% and 75% for sheep, goat and cattle respectively (Abriham *et al*., 2018). Thus, sheep and goat play an important economic role and make a significant contribution to both domestic and export markets through provision of food and non-food products (*Hurisa et al.,* 2018).

Although sheep and goat plays a significant role in national economy of the country to date the benefit obtained from these livestock are held back by different constrains. Among the major constraints livestock diseases are the important technical constraints that have hindered the development of the sector by decreasing production and hampering trade in animal and animal products (Jilo *et al.,* 2016). Among the major small ruminant diseases affecting the production and productivity *sheep and goat pox* is the one which is widely distributed in all region of the country (Tsegaye *et al.,* 2013).

Sheep and goat pox is the diseases caused by *sheep and goat pox virus* of family *poxviaridae* and genus of *Capripox virus* which is one of the largest, enveloped double stranded deoxyribose nucleic acid (DNA) viruses (www.ictvonline.org, Accessed on 29 July, 2019)**.** It causes highly infectious disease in sheep and goats where the disease is less commonly seen in indigenous breeds in area where it's endemic as compared with exotic breeds. It is transmitted by direct contact, indirect contact with infected object or fomites and through insect that can mechanically transmit the diseases. Up on establishment of infection in the host it can causes highly devastating systemic viremia which is characterized by widespread skin eruption, fever, generalized papules or nodules, vesicles (rarely) on hairless area of the skin, internal lesions in the lungs, respiratory and gastrointestinal mucosa and cause death of the animals (Abd-Elfatah *et al.,* 2018).

The diseases is distributed in most part of the world where it is commonly seen in Middle East, Africa (north of the equator), the Indian subcontinent, much of central Asia, and in South-Eastern Europe where sporadic outbreaks occur. Recently outbreaks have been recorded in Kazakhstan, Mongolia, Azerbaijan, Turkey, Greece and Bulgaria (Beard *et al*., 2010; Gelaye *et al*., 2013; Tuppurainen *et al*., 2017).

In Africa the number of countries affected by sheep and goat pox viruse were showing an increase in the trend of the diseases particularly for three consecutive years before 2011. However, the number of countries affected by sheep and goat pox virus remarkably decreased after 2011 in which twelve countries were reported from twenty six countries affected by the diseases in 2010 that indicate the reduction of the diseases by 46%. There is no tangible reason for the report of decrease in the diseases as there is no continental control and prevention program but it may happen due to national intervention. In Africa among the endemic countries that recorded high number of outbreak in 2011 Ethiopia were the first where high outbreak is recorded (AU IBAR, 2011).

Sheep and *goat pox* are among the most important diseases of sheep and goats in Ethiopia following *Peste des petits ruminants* (PPR) and *contagious caprine pleuropneumonia* (CCPP) that affect small ruminants entailing a huge economic loss and listed as trans-boundary disease of animal affecting the economy of the country (Befikadu and Endale, 2017).

A recent study by Gelaye *et al.* (2015) and Fentie *et al.* (2017) indicated sheep and goat pox (SGP) disease virus is responsible for the *Capripox* outbreaks in small ruminants in different parts of Ethiopia. It is among major diseases that restrict trade, limit introduction of exotic breeds of sheep and goats and hindering efforts to improve local sheep and goats. The diseases are also associated with significant production losses because of reduced milk and meat yield, decreased weight

gain, increase abortion rates, damage to wool and skin, increased susceptibility to pneumonia and fly strike and causing direct loss due to mortality of the animal. Therefore, the objectives of this seminar paper are:

- ✓ To review the current status, distribution and economic impact of sheep and goat pox diseases in Ethiopia.
- ✓ To highlight challenges and gaps in the control of the disease.

2. LITRETURE REVIEW

2.1. Definitions

Sheep and goat pox (SGP) is an acute to chronic contagious disease of sheep and goats characterized by generalized pox lesions throughout the skin and mucous membranes, persistent fever, lymphadenitis and often a focal viral pneumonia with lesions distributed uniformly throughout the lungs, liver, kidney and parts of gastrointestinal tract (Balamurugan and Venkatesan, 2015).

2.2. Etiology

2.2.1. *Sheep and Goat Pox Virus*

Sheep pox and goat pox (SGP) viruses are viruses that belonging to family *Poxviridae*, subfamily *Chordopaxvirinae* and genus of *Capripox viruses* (www.ictvonline.org, Accessed on 29 July, 2019). These are large (170–260 nm by 300-450 nm), double stranded doxyribose nucleic acid (DNA) and enveloped viruses. The length of genome of SGP viruses is about 150-kbp which includes at least 147 putative genes shared between the species of viruses (Muhaidi *et al*., 2018). Members of genus *Capripox virus* (CaPV) are closely related with identity between the members of the same genus is about 96% and 97% similarity between the isolates of the same species however, genomes of SGP viruses contain some nucleotide differences revealing that they are phylogenetically distinct and probably both of them have derived from an LSDV-like virus (Mahmoud and Khafagi, 2016).

Recently, P32-gene based PCR-RFLP, RPO30 and GPCR genes based sequencing and analyses have been applied for the differentiation of strains of *Sheep pox virus* (SPPV) and *Goat pox virus* (GTPV) from field samples (Saminathan *et al*., 2016, Khameis *et al*., 2018). One of the most important differences between SGP viruses is the presence of aspartic acid at position 55 of P32 gene in SP virus but absent at such position in the rest viruses of the genus. CaPVs are not easily distinguishable morphologically from Orthopoxviruses and serologically, these viruses share antigens with parapox viruses which are attributed due to the genetic similarity between the viruses (Roy *et al*., 2008). The virus is morphologically contain envelop, two lateral bodies, mature virion membrane, core wall and nucleocapsid as shown in the Figure 1.

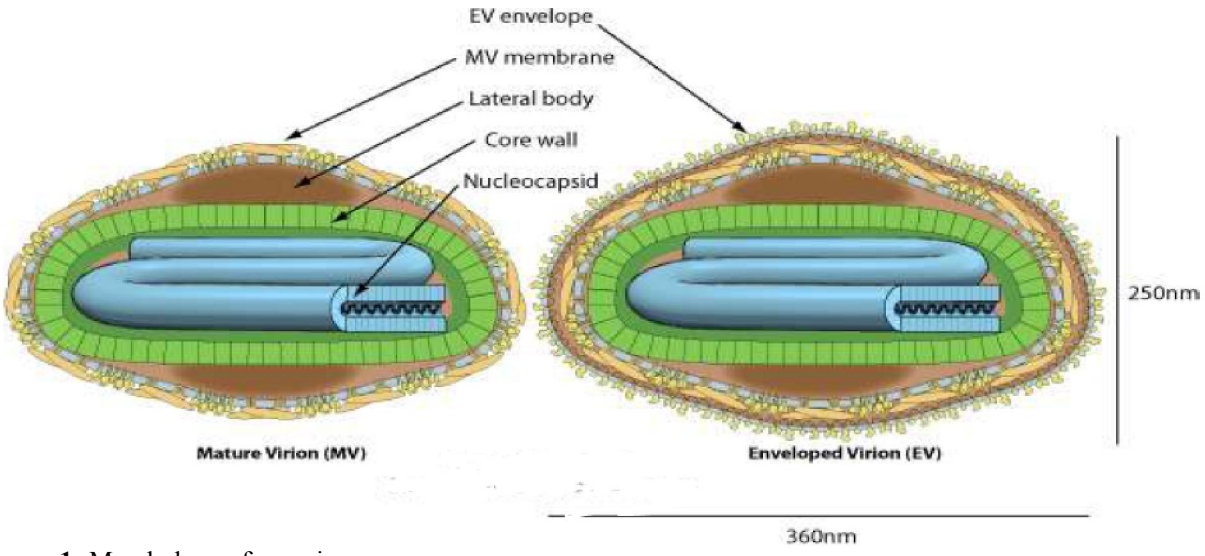

Figure 1: Morphology of pox virus
Source: Aberaham (2018)

2.2.2. *Classification*

According to the international committee on Taxonomy of viruses the virus belongs to family *Poxviridae*, subfamily *Chordopoxvirinae*, Genus *Capripoxvirus* as summarized in Figure 2.

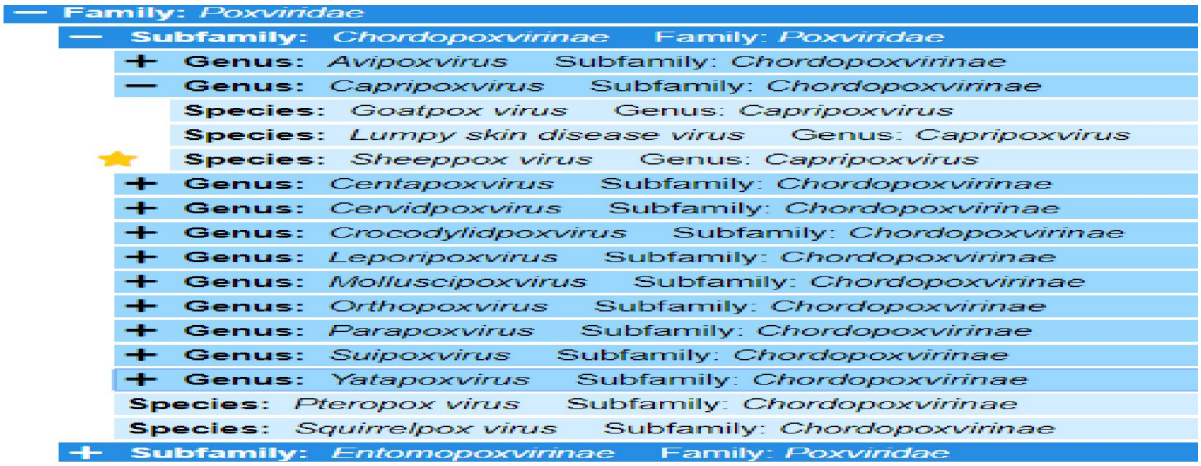

Figure 2: Taxonomic classification of *poxviridae*
Source: www.ictvonline.org, Accessed on 29 July, 2019.

