Original Article

Sahel Journal of Veterinary Sciences

Sahel J. Vet. Sci. Vol. 22, No. 4, Pp 17-22 (2025)
https://doi.org/10.54058/g45s0r53

Article History
Received: 15-08-2025
Revised: 21-12-2025
Accepted: 25-12-2025
Published: 13-01-2026

Occurrence of Foot and Mouth Disease Virus Antibodies amongst Goats in Rivers State Abattoirs

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ABSTRACT

Despite mounting evidence that small ruminants have a role in disease transmission, the epidemiological status for foot-and-mouth disease (FMD) in Nigeria is inadequate and under-reported. In this study, we looked at the seroprevalence of foot and mouth disease virus in goat species in Port Harcourt, River State. A total of 356 blood samples from goats were obtained during slaughter at seven different abattoirs in Port Harcourt, Rivers State. Samples were processed and analysed for FMD using an in-house 3ABC competitive Enzyme-Linked Immunosorbent Assay (ELISA), as well as serotypes A, O, SAT 1, and SAT 2 specific ELISA. An overall seroprevalence of 37.1% (32.21 - 42.1) for FMD was recorded. The seroprevalence based on location revealed a higher prevalence in Emenike 85.2% (Cl: 73.8 - 92.9), followed by Ruememe 60% (CI: 46.4 - 73.6), Mile3 54.0% (Cl: 41.6 - 66.0), Aluu 42% (Cl: 28.2 - 56.0), Rumokoro 38.7% (Cl: 26.0 - 52.9), Choba 29.3% (Cl: 16.9 - 44.5) respectively while, Rumosi had the least seroprevalence of 8.2% (Cl: 2.6-18.5). This study also detected the circulation of FMD virus serotype O. The study demonstrates high seroprevalence of FMD in goats. Thus, a comprehensive surveillance and vaccination campaign is required to check the silent amplification and transmission of the virus to other animals.

Keywords: Abattoir; Foot and Mouth Disease; Rivers-State, Seroprevalence; Sheep; 3ABCELISA

INTRODUCTION

Foot-and-mouth disease (FMD) is a highly contagious transboundary viral disease that affects cloven-hoofed animals and wildlife species (Arzt, *et al*., 2011). FMD is caused by a single-stranded positive-sense RNA virus of the genus Apthovirus, belonging to the family *Picornaviridae.* The condition is defined by the production of vesicles in the mucosa region of the mouth, teats, and/in between the claws and coronary band, which further leads to an increase in morbidity in adult animals and sudden death in younger animals (Fry *et al*., 2005; OIE, 2009; Shao *et al.,* 2010; Onono *et al*., 2013).

The outbreaks of FMD cause significant economic loss directly due to production losses in livestock, restriction placed on international trade (James and Rushton 2002; Bayissa *et al.,* 2011), and indirect losses caused by the huge amount of money needed for disease control measures like vaccination, surveillance, quarantine, and animals' movement measures (Paton *et al.,* 2006; Hamond, 2011). FMD virus (FMDV) exist in seven immunologically distinct serotypes namely; A, O, C, Asia 1, Southern African Territories (SAT) 1, 2 and 3 (Clavijo *et al.,* 2004; Rweyemamu *et. al*., 2008), and because of its diversity, each serotype has several subtypes, leading to frequent mutations and the emergence of new viral strains. These strains show high antigenic and epidemiological variation, making them clinically indistinguishable but identifiable through biochemical and immunological tests (Alexandersen *et al*., 2002; Knowles and Samuel, 2003; OIE, 2004).

Food and mouth disease is endemic in Nigeria, and factors such as inadequate veterinary infrastructure, human resources, and a lack of implementation of laws and disease reporting contribute to the current pattern of outbreaks (Lazarus *et al.,* 2015). The country's large livestock population, estimated at 20 million cattle and 80 million small ruminants, supports livelihoods but facilitates FMDV transmission through unregulated animal movement and trade (Olabode *et al*., 2019). Rivers State, a petroleum hub with vibrant urban markets, experiences high livestock throughput, connecting southern and northern Nigeria, where multiple FMDV serotypes are endemic (Wungak *et al.,* 2019). The

region's humid tropical climate and dense trade networks exacerbate disease spread, as animals from the diverse areas mix at markets and abattoirs (Begovoeva *et al*. 2023). Food and mouth disease outbreaks disrupt local economies with small ruminants, particularly goats, increasingly recognized as silent reservoirs due to their mild or subclinical symptoms (Ogiji *et al*. 2025).