2.2.3. *Genomic organization*

Virons are brick shaped, enveloped with complex symmetry and about 300x270x200 nm in size. Double stranded genomic DNA with about 150kbp size containing less variable central region bounded by two identical inverted terminal repeats (ITR) at the ends (Tulman *et al*., 2001; Tulman *et al*, 2002). Within the family *Chordopoxvirinae*, CaPV have the highest A-T content of 73-75% which gives the virus characteristics to undergo an extensive cross hybridization between the species of the virus (Santhamani *et al*., 2014).

Viral genome shares 147 putative genes which encode protein of 53-2,027 amino acids in size likely involved in structure, replication, virulence and host range (Zhao *et al*., 2017). The SPPV, GTPV and LSDV exhibit 96% amino acid and nucleotide identity over their entire genome length but, nine LSDV genes with probable virulence and host range function are disrupted in the genome of SPPV and GTPV. Both SPPV and GTP are likely derived from LSDV like ancestor but they possess specific nucleotide difference suggesting that both are phylogentically distinct (Madhavan *et al*., 2016). The coding region of CaPV genome has 1-156 ORFs in which the central ORFs (024-123) are conserved genes involved in replication and transcription mechanism. Whereas, the terminal ORFs (01-023 and 124-156) are variable in nature involving in host immune evasion and host range functions (Santhamani *et al*., 2014).

2.2.4. *Physicochemical properties*

In general, sheep and goat pox viruses (SGPV) will be inactivated at 56°C within two hour or at 65°C within half an hour. They can survive at a pH between 6.6 and 8.6 but, they are susceptible to highly acidic or alkaline pH, for example, 2% HCl or H_2SO_4 can completely destroy these viruses within 15 min (OIE, 2014). They can persist for long period of time in suitable environmental condition like in scab and hair or wool of the animals for 3 months. The virus can also survive up to 6 month in a dark, cool environment and shaded animal accommodations. However, they are susceptible to sunlight (Hopker *et al*., 2019).

2.3. Epidemiology

2.3.1. *Geographic range*

There are distinct differences between the geographic distribution among the members of Capripox viruses (*Sheep pox*, *Goat pox* and *Lumpy Skin Disease viruses*). The geographic range of *Sheep pox* and *Goat pox* (Figure 1) has been restricted in the last 50 years mainly to Asia and Africa, extending from Africa north of the Equator, into the Middle East, Turkey, and Asia including regions of the former Soviet Union, India and China. *Sheep pox* or *Goat pox* extended their range into Bangladesh in 1984 and more recently into Vietnam (2005 and 2008) and Mongolia (2006 and 2007) in the east and repeated incursions have been reported in Greece in southern Europe (2007). In addition, the disease has been reported in the Caucasus region, Kazakhstan and Kyrgyzstan but, American continent and Australia are free from Capripox virus infections (Babiuk *et al.,* 2009; Gu *et al*., 2018).

In Europe the disease was first reported by Norway in 1879 although the disease has been eradicated first in England and then in other European countries. In the same way eradication and vaccination programs were applied in Turkey but, the infection is still occasionally reported in sheep and goats. This variability can be associated with severity of pox epidemics with years, presence of the disease in different animals in vaccinated regions and genomic differences between field strains and vaccine strains have been reported as the main cause for the diseases outbreak in Turkey (Hasoksuz *et al*., 2014).

The spread of *Sheep and goat pox* into new areas is also predominantly associated with the increase of illegal animal movement through trade as well as inadequate or breakdown of veterinary services. Countries free of *Capripox virus* usually have in place legislation based on OIE recommendations that attempt to prevent the trans-boundary spread of production limiting diseases, but increasingly these are becoming more difficult to enforce, including on the border of the European Union (Yeruham *et al*., 1995). The global occurrence of SPP and GTP from 2005 to 2017 and the number of years of presence is reported in the maps below (as in Figures 1) (Tuppurainen *et al*., 2017; Hursia *et al.,* 2018).

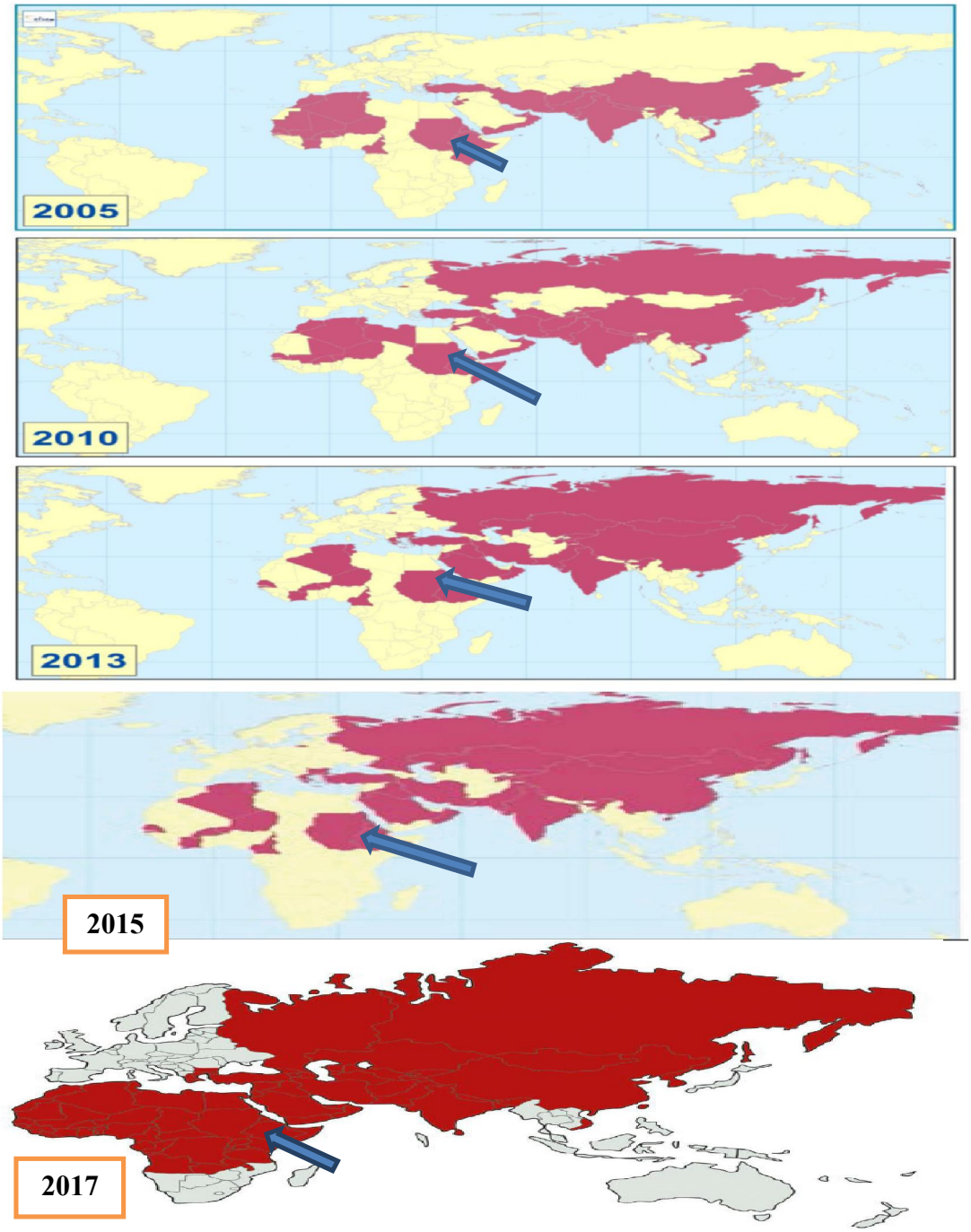

Figure 3: Global occurrence of SPP and GTP as reported to OIE.
Source: Tuppurainen *et al*. (2017); Hursia *et al*. (2018).

Countries reporting SPP and GTP are highlighted in red color as revealed on the figures, the disease is propagating in Africa, Middle East and Asia and the arrow head indicate as SGP is occur throughout the regions of Ethiopia.

2.3.2. *Host specificity*

Sheep and goat pox viruses can only infect small ruminant species and have a tropism for certain cell types but, they are not infectious to humans. *Sheep pox virus* and *Goat pox virus* cause clinical disease in sheep and goats respectively. However, there is a wide range of clinical disease seen with different field isolates. Some isolates are uniformly pathogenic in both sheep and goats such as some *Capripox virus* strains from Kenya and Middle East (Yemen and oman sheep isolate) were reported as they infect both species (Al-Shabebi *et al*., 2014; Hota *et al.,* 2018). Most isolates however, cause more severe disease in either sheep or goats and cause only mild or sub-clinical infection in either of the two species (Mondal *et al*., 2004). Some reports about natural outbreaks reflect that goats have relatively mild clinical disease when infected with SPPV compared to severe disease in sheep likewise; sheep have relatively mild clinical disease when infected with GTPV compared to goat's infection (Zhou *et al*., 2012).

Moreover, there are two types of *Sheep pox virus* in which one affects both sheep and goats like Kenyan sheep and goat (KSG) strain while the other is host specific. Recent records indicate that strains of *Sheep pox* do pass between sheep and goats where it can undergo recombination that enable the viruses to have intermediate host preferences and a range of virulence (Yune and Abdela, 2017). Thus, Isolates of *Sheep pox* and *Goat pox* are not host-specific they can infect goats and sheep and those who have recovered from infection with SGPV isolates from a heterologous host have immune to any challenge with a virulent homologous virus (Sadri and Fallahi, 2010).

To date there is no evidence of SPPV and GTPV viruses in wildlife. It is assumed that wildlife do not play a relevant role in the epidemiology of SPP and GTP although it cannot be excluded that wild sheep and wild goats can be infected with SPPV. In support of this fact, the lumpy skin disease virus closely related to SPPV/GTPV has been isolated from wild ruminants (Tuppurainen and Oura, 2012).

2.3.3. *Risk factor*

Sheep and goat pox viruses are also highly stable in normal environment condition and can survive for prolonged time like in cool environment with or without presence of susceptible animal. It can remain infectious for up to six months in sheep pens and may also be found on the wool or hair for as long as three months after infection. But, it is sensitive to 1% of formalin, extreme PH which is either acidic or basic conditions and they are also inactivated by sun light and heat (Yilmaz *et al*., 2016).

Group of Sheep and goat of all age, breed and sex are susceptible to sheep and goat pox. In areas where *Sheep and goat pox* is enzootic imported breeds of sheep and goats, lambs, kids and immunologically compromised animals are highly susceptible to the viruses (ESGPIP, 2009). *Goat pox virus* is highly host-specific infecting only goats, but host specificity varies from isolate to isolate of the virus. It is possible that the host preference shown by different strains is due to their adaptation to the presence of either sheep or goat alone in a limited geographical area (Sadri and Fallahi, 2010).

Environmental conditions play a great role in the occurrence of *Sheep and goat pox* diseases since it has impact on the agent, host and vectors as well as interaction between them. These predisposing factors have role in maintenance of stable flies (*Stomoxys calcitrans*), Tsetse fly and *Musca* species to susceptible animals which are mechanical vectors for transmission of disease (Radostits *et al*., 2006). The presence of conducive environmental condition like cold temperature can also favors the survival of the virus for long period of time in addition to the resistance ability of the virus although conditions like sun light can still inactivate the virus (AUSVETPLAN, 1996).

2.3.4. *Transmission*

Viral shedding occurs in nasal; oral and ocular secretions starting from the appearance of papules with the quantity and duration of shedding dependent on the virus isolate and host species. It is common that viral DNA and infectious virions can be detected in some secretions for up to a month following resolution of acute disease (Bowden *et al*., 2008). The amount of viral shedding correlates with the severity of clinical disease with sheep and goats displaying mild clinical signs shedding less amount of virus than sheep and goats that have more severe clinical disease. The high concentrations of virus in the skin and the ability of the virus to remain viable in scabs for few months in the environment may also contribute to the spread of *Sheep pox* and *Goat pox* (Babiuk *et al*., 2008).

Sheep and goat pox virus can be transmitted mainly through direct contact between an infected and a susceptible animal where infected animals also have high virus titres in skin lesions and scabs. Skin to skin contact can directly spread the virus via skin abrasion and sucking lambs and kids may contract infection from the milk and the skin of the teats (EFSA, 2014). It can also spread in droplets or aerosols through coughing, sneezing, head shaking and breathing

(Babiuk *et al*., 2008). In endemic regions, infections may go unnoticed and in that situation movement of animals from infected farms often months after recovery can often lead to introduction of the disease into naive flock (Bhanuprakash *et al*., 2006).

The high concentrations of the virus in the skin scab may also contribute to the spread of SPP and GTP via insect vectors. There is evidence that stable flies (*Stomoxys calcitrans*) Tsetse fly and *musca* species can act as an efficient mechanical vector of SPPV and GTPV however, no transmission was detected with biting (*Mallophaga* species) and sucking lice (*Damalinia* species). Flies transmit the virus to susceptible sheep and goats can able to carry the virus that can be remain viable for four days in some flies. High virus titres, intrinsic resistance of the virus, vectors with large mouthparts and their frequent feeding habits are the basic factors favoring mechanical transmission (Rodistits *et al*., 2006; Tuppurainen *et al*., 2017).

Virus in saliva, ocular and nasal discharge, skin lesions and scabs, urine and faeces may contaminate feed, water, wool and the environment leading to an indirect transmission of the virus either orally or via skin abrasions. Infectious virus is well protected inside scabs which are shed by infected animals. when scabs dissolve the virus may be released into the environment and this may continue for several months after the outbreak but, there is no report that have been published on survival of SPPV/GTPV in litter, fodder and feed (EFSA, 2014).

2.3.5. *Morbidity and Mortality*

Sheep and goat pox are one of OIE list notifiable and trans-boundary diseases that affect sheep and goat where it should be notified within 24 hour of confirming the disease (Mirzaie *et al.,* 2015). Morbidity and mortality in sheep and goats depends on the breed, level of immunity, previous exposure to *Sheep pox* or *Goat pox*, the age of the animal and the strain of the virus. In endemic areas mild infections are common in healthy and adult individuals where mortality rate 5-10% but, it can reach up to 100% in newly introduced exotic sheep or goats, lambs and kids, lactating females, immune compromised shoats and those living in an area that hasn't experienced SPPV and GTPV infections in some time. In flocks with reoccurring sheep pox and goat pox infections, morbidity rates can vary from 1–75 percent, but mortality is almost always less than 10 percent (CABI, 2015).

2.4. Pathogenesis

Incubation period of *Sheep pox* is 4-8 days and that of *Goat pox* is 4-15 days. *Sheep and goat pox virus* have tropism for epithelia tissue in which after the virus enter to the host through any route of infection it can replicate locally and infest epithelial tissue of the host. The virus can then multiply to high titer up to seven days of post infection thereby spread to the regional lymph nodes where it can further multiply and cause more infection. After 3-4 days, it causes primary viremia in which the viremia will spread to different parts of the body thus affecting spleen, lung, gastrointestinal tract and liver. In skin, nodules develop from 7 to 14 days after inoculation where the virus titers persisted and within 24 hours of the appearance of generalized papules affected animal develop conjunctivitis, rhinitis and enlargement of all superficial lymph nodes particularly prescapular lymph nodes. It also causes excessive salivation after infection but the virus titer can decreased with the development of serum antibodies (OIE, 2012).

There are five stages in the development of poxvirus infection. Roseola stage is stage in which Skin lesions typically begin with small red spots within three days of infection followed by papules which is accompanied by development of febrile state after three days of Roseola stage. During this stage nodular skin lesions that are developed from roseola stage (red spots) are hard during palpation and within 5-6 days are changed in to vesicles and known as vesicular stage. Following the vesicular stage pustular stage develops within 3 days which later on develop in to the last stage of pox lesion which is the scab formation and it is characterized by containing high loads of viruses (Bowden *et al.,* 2008).

2.5. Clinical signs

In natural cases, these diseases have an incubation period of four days up to two weeks. Symptoms start with nasal and ocular discharge, pyrexia (40–42 °C), difficulty breathing, depression and loss of appetite. Skin lesions are usually first noticed on the face around the lips and nares and on the eyelids (as in Figure 2) (Mahmoud *et al*., 2016). Skin lesions progress through macular, papular, vesicular and pustular stages until scabs form. The lesions may cover the entire body but are more easily detected on the hairless parts of the skin and mammary glands (Chu *et al*., 2011). Clinically observation of the disease with lesions of papule development under the tail of sheep and goat is highly indicative and almost considered as pathognomonic signs of the diseases as in Figure 3 (EFSA, 2014).

Ulcerative lesions appear on the mucous membranes of the mouth, nasal cavities and throughout the digestive and respiratory tracts (Bowden *et al*., 2008). The animal may recover in three to four weeks with permanent depressed scars. In lambs and particularly in suckling animals the disease is usually severe with lesions on the oral mucosa, in the anterior nares and throughout the digestive tract. Pneumonia, enlargement of the udder and abortion may occur in severe cases (Zangana and Abdullah, 2013).

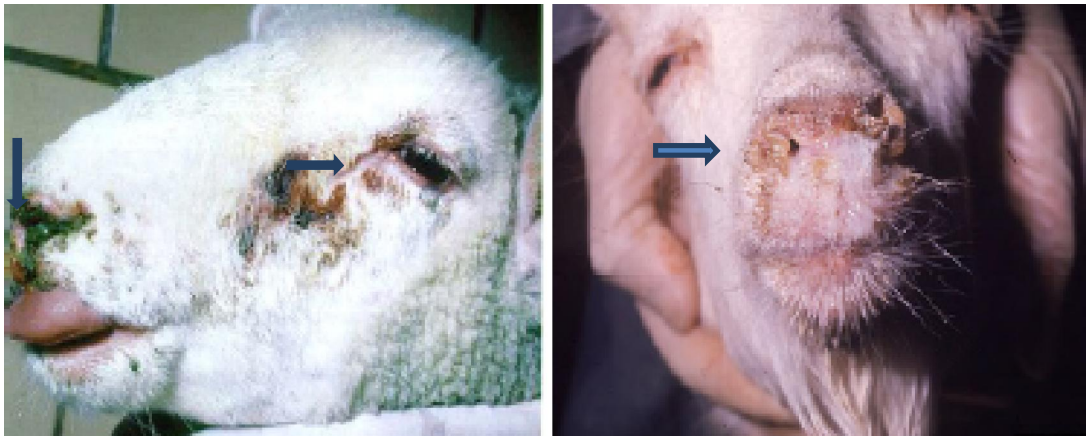

Figure 4: Oral, nasal and ocular lesion of *sheep and goat pox*

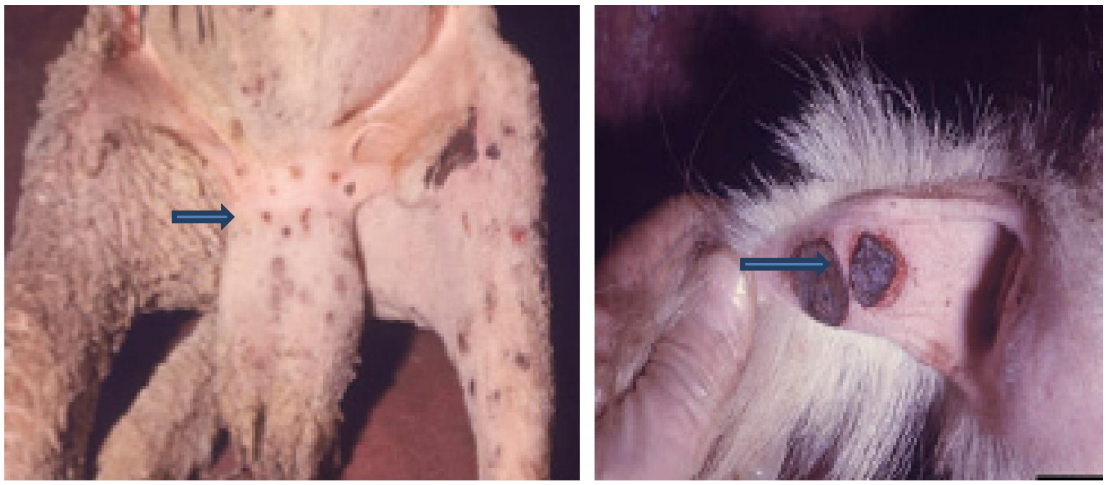

Figure 5: *Sheep and goat pox* lesion under the tail
Source: Yune and Abdela (2017).