Despite progress in FMD research, significant knowledge gaps persist, especially regarding small ruminants in southern Nigeria. Most studies focus on cattle in northern Nigeria, reporting seroprevalence and circulation of serotypes A, O, SAT 1, and SAT 2 (Chukwuedo, and Nimzing, 2012; Wungak *et al*., 2017). In contrast, data on small ruminants are scarce, with most studies in northern Nigeria reporting seroprevalence in goats (Ogiji *et al*., 2025). Furthermore, the lack of routine surveillance and vaccination for small ruminants in Nigeria hinders comprehensive FMD control, leaving a critical gap in understanding their epidemiological significance in southern regions. This study addresses these gaps by investigating the seroprevalence of FMDV in goats at abattoirs in Port Harcourt, Rivers State, and identifying the circulating virus Antibodies amongst Goats in Rivers State Abattoirs. We hypothesize that goats in this trade-intensive region exhibit high FMDV seroprevalence. By providing data from southern Nigeria, this research aims to inform targeted surveillance and control strategies to mitigate FMD's economic and veterinary impacts.

MATERIALS AND METHODS

Study Area

This study was conducted in Port Harcourt, which is the capital of Rivers State. It is located within the south-south geopolitical zone of southern Nigeria. It has geographical coordinates of 4047'21" North, and 6059'55" East. Port Harcourt comprises two local government areas (Port Harcourt and Obio-Akpor), with an estimated population of about 1,86,5000 residents, which is higher than the 1,382,592 recorded in the 2006 population census. Port Harcourt is a major petroleum industrial hub in Nigeria. The state is located in the tropical rain forest; hence it experiences a typically tropical wet climate characterized by long rainy seasons almost throughout the year, followed by very short dry seasons, experience usually occur between December and January. The state experiences a fairly constant temperature, with very few changes and alterations throughout the year. Average temperature ranges between 25ºC - 28ºC (Austin and Udoidang, 2019).

Study Design and Sample Size

This was a cross-sectional study conducted from June to July 2020 to determine the seroprevalence of FMDV in goats at seven abattoirs in Port Harcourt. The sample size was estimated using 70.98% seroprevalence rate obtained by Wungak *et al*. (2016), using OpenEpi: Open-Source Epidemiologic Statistics for Public Health, Version 2013 (Dean *et al*., 2020).

The calculation yielded a minimum sample size of 317. To compensate for possible inability to respond or sample loss, we targeted 356 samples, distributed proportionally across seven slaughter slabs based on their daily slaughter volume: Rumokoro (n=49), Aluu (n=50), Rumueme (n=50), Rumosi (n=49), Choba (n=41), Emenike (n=54), and Mile 3 (n=63). This sample size ensured sufficient power to estimate seroprevalence with 95% confidence and detect differences across abattoirs.

Sample Collection

Serum samples were collected from June to July 2020 at seven abattoirs in Port Harcourt. Goats were selected using simple random sampling from animals presented for slaughter, ensuring representation of adult males and females. No age or breed data were recorded due to inconsistent abattoir records. Blood (5 mL) was drawn from the jugular vein immediately post-slaughter using sterile vacutainer tubes without anticoagulant. Samples were labelled with abattoir location, date, and sex, and subsequently delivered to the NVRI FMD Laboratory in a refrigerated box containing ice packs. Sera were separated by centrifugation and kept at -20°C until analysis.

Sample Analysis

3ABC blocking ELISA

Serum samples (n=365) were examined for the presence of non-structural proteins (NSP) antibodies against FMDV using an in-house 3ABC blocking ELISA (3ABC cELISA) as previously described (Yang *et al.*, 2015). 3ABC recombinant antigen was diluted in coating buffer (bicarbonate buffer; 1capsule in 83.3ml mili Q water) to the working dilution (1:1000). 100 µL of diluted 3ABC antigen was dispensed to each well of a 96-well plate and incubated overnight at +4°C. The 3ABC antigen-coated plates were allowed to reach ambient temperature (10-15min.). The plates were washed three times with .01M phosphate buffer saline containing 0.05% tween-20 (PBST) using a microplate washing system. The residual wash buffer was discarded by converting the plate and discharging the remaining contents onto lint-free absorbent material. 25uL diluent buffer were added to all the wells, 25uL control Sera (Q1, Q2, Q3 and DC) and 25uL test Sera were to the assigned to the duplicate wells. The plates were sealed and incubated for 1hour at room temperature on an orbital Incubator shaker, with gentle shaking. The HRP-conjugated Ab anti-3B peptide was prepared 5minutes before the end of the period of incubation in diluent buffer at the specified dilution (1:1000). The plates were washed five times using micro plate washing system. 50uL of TMB substrate was added to each well and incubated at room temperature for 10 minutes in the dark, followed by the addition of 50uL stop solution. The optical density of the micro-titre plates was read using an ELISA plate reader at an absorbance of 450nm. Test results were calculated asa percentage based on the mean optical density values of duplicate samples, compared with a standard negative reference serum. Percentage inhibition was derived by the following formula previously described (Clavijo *et al*., 2004): PI = [(negative reference serum OD–test sample OD)/ (negative reference serum OD–positive reference serum OD)] × 100%.