2.6. Postmortem lesions

Upon death of the animal the skin contains congested bloody, swollen and necrotic lesions. The mucous membranes of the eyes, nose, mouth, vulva and prepuce is necrotized or ulcerated and all the body lymph nodes are enlarged or swollen. Lymph nodes draining infected areas are enlarged up to eight time normal size, swollen with body fluids, congested and hemorrhagic. The lungs often contain severe and extensive pox lesions. Pox lesions are also common on abomasal mucosa, rumen, large intestine, tongue, pharynx, trachea and esophagus. Pale areas of approximately 2 cm in diameter pox lesions are occasionally seen on the surface of the kidney and liver. The lesions in the different parts of internal organs are summarized in figure 6 (Aberaham, 2018).

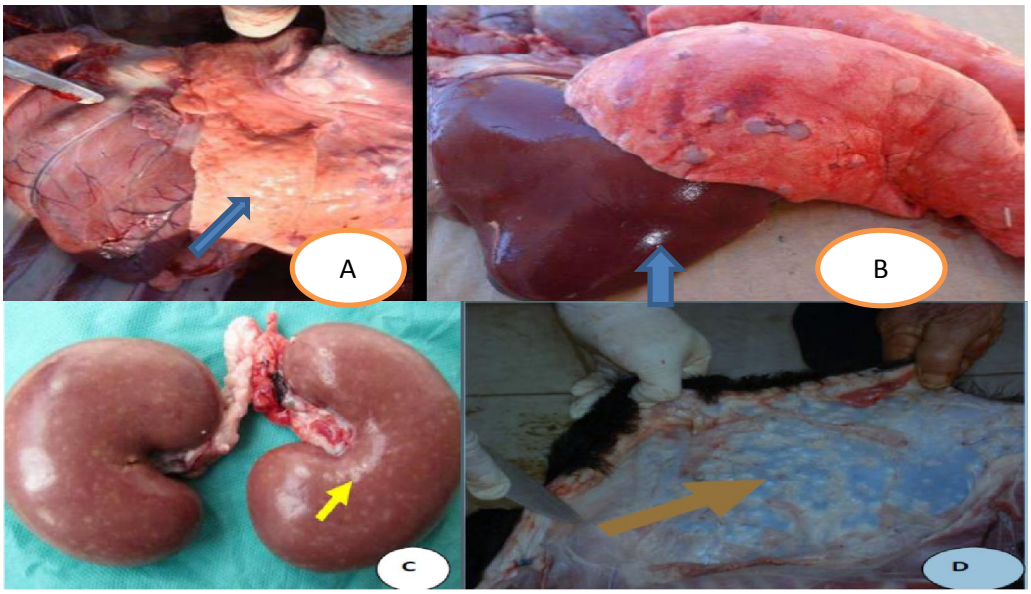

Figure 6: Postmortem lesion of SGPV on lung, liver, kidney and skin of sheep and goat
Source: Marzaie *et al.* (2015).

Postmortem lesion on lung (A) contains severe and extensive pox lesions, liver (B) and kidney (C) showing pale necrotized areas on the surface and skin lesion (D) with extensive pox lesions.

2.7. Histopathology

Histo-pathologically there are extensive inflammatory, necrotic and proliferative changes typical of pox lesions. The presence of epithelioid cells that infiltrate the lesions and intra-cytoplasmic inclusion bodies are characteristic for *sheep and goat pox* (AUSVETPLAN, 1996). The diseases can cause epidermal changes like acanthosis (Figure 7C), parakeratosis and hyperkeratosis with degeneration of proliferating epithelial cells. In the dermis it forms micro-vesicles of various sizes filled with pink fluid, vasculitis, infiltration with macrophages, fibroblasts and necrotized tissues or cells (Figure 7A). Also in some skin it can cause granulation of the tissue, necrosis which contains necrotic debris and formation of pus (Figure 7B). In respiratory system it forms pulmonary nodules which are characterized by proliferative bronchiolitis and alveolitis, giving the appearance of gland-like structures (Mersha, 2011).

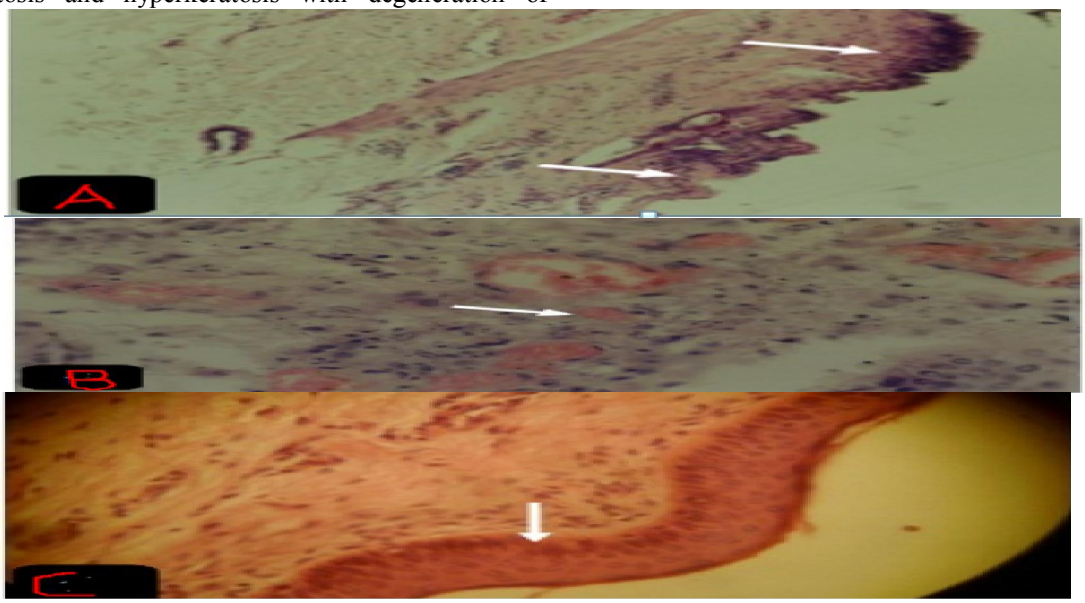

Figure 7: Histopathological lesion of SGPV on dermis and epidermis of sheep and goat.
Source: Mersha (2011).

The arrow head indicated show histopathological lesion of skin sample with inflammatory cell infiltrations and necrosis of the epidermis (A) and necrotic areas and cellular debris in the dermis (B) and acanthosis in epidermis (C).

2.8. Diagnosis

Sheep and goat pox can be diagnosed commonly based on observable clinical sign, clinical pathology and species of affected host which are also important in the diagnosis of the diseases. However, clinically the diseases shows similar manifestation with different diseases which affect sheep and goat and it need to be differentiated from these disease such as; Bluetongue, contagious ecthyma, foot and mouth diseases (FMD), dermatophillosis/streptothricosis, mange, photosensitization, Peste des Petite Ruminants (PPR) and multiple insect bites as they cause similar skin lesions in the affected hosts. Therefore laboratory confirmation is based on conventional antigen/antibody detection test and molecular techniques which are important in the differentiation and confirmation of the diseases (OIE, 2014).

2.8.1. *Microscopic examination*

Electron microscopy (EM) is used to identify *Capripox viruses* although differentiation between the three species and also between the *Capripox virus* and *Orthopox virus* is difficult. However, almost all *Orthopox viurses* do not cause lesions in cattle (except *vaccinia* and *cowpox*), sheep and goat. Therefore when the diseases occur in the sheep and goat show lesions it may not be due to *Orthopox virus* as the virus cannot affect small ruminants. Although EM is an important alternative in the diagnosis it requires special equipment and high concentrations of antigen (Haegeman *et al*., 2019).

2.8.2. *Virus isolation*

Skin papule, lung lesion and lymph node are the preferable material for the virus isolation and antigen detection. The animal has to be sampled on the first week of occurrence of clinical signs because after a week the animal can produce neutralizing antibodies against the virus (Rao and Bandyopadhay, 2000). Blood and buffy coat are ideal source of isolation of the virus during viremia or before or within 4 days of generalizations (Bhanuprakash *et al*., 2006). Capripox viruses are able to grow on multiple types of cells (muscle, adrenal, thyroid, kidney, lung or dermis cells) of bovine, ovine or caprine origin. The primary lamb kidney (PLK) and the primary Lamb testis (PLT) are the most commonly used cells for primary isolation and adaption of CaPV (Haegeman *et al*., 2019). Virus can also be grown in established cell lines such as Vero cells, MDBK cells and OA3Ts cell lines. Both SPPV and GTP produce similar cytophatic effects like ballooning, high refractility, rounding, intra-cytoplasmic inclusion bodies, chromatin fragmentation, detachment and plaque formation (Madhavan *et al*., 2016).

2.8.3. *Virus neutralization test*

Virus neutralization test (VNT) is still one of the most used assays to demonstrate the presence of *Capripox* antibodies notwithstanding the fact that only neutralizing antibodies are detected (Fentie *et al*., 2017). In a first VNT method a test serum can be titrated against a constant titre of *Capripox virus* 100 TCID50 (50% tissue culture infective dose) (OIE 2017). Although neutralization is very specific for almost all the viruses, the test is not very effective in diagnosing sheep and goat pox mainly due to partial neutralization, low serum neutralization indices and virus breakthrough due to variable susceptibility of cell cultures. Further, neutralization has been considered to be unreliable in determining the immune status of an animal (Abdi, 2017).

The use of Vero cells in neutralization has been reported to give more consistent results than the LT or LK cells. A constant virus-variable serum method using serum dilutions in the range of 1/5–1/500 and fetal calf muscle cells can overcome the virus breakthrough as these cells are least sensitive than LT or LK cells (OIE, 2000). Despite all these drawbacks, many researchers have employed SNT to study the antigenic relationship between SPV, GPV and LSD (Abdi, 2017), to confirm the disease or to assess the post-vaccinal immune status (Bhanuprakash *et al*., 2003).

Because of the variable sensitivity of cell culture to Capripox virus and to consequent difficulty of ensuring the use of 100TCID50, the neutralization index is the preferred method. It is done by titrating a standard virus strain against a constant concentration of the test serum. A neutralization index (NI) can be calculated as the log difference of the titre of the test serum and a negative control serum. A sample is considered to be positive if the NI is equal or above to 1.5 (OIE, 2017).