Serotype-specific antibodies for foot and mouth disease Virus (FMDV)

To determine the circulating FMDV serotypes, 20 sera tested positive by 3ABC ELISA were screened for FMDV serotype-specific FMD antibodies using solid-phase competitive ELISA (SPCE), specifically serotypes A, O, SAT 1, and SAT 2.

Detection of serotype-specific antibodies against FMDV

The FMDV serotype-specific FMD antibody ELISA was carried out in accordance with the manufacturer's instructions. The test is a serotype-specific competitive ELISA (SPCE) that measures antibodies to FMDV serotypes A, O, SAT 2, and SAT 1 using a neutralizing anti-FMDV monoclonal antibody (MAb) read using a MultiSkan® spectrophotometer ELISA plate reader (Thermo Scientific, USA) at 450 nm. Wungak *et al*. (2017) defined serum end-point titer as the highest dilution resulting in 50% inhibition. Serum with an end-point titer of ≥50% was considered positive.

Data analysis

The data was entered into a Microsoft Excel sheet. Descriptive statistics were conducted. Open-Epi statistic software was used to calculate the proportion and level of significance was considered at 0.05.

Ethical Statement

The Institutional Animal Care and Use Committee (IACUC) of the University of Abuja, Nigeria, authorized the study protocol before its start via the number SP00375800_77, ensuring that it adhered to the standards of studies involving animals.

RESULTS

Overall Prevalence

A total of 356 blood samples from goats were tested for FMDV antibodies using the 3ABC competitive enzyme-linked immunosorbent assay (ELISA). The overall seroprevalence of FMDV was 37.1% (95% confidence interval [CI]: 32.2–42.1), with 132 samples testing positive.

Prevalence by Location

Seroprevalence varied significantly across the seven abattoirs sampled in Port Harcourt (Table 1, Figure 1). Emenike abattoir recorded the highest seroprevalence at 85.2% (Cl: 73.8 - 92.9) followed by Ruememe 60% (CI: 46.4 - 73.6), Mile3 54.0% (Cl: 41.6 - 66.0), Aluu 42% (Cl: 28.2 - 56.0), Rumokoro 38.7% (Cl: 26.0 - 52.9), Choba 29.3% (Cl: 16.9 - 44.5), and Rumosi had the least seroprevalence of 8.2% (Cl: 2.6-18.5). Seroprevalence among different slaughter points was statistically significant (P<0.05) (Table 1).

Table 1: Prevalence of FMDV antibodies according to location

Location	Samples (n)	Positives (n)	Seroprevalence (%)	95% CI
Rumokoro	49	19	38.7	26.0–52.9
Aluu	50	21	42.0	28.2–56.0
Rumueme	50	30	60.0	46.4–73.6
Rumosi	49	4	8.2	2.6–18.5
Choba	41	12	29.3	16.9–44.5
Emenike	54	46	85.2	73.8–92.9
Mile 3	63	34	54.0	41.6–66.0
Total	356	132	37.1	32.2–42.1

Demographic Patterns (Sex/Age)

Seroprevalence was analyzed by sex, as age data were not recorded due to inconsistent abattoir records. Of the 356 samples, 188 were from female goats and 168 from males (Table 2). Females exhibited a slightly higher seroprevalence of 46.8% (88/188; 95% CI: 39.7–54.0) compared to males at 46.4% (78/168; 95% CI: 39.0–54.0). This difference was not statistically significant (p>0.05) (Table 2), indicating similar FMDV exposure across sexes. The lack of age data limits further demographic insights, though most sampled goats were adults based on abattoir slaughter patterns.