2.8.4. *Antigen capturing enzyme linked immune sorbent assay*

Following the cloning of the highly antigenic *Capripox virus* structural protein P32, it is possible to use expressed recombinant antigen for the production of diagnostic reagents, including the raising of P32 mono-specific polyclonal antiserum and the production of monoclonal antibodies (MAbs) (OIE, 2010). These reagents have facilitated the development of a highly specific ELISA. Using hyperimmune rabbit antiserum raised by inoculation of rabbits with purified *Capripox virus*, *Capripox* antigen from biopsy suspensions or tissue culture supernatant

can be trapped on an ELISA plate. The presence of the trapped antigen can then be detected using guinea-pig serum raised against the group-specific structural protein P32, commercial horseradish-peroxidase-conjugated rabbit anti-guinea-pig immunoglobulin and a chromogen/substrate solution (OIE, 2008).

2.8.5. *Fluorescent antibody tests*

Capripox virus antigen can also be identified on infected cover-slips or tissue culture slides using fluorescent antibody tests. Cover-slips or slides should be washed and air-dried and fixed in cold acetone for 10 minutes. The indirect test using immune sheep or goat sera is subject to high background color and nonspecific reactions. However, a direct conjugate can be prepared from sera from convalescent sheep or goats or from rabbit's hyperimmunised with purified *Capripox virus*. Uninfected tissue culture should be included as a negative control because cross-reactions due to antibodies to cell culture antigens can cause problems. The fluorescent antibody tissue section technique has also been used on cryostat-prepared slides (OIE, 2008).

2.8.6. *Western blotting*

Western blotting of test sera against *Capripox virus* infected cell provides a sensitive and specific system for the detection of antibody to *Capripox virus* structural proteins. However, the test is expensive and difficult to carry out. Positive test samples and controls produce a consistent reaction with the major structural proteins of *Capripox virus* of molecular weights 67, 32, 26, 19 and 17 kDa, whereas negative serum samples will not react in this pattern. Western Blotting analysis is labor intensive, not always easy to interpret and it is less suited for high throughput (OIE, 2010).

2.8.7. *Viral genome detection*

Detection of viral genome is used to poof the presence of virus (infectious or not) in a given sample which can be achieved by polymerase chain reaction (PCR) based technologies or direct hybridization. Various PCRs were developed using different targets, multiplication systems (isothermal versus thermal profiles) or visualization methods (endpoint versus real-time, agarose versus probes, intercalation dye). PCRs have also been developed for different purposes like detecting all *Capripox viruses* at once (PanPCR), *Capripox* genus specific detection, *Capripox* differentiation, wild type versus vaccine strain detection of the virus, multi disease detection and detection of a combination of viruses (Haegeman *et al*., 2019).

Polymerase chain reaction technique becomes more effective for the diagnosis of SPV and GPV from field samples when combined with restriction enzyme analysis (REA) of PCR-amplicons (Hosamani *et al*., 2004). Recently, SPV and GPV from infected cell culture supernatants and skin biopsy were clearly differentiated by REA of PCR amplified P32 gene products. In addition, gel-based PCRs are those which can differentiate between the three members of *Capripox* genus by combining it with restriction fragment length polymorphism (RFLP) or by targeting one species specifically. The P32 gene has been used for multiple PCR-RFLP assays to distinguish between SPPV and GTPV by using HinfI enzyme (Yan *et al*., 2012).

2.9. Economic importance of sheep and goat pox diseases

Sheep and goat pox is most important diseases that cause direct animal losses and the decreased productivity of surviving animals which on average causes 30-43% of annual losses in income and it can take up to six years for the flock or herd to recover from an outbreak. The mortality rate of SPP and GTP can sometimes be considerably high particularly amongst exotic breed of sheep and goats, lambs and kids **(**Tuppurainen *et al*., 2017). Where it is the highly contagious SPPV and GTPV are able to cause mortality up to 50% in susceptible flock. Young animals show more severe disease and mortality in lambs and kids may be as high as 100% (Hamouda *et al*., 2017).

At a national level, it can put restrictions on international trade of live animals and animal products, costly vaccination campaigns and compulsory limitations of animal movements can cause significant indirect financial losses. The poorest smallholder farmers and pastoralists whose income and well-being rely mostly on their livestock in sale of milk, animals, skin and manure bear the heaviest burden during outbreaks (Tuppurainen *et al*., 2017). In addition, SPP and GTP have been identified as one of the major impediments for genetic improvement of sheep and goat populations, influence development of intensive production and reduce reproductive performance of sheep and goat in Africa, Indian subcontinent and Asia (Kitching, 1986).

In a country like Ethiopia, Sheep and goats contribute 25% of the domestic meat consumption; about 50% of the domestic wool requirements; about 40% of fresh skins and 92% of the value of semi-processed skin export trade the diseases is most important and leads to detrimental effect on the country economy. It is estimated that 1,078,000 sheep and 1,128,000 goats are used in Ethiopia for domestic consumption annually. The current annual off-take rate of sheep and goats is 33%and 35%, respectively. There is also a growing export market for sheep and goat meat and live animal export. In 2010/11, the export value from sheep and goat's meat and live animal were about 63 million and 148 million USD, respectively (Getachew *et al*., 2015).

Despite all this contribution of sheep and goat, the diseases causes huge economic loss, restriction of international trade of animals and their products and listed as one of trans boundary disease affecting the country (Ayalet *et al*., 2012). In Ethiopia generally the annual economic loss due to disease, mortality, reduced reproductive and productive performance of small ruminants was estimated by 150 million USD where there is 5-7 million sheep and goats die each year due to disease where among the most common disease *Sheep and goat pox* is the one leads to loss (Tsegaye *et al*., 2013).

According to the report of Getachew *et al*. (2015) in selected districts of Afar Regional state in Awash Fentale district, the informants ranked respiratory syndrome, diarrhea syndrome and SGP diseases as the top three priority diseases. The disease is comparably more serious in lowland arid areas than in midland and highland agro ecologies. Moreover the effect of *Sheep and goat pox* on skin is significant in which healing of the skin affected by pox virus is slow and that forms permanent scars which can affect the quality of product of leather industry in turn causes huge economic losses in the tanning sector of the country (Abraham *et al*., 2017). The prevalence of sheep and goat pox defects that leads to rejection of skin at different tannery in Ethiopia summarized as follows in Table 1.

Table 1: Prevalence of skin defect due to *sheep and goat pox*

Disease (type of defect)	**Prevalence (%)**		**Tannery**	**Reference**
	Sheep	Goat		
Sheep and goat pox (pox lesion on skin)	44	56	Mojo export	Berhanu *et al*. (2011)
	19	17	Bahar dar	Azene *et al*. (2015)
	1.2	15.5	Sheba Tigray	Kahsay *et al*. (2015)
	4.2	5.3	Mojo and Addis Ababa	Bisrat (2014)

* The prevalence of defect in Mojo and Addis Ababa is collected from eight tanneries

2.10. Treatment, control and prevention

Sheep and goat pox has no effective treatment therefore in order to overcome the loss due to the disease treatment approach is dependent on control of secondary bacterial infection which can be achieved through parenteral administration of abroad spectrum antibiotic to avoid complication of bacterial infections. For early recovery of the animal Cleaning of infected areas with weak solution of potassium permanganate (1:10000) and topically application of antibiotic ointment is important for skin lesion, keeping the animal in well ventilated enclosure, provision of balanced diet is helpful and in case if animals are unable to feed 10% glucose saline should be given parentally (Senthilkumar and Thirunavukkarasu, 2010; CABI, 2015).

Vaccination is used to control sheep pox and goat pox in endemic areas. Depending on the region, a single vaccine may be employed in all small ruminants or there may be separate *Sheep pox* and *Goat pox* vaccines (CFSPH, 2017). As with most pox viruses, exposure to SPPV and GTPV results in strong and long-lasting immunity against re-infection. Therefore, the most commonly used vaccines against *Sheep pox* and *Goat pox* are attenuated live or inactivated strains of SPPV or GTPV. The three viruses in the *Capripox virus* genus are cross-protective, meaning vaccination against one will protect against infection by all three (Beard *et al*., 2010).

The common live attenuated CaPV strains vaccine currently in use for control and prevention of *Sheep and goat pox* in different parts of the world include Neethling strain of LSDV, *Kenyan Sheep and Goat Pox Virus* (KSGPV), Yugoslavian strain of *Sheep Pox Virus* (YSPV), Romanian strain of *Sheep Pox Virus* (RSPV) and Gorgan strain of *Goat Pox Virus* (GGPV). According to many studies, it has been proven that CaPV strains share a major neutralizing site so animals that are infected with one strain of CaPV family and survived from it, will be resistant to infection with any other strain (Varshovi *et al*., 2017).

Control and prevention approach should be based on quarantine of newly introduced animals, biosecurity measures such as prevention of contact with other herds and disinfection of fomites, isolation of infected herds and sick animals at least for 45 days after they have recovered from clinical signs. Whereas outbreaks in non-endemic areas can be controlled through controlling animal movement, depopulation of infected and exposed animals, proper cleaning and disinfection of farms and equipment. In addition, Proper disposal of infected carcasses is important like burning or burial is often used and application of insect repellents on to the carcasses might aid in reducing virus transmission before burial. Waiting periods before restocking can reduce the risk from environments such as pastures, which may be impossible to disinfect in case if the disease has spread more widely vaccination may also be recommended (CFSPH, 2017).

2.11. Status of sheep pox and goat pox disease in Ethiopia

Sheep and goat pox is one of major diseases of sheep and goats encountered in Ethiopia (Solomon *et al*., 2014). Among the top three African countries that recorded the highest number of outbreaks in 2011 Ethiopia were the first with 223 outbreaks followed by Somalia (170) and Algeria (44). Overall, a total of 541 epidemiological units were affected on the continent involving 9932 cases and 1619 deaths, with a case fatality rate of 16.3% (AU-IBAR, 2011).

Sheep and goat pox is found in all region of the country where it is comparably more serious in lowland arid areas than in midland and highland agro ecologies (Abraham *et al*., 2017). However, there is no literature on the prevalence and trends of *sheep and goat pox* in Ethiopia before 2008. But, 893 pox outbreaks were reported to the Ministry of Agriculture in 2007/08 fiscal year. Out of the total population of sheep and goat in the country, about 57,638 sheep and goats contracted the disease and 4,853,347 sheep and goats were at risk in areas where outbreaks occurred. Out of the 57,638 sick sheep and goats 6,401 animals died. In the outbreak areas, the disease reporting rate is very low which is only about 35-40% due to this the actual figures in terms of affected, vaccinated and dead animals is expected to be higher than the reported figures (ESGPIP, 2009).

Recent study by Gelaye *et al*. (2015) on the outbreak investigation on *Sheep and goat pox* disease showed that a total of 1,234 outbreaks happen in different corners of the country from 2008-2012 as shown in the table 2. Additional different studies carried out on the prevalence of *Sheep and goat pox* diseases based on observation of typical clinical signs of pox lesions in different areas of the country is summarized in the table 3 as follows.

Table 2: Summary of *Sheep and goat pox* outbreaks in Ethiopia from 2008 to 2012

Disease	affected species	Year	No. of outbreaks	No. of animals at risk	No. of Cases	No. of deaths
Sheep and goat pox	sheep and goat	2008	380	1,855,710	41,122	2896
		2009	358	1,668,527	12,065	1256
		2010	366	2,283,840	8111	1132
		2011	224	1,472,062	7324	1161
		2012	410	2,008,449	9101	999

No.: Number; Source: Gelaye *et al*. (2015)

Table 3: Clinical sign based prevalence of *sheep and goat pox* in different part of Ethiopia

Study area	Year of study	Species affected	Prevalence (%)	Reference
Adama	2008	Sheep Goat	10.34 12.88	Yacob *et al*. (2008)
Gonder	2016	Sheep and goat	5.94	Teshome (2016)
Amhara region (NS, NG,SG and WG)	2017	Sheep Goat	17 14	Fentie *et al*. (2017)
Central Ethiopia (Tiyo, Yaya Gulale, Sululta, Mulo and Adea-berga) districts	2018	Sheep Goat	35.82 28.44	Aberaham (2018)
Ada berga district	2017	Sheep Goat	33.3 27	Abdi (2017)
Eastern tigray (Ganta Afeshum)	2016	Sheep and goat	4.7	Berihu (2016)
Western tigray (Tsegede, welkayte and kafta-humera)	2018	Sheep and goat	15.7	Welay *et al*. (2018)
South west Ethiopia Gamo gofa zone	2017	Sheep Goat	10.44 13.11	Bereket *et al*. (2017)

* NS: North Shoa, NG: North Gonder, SG: South Gonder and WG: West Gojjam.

Both Tables 2 and 3 indicated that SP and GP disease are important priority diseases in the country that need further attention from the government for research and control via vaccination activities. But to my understanding there is no clear policy in the country regarding control of the diseases.

2.12. Challenges in control and eradication of sheep and goat pox disease

Sheep and goat pox are generally considered to be host specific. However, the ability of SPPV and GTPV strains to naturally or experimentally cross-infect and cause disease in both host species has been described previously. This apparent variability in SPPV and GTPV host range, the clinical similarity between *Sheep pox* and *Goat pox* and the inability to differentiate the two diseases by serological assays have led to the suggestion that sheep pox and goat pox are part of a disease complex caused by a single viral species and hinder the diagnosis of the disease with the conventional diagnostic methods (Tulman *et al*., 2002).
Various methods such as virus isolation, serology tests and polymerase chain reaction (PCR) are available for diagnosis of these diseases; these tests have certain limitations such as time-consuming, laborious, technical complexity and require expensive instrumentation especially in developing country which make it hard to be used in poorly equipped laboratories or as a pen-site test in the field (Yang *et al*., 2017). Since this rapidly transmitted virus causes large pandemics. *Sheep pox* and *Goat pox* virus infection require rapidly and correct diagnosis to prevent any outbreaks. Lack of the necessary facility for early detection, effective preventive and control programs makes the diseases endemic to Africa and Asian country where the pandemic still occur however, the virus has been eradicated from European countries (Karapinar *et al*., 2017).

In addition, in nature, genetic recombination occurs among the members of the same genera of poxviruses. One such natural recombinant *Capripox virus* is the Kenyan sheep and goat 0240 strain (KSG), which was isolated from an outbreak of *Capripox* wherein both sheep and goats were affected, has put its own challenge on the host range preference of the diseases and the control programs (Bhanuprakash *et al*., 2012).

As control and prevention approaches live attenuated SPPV, GTPV and LSDV derived vaccines are widely used in many endemic countries to control SPP and GTP. Among the live attenuated vaccine, SGPV vaccine and subunit formulations have been used experimentally in enzootic and outbreak areas as vaccines against *Sheep pox*, *Goat pox*, and *Lumpy Skin Disease* (Chibssa *et al*., 2019). However, vaccine-induced disease and vaccine failure are some of the challenges that need to improve CaPV vaccines through understanding of the genetic base of virus virulence and host range to produce high efficacy vaccine (Tulman *et al*., 2002; Chibssa *et al*., 2018). Report from Egypt by Abd-Elfatah *et al*. (2019) showed live attenuated RSPPV vaccine used in their country were not provide successful protection in goat and cattle with reoccurrence of diseases and report by Gelaye *et al*. (2015) from Ethiopia indicated that *Capripox* disease is highly significant in the country due low performance of local vaccine and insufficient vaccination coverage.

3. CONCLUSION AND RECOMMENDATIONS

Sheep and goat pox is acute to chronic contagious diseases which affect sheep and goats causing lesions on the hairless parts of the body and internal organs. In Ethiopia the diseases is distributed throughout the country where diseases outbreak occurred each year at different corners of the country. Thus it result in detrimental loss in the production and productivity, restriction of live animal export, products and by products and even leads to death of the animal which can directly or indirectly influence the economy of the country. Control and eradication of *Sheep and goat pox* is challenging due to illegal movement of animas that allow the extension of the disease to different parts of the world, genetic similarity of the virus among species and genus which influence the diagnosis of the disease, lack of early diagnostic test to control outbreaks, the ability of the virus to undergo recombination, vaccine efficacy and failure problems which leads to the reoccurrence of diseases after vaccination. Therefore, based on the above conclusive remarks the following recommendations are forwarded:

- Efficient control, prevention and eradication program has to be planed and implemented.
- Awareness should be created on the husbandry and herd management to minimize the transmission of the disease between sheep and goats.
- Early diagnostic approach has to be developed to reduce the loss due to the disease outbreak.
- Further study should be conducted at genetic level on the different strains of the virus with host preference for development of potent vaccine and to identify the cause of the disease outbreak post vaccination of the animals.

4. REFERENCES

1. Abd-Elfatah, E.B., El-Mekkawi, M.F., Bastawecy, I.M. and Fawzi, E.M. (2018): Identification and phylogentic analysis of sheep pox during an outbreak of sheep in Sharkia Governorate, Egypt. *Genetics and Molecular Research*, **17**(2)1-12.
2. Abd-Elfatah, E.B., El-Mekkawi, M.F., Aboul-Soud, E.A., Fawzi, E.M. and El-Soally, S.A. (2019): immunological response of a new trivalent Capripox virus vaccine in pregnant ewes and does. *Slovenian veterinary research*, **56**: 445–455.
3. Abdi, A.C. (2017): Isolation and characterization of pox virus circulating in sheep and goat from outbreak cases of Adea berga district, west shoa zone, central Ethiopia. MSc Thesis, Addis Ababa University, Faculty of Veterinary Medicine, Bishoftu, Ethiopia.
4. Aberaham D.A. (2018): Outbreak investigation, isolation and molecular Characterization of sheep and goat pox virus in centeral Ethiopia. MSc Thesis, Addis Ababa University, Faculty of Veterinary Medicine, Bishoftu, Ethiopia.
5. Abraham, J., Ayana, W. and Wale, F. (2017): Ante and Post Slaughter Defects of Hide and Skin in Ethiopia. *Researcher,* **9**(7)16-26**.**
6. Abriham, K., Etenesh, H.M. and Jiregna, D. (2018): Prevalence of Common Skin Diseases of Small Ruminants in Dibate District Metekel Zone of Benishangul Gumuz Regional State, Northwestern Ethiopia. *Multidisciplinary Advances in Veterinary Science,* **2**(1)283-292.
7. African Union Intera african Bureau for Animal Resources (AU-IBAR) (2011): Pan African Animal Health Yearbook, http://www.au-ibar.org/pan-african-animalhealthyearbook. Accessed on 24-Oct/2014.
8. Al-Shabebi, A., El-Sabagh, I., Abu-Elzein, E., Zaghawa, A., Al-Naeem, A. and Housawi, F. (2014): Molecular detection and phylogenetic analysis of sheep pox virus in Al – Hassa of Eastern Province of Saudi Arabia. *Advances in Animal and Veterinary Sciences*, **2**(2)31 – 34.
9. AUSTRALIAN VETERINARY EMERGENCY PLAN (AUSVETPLAN) (1996): Disease Strategy for the control and eradication of sheep pox and goat pox. 2nd Edition, Australia. Pp. 1-19.
10. Ayalet, G., Fasil, N., Jembere, S., Mekonen, G., Sori, T. and Negussie, H. (2012): Study on immunogenicity of combined sheep and goat pox and peste des petitis ruminants vaccines in small ruminants in Ethiopia. *African Journal of Microbiology Research,* **6**(44)7212-7217.
11. Azene, D., Fentahun, T. and Admassu, B. (2015): Study on the Major Defects That Causes Sheep and Goat Skins Rejection in Bahir Dar Tanning Industry, Ethiopia. Academic Journal of Animal Diseases, **4**(3)170-176.
12. Babiuk, S., Bowden, T.R., Boyle, D.B., Wallace, D.B. and Kitching, R.P. (2008): Capripoxviruses: An Emerging Worldwide Threat to Sheep, Goats and Cattle. *Transboundary and Emerging Diseases,* **55**(7)263-272.
13. Babiuk, S., Bowden, T.R., Parkyn, G., Dalman, B., Hoa, D.M., Long, N.T., Vu, P., Bieu, D.X., Copps, J. and Boyle, D.B. (2009): Yemen and Vietnam Capripox viruses demonstrate a distinct host preference for goats compared with sheep. *Journal of General Virology,* **90**: 105–114.
14. Balamurugan, V. and Venkatesan, G. (2015): Immunological Approaches for Diagnosis and Control of Viral Diseases of Sheep and Goats. *Journal of Immunology and Immunopathology*, **17**: 1-16.
15. Beard, P.M., Sugar, S., Bazarragchaa, E., Gerelmaa, U., Tserendorj, S., Tuppurainen, E. and Sodnomdarjaa, R. (2010): A description of two outbreaks of Capripox virus disease in Mongolia. *Veterinary Microbiology*, **142**: 427–431.
16. Befikadu, S. and Endale, T. (2017): Major Transboundary Disease of Ruminants and their Economic Effect in Ethiopia. *Global Journal of Medical Research,* **17**(2)27-36.
17. Bereket, M., Haba, H. and Sefinew, A. (2017): Prevalence and risk factors associated to skin diseases in small ruminants in Gamo Gofa zone, south-Western Ethiopia. *Journal of Veterinary Medicine and Animal Health*, **9**(8)228-234.
18. Berhanu, W., Negussie, H., Alemu, S. and Mazengia, H. (2011): Assessment on major factors that cause skin rejection at Modjo export tannery, Ethiopia. Tropical Animal Health and Production, **43**: 989–993.
19. Berihu, H. (2016): Study on Identification of the Prevalent Livestock Diseases and their Copping Mechanisms in Eastern Zone of Tigray, the Case of Ganta Afeshum. *International Journal of Engineering Development and Research,* **4**(3)753-758.
20. Bhanuprakash, V., Indrani, B.K., Moorthy, A.R.S. and Krishnappa, G. (2003): Isolation, purification and comparison of protein profiles of sheep poxviruses. *Indian Journal of Comparative Microbiology and Immunology of Infectious Diseases*; **24**: 15–20.
21. Bhanuprakash, V., Indrani, B.K., Hosamani, M. and Singh, R.K. (2006): The current status of sheep pox diseases. *Comparative*