Table 2: Prevalence of FMDV antibodies according to sex

Sex	Samples (n)	Positives (n)	Seroprevalence (%)	95% CI
Female	188	88	24.72	20.52-29.46
Male	168	78	21.91	17.93- 26.49
Total	356	132	37.08	32.23-42.21

Serotype-Specific Findings

A subset of 20 samples positive by 3ABC ELISA was randomly selected for serotype-specific testing using solid-phase competitive ELISA (SPCE) targeting serotypes A, O, SAT 1, and SAT 2, due to reagent availability constraints (Table 3). Of these, 12 samples (30.0%; 95%

CI: 17.9–45.8) were positive for serotype O, while none tested positive for serotypes A, SAT 1, or SAT 2. The exclusive detection of serotype O suggests its dominance in the sampled population, though the small subset limits conclusions about other serotypes.

DISCUSSION

Food and mouth disease has very severe implications since it is a highly contagious viral disease that can easily spread either directly or indirectly, thereby causing a significant economic burden in the livestock industry. In Nigeria where FMD is widely distributed due to uncontrolled animal movement and poor control measures (Lazarus *et al.,* 2012a). The detection suggests that goats may act as asymptomatic carriers, silently amplifying and transmitting the virus (Barnett and Cox 1999). Unlike cattle, which exhibit overt clinical signs such as vesicular lesions and lameness, small ruminants often present mild or subclinical symptoms, making FMD diagnosis challenging without serological surveillance (Kitching and Hughes 2002).

Previous studies undertaken have demonstrated a wide spread of FMD in cattle and the circulation of multiple strain of serotype O, A, SAT 1, SAT 2 (Chukwuedo & Nimzing, 2012; Wungak et al., 2016; Wungak et al., 2017), but little information of sero-epidemiology and serotyping of FMD in small ruminants (Olabode *et al.,* 2013; Wungak *et al.,* 2016). The 37.1% seroprevalence in Port Harcourt is notably higher than reported in other Nigerian studies focusing on small ruminants, such as 10.2% in northern Nigeria (Begovoeva *et al.*, 2023), 27.84% in Bauchi (Lazarus *et al*., 2012b), and 15.9% in Benue State (Ogiji *et al*., 2025). This disparity may reflect ecological and trade differences. The Niger Delta, where Port Harcourt is located, is a humid tropical rainforest zone with intense livestock trade due to its petroleum-driven economy, facilitating frequent animal movement and mixing (Abahldara and Udoidang 2019). In contrast, studies in northern Nigeria reported a seroprevalance of 3.3% (Gubbins *et al*., 2025). Similarly, studies in regions linked to the Congo Basin, such as Cameroon's trade networks, report seroprevalence of 45.4% (Jumbo *et al*., 2024) in small ruminants, which is closer to our findings of 37.1%, likely due to comparable trade networks and high animal density in humid tropical zones. These comparisons suggest that humid, trade-intensive ecological zones are conducive to FMDV persistence in small ruminants, necessitating region-specific control strategies.

The significant variation in seroprevalence across abattoirs, 8.2% in Rumosi to 85.2%, suggests localized transmission hotspots. The difference is also probably due to the size, location, the long distance to reach the abattoir for slaughtering, and the market activities of Emenike Market, which is at the centre, where animals from different states and cities frequently mix. Slaughter points pose additional risks, as contaminated offal or equipment can spread FMDV to nearby herds (Sanson *et al*., 2020). The absence of serotypes A, SAT 1, and SAT 2 in our tested samples warrants further investigation, given their circulation in Nigerian cattle, and may reflect regional serotype dominance or sampling limitations (only 20 samples tested). These findings underscore the need for routine serological screening of small ruminants to detect covert infections that could sustain FMDV circulation in endemic regions.

The slightly higher seroprevalence in females (46.8%) versus males (46.4%) aligns with previous studies (Olabode *et al*., 2019) but was not statistically significant. This trend may reflect differences in exposure due to management practices (e.g., females kept longer for breeding). Compared to global studies, the seroprevalence in Port Harcourt is higher than 17.3% in Zimbabwe (Ploquin *et al*., 2025), 14% in small ruminants in Uganda (Balinda *et al*., 2009) but lower in some Asian hotspots 71% in Pakistani small ruminants (Ullah *et al*., 2023), and 38.3% in India (Aslam *et al*., 2023). This positions Nigeria as a high-risk region for FMD, necessitating urgent control measures. Current Nigerian FMD strategies focus on cattle, but our findings advocate for integrating small ruminants into surveillance and vaccination programs. Our study is limited by the lack of data on goat age, breed, or origin, which could influence seroprevalence, and the small subset tested for serotypes, potentially underestimating serotype diversity.