Immunology and Microbial of Infectious Diseases, **29**: 27-60.
22. Bhanuprakash, V., Hosamani, M., Venkatesan, G., Balamurugan, V., Yogisharadhya, R. and Singh, R.K. (2012): Animal poxvirus vaccines: a comprehensive review. *Expert Review Vaccines*, **11**(11)1355–1374.
23. Bisrat, G.U. (2014): Investigation of Major Factors That Cause Skin and Hide Rejection in Ethiopia: The Case of Tanneries in Addis Ababa and Modjo Towns. *Journal of Africa Leather and Leather Products Advances,* **1**(1)35-43.
24. Bowden, T.R., Babiuk, S.L., Parkyn, G.R., Copps, J.S. and Boyle, D.B. (2008): Capripox virus tissue tropism and shedding: A quantitative study in experimentally infected sheep and goats. *Virology,* **371**: 380-393.
25. Center for Agriculture and Biosciences International (CABI) (2015): Sheep and Goat Pox. *http://www.cabi.org/isc/datasheet/81537.*
26. Center for Food Security Public Health (CFSPH) (2017): Sheep and goat pox. Iowa State University, College of Veterinary Medicine and Institution of International cooperation in Animal Biologics, an OIE collaborating center. Pp. 1-5.
27. Central Statistic Authority (CSA) (2014): Agricultural sample survey report on Livestock and livestock characteristics, Addis Ababa, Ethiopia. **2**: 12-15.
28. Chibssa, T.R., Grabherr, R., Loitsch, A., Settypalli, T.B., Tuppurainen, E., Nwankpa, N., Tounkara, K., Madani, H., Omani, A., Diop, M., Cattoli, G., Diallo, A. and Lamien, C.E. (2018): A gel-based PCR method to differentiate sheep pox virus field isolates from vaccine strains. *Virology Journal*, **15**:59.
29. Chibssa, T.R., Settypalli, T.B., Berguido, F.J., Grabherr R., Loitsch, A., Tuppurainen, E., Nwankpa, N., Tounkara, K., Madani, H., Omani, A., Diop, M., Cattoli, G., Diallo, A. and Lamien, C.E. (2019): An HRM Assay to Differentiate Sheep pox Virus Vaccine Strains from Sheep pox Virus Field Isolates and other Capripox virus Species. *Scientific Reports*, **9**:664-676.
30. Chu, Y., Yan, X., Gao, P., Zhao, P., He, Y., Liu, J. and Lu Z. (2011): Molecular detection of a mixed infection of *Goat pox virus*, *Orf virus*, and *Mycoplasma capricolum* subsp. *capripneumoniae* in goats. *Journal of Veterinary Diagnostic Investigation*, **23**(4)786–789.
31. Ethiopian Sheep and Goats Productivity Improvement Program (ESGPIP) (2009): Common defects of sheep and goats skin in Ethiopia and their causes, Technical Bulletin 19.
32. European Food Safety Authority Panel on Animal Health and Welfare (EFSA) (2014): Scientific Opinion on sheep and goat pox. *European Food Safety Authority Journal*, **12**(11)1-107.
33. Fentie, T., Fenta, N., Leta, S., Molla, W., Ayele, B, Teshome, Y., Nigatu, S. and Assefa, A. (2017): Sero-prevalence, risk factors and distribution of sheep and goat pox in Amhara Region, Ethiopia. *BMC Veterinary Research*, **13**: 1-8.
34. Food and Agriculture Organization of the United Nations (FAO) (2013): Supporting livelihoods and building resilience through Peste des Petits Ruminants (PPR) and small ruminant diseases control. Animal Production and Health Position Paper. Rome. Pp. 1-24.
35. Gelaye, E., Lamien, C.E, Silber, R., Tuppurainen, E.S., Grabherr, R. and Diallo, A. (2013): Development of a Cost-Effective Method for Capripox virus Genotyping Using Snapback Primer and dsDNA Intercalating Dye. *Public Library of Science ONE*, **8**(10)759-771.
36. Gelaye, E., Belay, A., Ayelet, G., Jenberie, S., Yami, M., Loitsch, A., Tuppurainen, E., Grabherr, R., Diallo, A. and Lamien, C.E. (2015): Capripox disease in Ethiopia: genetic differences between field isolates and vaccine strain, and implications for vaccination failure. *Antiviral Research*, **119**: 28–35.
37. Gelaye, E., Mach, L., Kolodziejek, J., Grabherr, R., Loitsch, A., Achenbach, J.E., Nowotny, N., Diallo, A. and Lamien, C.E. (2017): A novel HRM assay for the simultaneous detection and differentiation of eight poxviruses of medical and veterinary importance. *Journal of Scientific Reports*, **7**:42892.
38. Getachew, G., Gedlu, M., Demeke, S., Ashebir, A., Mesfin, S. and Getnet, A. (2015): Participatory disease surveillance (PDS) of sheep and goats diseases in selected districts of Afar Regional State: Particular focus on Pestes des petite ruminants (PPR) and Sheep and goat pox disease (SGP). *Ethiopian Veterinary Journal,* **19** (1)83-105.
39. Gu, S.P., Shi, X., Liu, X., Wang, Z., Zheng, M., Li, Y., Huo, N., Tang, F., Bail, R., Shi, Z. and Yuan, J. (2018): Identification and phylogenetic analysis of the sheep pox virus Shanxi isolate. *Biomedical Research,* **29** (3)523-529.
40. Haegeman, A., De Vleeschauwer, A., De Leeuw, I., Vidanovi´c, D., Sekler, M., Petrovi´c, T., Demarez, C., Lefebvre, D. and De Clercq, K. (2019): Overview of diagnostic tools for Capripox virus infections, *Preventive Veterinary Medicine*, doi.org/10.1016/j.prevetmed.2019.104704.
41. Hamouda, M., Al-Hizab, F. and El-Sabagh, I. (2017): Clinical, pathological and molecular diagnosis of sheep pox virus in Saudi Arabia. *Journal of Animal and Plant Sciences*, **27**(1)91-97.

42. Hasoksuz, M., Gulyaz, V. and Sarac, F. (2014): Molecular Characterizations of Sheep pox Virus Strains. *Journal of Faculty of Veterinary Medicine,* Istanbul University, **40**(1)95-102.
43. Hopker, A., Pandey, N., Saikia, D., Goswami, J., Hopker, S., Saikia, R. and Sargison, N. (2019): Spread and impact of goat pox (Bsagolay bohonta) in a village smallholder community around Kaziranga National Park, Assam, India. *Tropical Animal Health and Production,* **51**: 819–829.
44. Hosamani, M., Mondal, B., Tembhurne, P.A., Bandyopadhyay, S.K., Singh, R.K. and Rasool, T.J. (2004): Differentiation of sheep pox and goat pox viruses by sequence analysis and PCR-RFLP of P32 gene. *Virus Genes*. **29**(1)73-80.
45. Hota, A., Biswal, S., Sahoo1, N., Venkatesan, G., Arya, S., Kumar, A., Ramakrishnan, M.A., Pandey, A.B. and Rout, M. (2018): Seroprevalence of Capripox virus infection in sheep and goats among different agro-climatic zones of Odisha, India. *Veterinary World*, **11**(1)66-70.
46. Hurisa, T.T., Jing, Z., Jia, H., Chen, G. and He, X-B. (2018): A Review on Sheep pox and Goat pox: Insight of Epidemiology, Diagnosis, Treatment and Control Measures in Ethiopia. *Journal of Infectious Diseases Epidemiology,* **4**: 1-8.
47. Jilo, K., Abdela, N. and Adem, A. (2016): Insufficient veterinary services as a major constraints in pastoral area of Ethiopia: A review. *Journal of Biology, Agriculture and Healthcare,* **6**: 94-101.
48. Kahsay, T., Negash, G., Hagos, Y. and Hadush, B. (2015): Pre-slaughter, slaughter and post-slaughter defects of skins and hides at the Sheba Tannery and Leather Industry, Tigray region, northern Ethiopia. *Onderstepoort Journal of Veterinary Research,* **82**(1)1-7.
49. Karapinar, Z., Ilhan, F., Dincer, E. and Yildirim, S. (2017): Pathology and phylogenetic analysis of *Capripox virus* in naturally infected sheep with sheep pox virus. *Pakistan Veterinary Journal*, **37**(1)78-84.
50. Khameis, A.S., Atteya, L.F., Mansour, A.H., Abdelhady, H.A. and. Saad, A.A. (2018): Molecular detection and phylogenetic analysis of sheep pox virus in El Menofiya Governorate. *Journal of Virology Science,* **3**: 49-57.
51. Kitching, R.P. (1986): The control of sheep and goat pox. *Revue Scientifique et Technique De L Office International Des Epizooties,* **5**(2)503-511.
52. Madhavan, A., Venkatesan, G. and Kumar, G. (2016): Capripox viruses of Small Ruminants: Current Updates and Future Perspectives. *Asian Journal of Animal and Veterinary Advance*, **11**(12)757-770.
53. Mahmoud, A.Z., Khalafalla, A.I. and Abdellatif, M.M. (2016): An epidemiological study of sheep and goat pox outbreaks in the Sudan. *Food Biology,* **5**: 1-5.
54. Mahmoud, M. A. and Khafagi, M. H. (2016): Detection, identification and differentiation of Sheep pox virus and Goat pox virus from clinical cases in Giza Governorate, Egypt. *Veterinary World*, **9**: 1445-1449.
55. Mersha, C. (2011): Clinical and Histopathological Study of Sheep Pox in Ethiopia. *International Journal of Natural Sciences*, **1**(4)89-92.
56. Mirzaie, K., Barani, S.M. and Bokaie, S. (2015): A review of sheep pox and goat pox: perspective of their control and eradication in Iran. *Journal of Advanced Veterinary and Animal Research,* **2**(4)373-381.
57. Mondal, B., Hosamani, M., Dutta, T.K., Senthilkumar, V.S., Rathore, R. and Singh, R.K. (2004): An outbreak of sheep pox on a sheep breeding farm in Jammu, India. *Revue Scientifique et Technique De L Office International Des Epizooties*, **23**(3)943-949.
58. Muhaidi, M.J., Hamad, M.A. and Al-hayani, N.N. (2018): Molecular and Phylogenetic Analysis of Sheep Pox Virus in Iraq. *Journal of Pure Applied Microbiology*, **12**(4) 1809-1814.
59. Nottor, D.R. (2012): Genetic improvement of reproductive efficiency of sheep and goat. *Animal Reproduction Science*, **130**: 147-151.
60. Organization of international des Epizootes (2000): Manual of standards for diagnostic tests and vaccines. 4th ed.; [chapter 2.1.10].
61. Organization of Internationale des Epizooties (World Health Organization for Animals) OIE (2008): Sheep Pox and Goat Pox. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, Paris, France. Pp. 1058-1068.
62. Organization of Internationale des Epizooties (World Health Organization for Animals) OIE (2010): Sheep Pox and Goat Pox. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, Paris, France. Pp. 1-12.
63. Organization of Internationale des Epizooties (World Health Organization for Animals) OIE (2012): Sheep Pox and Goat Pox. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, Paris, France.
64. Organization of Internationale des Epizooties (World Health Organization for Animals) OIE (2014): Sheep Pox and Goat Pox. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, Paris, France. Pp. 1-5.
65. Organization of Internationale des Epizooties (World Health Organization for Animals) OIE (2017): Sheep Pox and Goat Pox. Manual of Diagnostic Tests and Vaccines for Terrestrial Animals, **7**(13)1-12.

66. Radostits, O.M., Gay, C.C., Hinchcliff, K. W. and Constable, P. D. (2006): A textbook of the diseases of cattle, horses, sheep, pigs and goats. 10th Edition, SAUNDERS ELSIVEIRE, Pp. 1430-1432.
67. Rao, T.V.S. and Bandyopadhay, S.K. (2000): A compressive review of goat pox and sheep pox and their diagnosis. *Animal Health Research Review*, **1**: 127-136
68. Roy, P., Purushothaman, V. and Sreekumar, C. (2008): Sheep pox disease outbreaks in Madras Red and Mechery breeds of indigenous sheep in Tamilnadu. *India Research in Veterinary Science*, **85**: 617-621.
69. Sadri, R. and Fallahi, R. (2010): A new approach to develop a vaccine against *Capripox* infection in sheep and goats using a new strain of sheep pox virus in Iran. *International Journal of Veterinary Research,* **4**(4)221-224.
70. Saminathan, M., Rana, R., Ramakrishnan, M.A., Karthik, K., Malik, Y.S. and Dhama, Y. (2016): Prevalence, Diagnosis, Management and Control of Important Diseases of Ruminants with Special Reference to Indian Scenario. *Journal of Experimental Biology and Agricultural Sciences*, **4**: 339-367.
71. Santhamani, R., Yogisharadhya, R., Venkatesan, G., Shivachandra, S.B., Pandey, A.B. and Ramakrishnan, M.A. (2014): Molecular characterization of Indian sheep pox and goat pox viruses based on RPO30 and GPCR genes. *Virus Genes*, DOI 10.1007/s11262-014-1095-3.
72. Senthilkumar, V. and Thirunavukkarasu, M. (2010): Economic losses due to sheep pox in sheep farms in Tamil Nadu. *Tamil Nadu Journal of Veterinary and Animal Sciences,* **6**: 88-94.
73. Solomon, A.K., Mwai, O., Grum, G., Haile, A., Rischkowsky, B.A., Solomon, G. and Dessie, T. (2014): Review of goat research and development projects in Ethiopia, International Livestock Research Institute (ILRI) Project Report. Nairobi, Kenya: Pp. 4-17.
74. Teshome, D. (2016): Prevalence of major skin diseases in ruminants and its associated risk factors at University of Gondar Veterinary Clinic, North West Ethiopia. *Journal of Science and Development*, **4**: 138.
75. Tsegaye, D., Belay, B. and Haile, A. (2013): Prevalence of Major Goat Diseases and Mortality of Goat in Daro-Labu District of West Hararghe, Eastern Ethiopia. *Journal of Scientific and Innovative Research*, **2**(3)665-672.
76. Tulman, E.R., Afonso, C.L., Lu, Z., Zsak, L., Kutish, G.F. and Rock, D.L. (2001): Genome of lumpy skin diseases virus. *Journal of Virology*, **75**:7122-7130.
77. Tulman, E.R., Afonso, C.L., Lu, Z., Zsak1, L., Sur, J.H., Sandybaev, N.T., Kerembekova, U.Z., Zaitsev, V. L., Kutish, G. F. and Rock, D. L (2002): The Genomes of Sheep pox and Goat pox Viruses. *Journal of Virology*, **76**(12)6054–6061.
78. Tuppurainen, E.S. and Oura, C.A. (2012): Review: lumpy skin disease: an emerging threat to Europe, the Middle East and Asia. *Transboundary and Emerging Diseases*, **59**: 40-48.
79. Tuppurainen, E.S., Venter, E.H., Shisler, J.L., Gari, G., Mekonnen, G.A., Juleff, N., Lyons, N.A., De Clercq, K., Upton, C., Bowden, T.R., Babiuk, S. and Babiuk, L. A. (2017): Review: Capripox virus Diseases: Current Status and Opportunities for Control. *Transboundary and Emerging Diseases*, **64**: 729–745.
80. Varshovi, H.R., Norian, R., Azadmehr, A. and Ahangaran, N.A. (2017): Immune response characteristics of Capripox virus vaccines following emergency vaccination of cattle against lumpy skin disease virus. *Iranian Journal of Veterinary Science and Technology*. **9**: 34-40.
81. Welay, G.M., Tedla, D.G., Teklu, G.G., Weldearegay, S.H., Shibeshi, M.B., Kidane, H.H., Gebrezgiabher, B.B. and Abraha, T.H. (2018): A preliminary survey of major diseases of ruminants and management practices in Western Tigray province, northern Ethiopia. *BMC Veterinary Research*, **14**:2-9.
82. Yacob, H. T., Nesanet, B. and Dinka A. (2008): Prevalence of major skin diseases in cattle, sheep and goats at Adama Veterinary Clinic, Oromia regional state, Ethiopia. *Revue de Médecine Vétérinaire,* **159**: 455-461.
83. Yan, X.M., Chu, Y.F., Wu, G.H., Zhao, Z.X., Li, J., Zhu, H.X. and Zhang, Q. (2012): An outbreak of *Sheep pox* associated with goat poxvirus in Gansu province of China. *Veterinary Microbiology*, **156**(3)425-428.
84. Yang, Y., Qin, X., Zhang, X., Zhao, Z., Zhang, W., Zhu, X., Cong, G., Li, Y. and Zhang, Z. (2017): Development of real-time and lateral flow dipstick recombinase polymerase amplification assays for rapid detection of Goat pox virus and Sheep pox virus. *Virology Journal*, **14**: 1-8.
85. Yeruham, I., Nir, O., Braverman, Y., Davidson, M., Grinstein, H., Haymovitch, M. and Zamir, O. (1995): Spread of lumpy skin disease in Israeli dairy herds. *Veterinary Record,* **137**:91-93.
86. Yilmaz, E.F., Arayici, P.P., Maharramov, A.M. and Mustafaeva, Z. (2016): Approaches to Designing of New Generation Vaccines against the Sheep Pox Disease. *BIOTECHNOLOGIA ACTA*, **9**(6)7-15.
87. Yune, N. and Abdela, N. (2017): Epidemiology and Economic Importance of

Sheep and Goat Pox: A Review on Past and Current Aspects. *Journal of Veterinary Science and Technology,* **8**: 1-5.

88. Zangana, I.K. and Abdullah, M.A. (2013): Epidemiological, clinical and histopathological studies of lamb and kid pox in Duhok, Iraq. *Bulgarian Journal of Veterinary Medicine*, **16**: 133-138.
89. Zhao, Z., Wu, G., Yan, X., Zhu, X., Li, J., Zhu, H., Zhang, Z. and Zhang, Q. (2017): Development of duplex PCR for differential detection of Goat pox and Sheep pox viruses. *BMC Veterinary Research*, **13**:278.
90. Zhou, T., Jia, H., Chen, G., He, X., Fang, Y., Wang, X., Guan, O., Zeng, S., Cui, Q. and Jing, Z. (2012): Phylogenetic analysis of Chinese Sheep pox and Goat pox virus isolates. *Virology Journal,* **9**: 25.

Internet website references

International Committee on Taxonomy of Viruses: www.ictvonline.org. Accessed on: 29 July, 2019.

6/2/2021