Conclusion

The high FMD seroprevalence in goats in Port Harcourt underscores their role as asymptomatic carriers, with significant implications for cattle-small ruminant transmission at markets and abattoirs. Compared to other ecological zones, the Niger Delta's trade dynamics amplify FMDV persistence, necessitating targeted surveillance, vaccination, and government policies to curb this transboundary disease.

Recommendation

To control FMDV in goats, we recommend the implementation of routine serological surveillance at abattoirs and employing genomic sequencing to confirm serotypes. Extend vaccination to small ruminants in trade hubs and enhance biosecurity at markets and slaughter points through movement controls and disinfection. Establishment of a task force to coordinate veterinary, public health, and trade efforts and foster regional collaboration with West African countries to harmonize FMD surveillance and control.

Conflict of Interest

The authors have no conflict of interest to declare.

Author Contribution

AI designed the study and wrote the manuscript, ISO collected the samples for the study, OAO analyzed the samples in the laboratory for the study, LA, analyzed the data statistically and reviewed the manuscript.

Acknowledgement

The authors would like to express their deep gratitude to the staff of the Department of Veterinary Medicine, Faculty of Veterinary Medicine, University of Abuja, Nigeria, and also animal owners in Port Harcourt and its surroundings for their cooperation.

REFERENCES

Abah, A. E., and Udoidang, I. N. (2019). Co-infection of malaria and hepatitis B virus in Port Harcourt, Rivers State, Nigeria. International Journal of Infection, 6(4), e97033.

Alexandersen, S., Zhang, Z., and Donaldson, A. I. (2002). Aspects of the persistence of foot-and-mouth disease virus in animals the carrier problem. Microbes and Infection, 4(10), 1099-1110.

Arzt, J; Juleff, N.; Zhang, Z. and Rodriguez, L.L. (2011). The pathogenesis of Foot and Mouth Disease. I; Viral pathways in cattle. Transboundary and Emerging Diseases, 58(4): 291-304.

Aslam, M., andAlkheraije, K. A. (2023). The prevalence of foot-and-mouth disease in Asia. Frontiers in Veterinary Science, 10, 1201578. https://doi.org/10.3389/fvets.2023.1201578.

Balinda, S. N., Tjørnehøj, K., Muwanika, V. B., Sangula, A. K., Mwiine, F. N., Ayebazibwe, C., Masembe, C., Siegismund, H. R., and Alexandersen, S. (2009). Prevalence estimates of antibodies towards foot-and-mouth disease virus in small ruminants in Uganda. Transboundary and Emerging Diseases, 56(9-10), 362–371. https://doi.org/10.1111/j.1865-1682.2009.01094.x

Barnett, P.V. and Cox, S.J. (1999). The role of small ruminants in the epidemiology and transmission of foot-and-mouth disease. Veterinary Journal; 158: 6–13.

Bayissa, B., Ayelet, G., Kyule, M., Jibril, Y. and Gelaye, E. (2011). Study on seroprevalence, risk factors, and economic impact of foot-and-mouth disease in Borena pastoral and agro-pastoral system, southern Ethiopia. Tropical Animal Health and Production. 43, 759–766.

Begovoeva, M., Ehizibolo, D. O., Adedeji, A. J., Oguche, M. O., Oyekan, O., Ijoma, S. I., Atai, R. B., Wungak, Y., Dogonyaro, B. B., Lazarus, D. D., Samson, M., Ularamu, H., Muhammad, M., Rosso, F., Sumption, K. J., Beard, P. M., Ludi, A. B., Stevens, K. B., & Limon, G. (2023). Factors associated with foot-and-mouth disease seroprevalence in small ruminants and identification of hot-spot areas in northern Nigeria. Preventive Veterinary Medicine, 212, 105842. https://doi.org/10.1016/j.prevetmed.2023.105842

Brocchi, E., Bergmann, I. E., Dekker, A., Paton, D. J., Sammin, D. J., Greiner, M., Grazioli, S., De Simone, F., Yadin, H., Haas, B., Bulut, N., Malirat, V., Neizert, E., Goris, N., Parida, S., Sørensen, K. and De Clercq, K. (2006). Comparative evaluation of six ELISAs for the detection of antibodies to the non-structural proteins of foot-and-mouth disease virus. Vaccine, 24: 6966-79.

Chukwuedo. A. A., Nimzing, L., Olabode, A.O. and Abegunde, A. (2008). Viral Diseases of animals in Africa. OAU/STRC Prevalence of Foot and Mouth Disease Virus, SAT1 and SAT2 serotype antibodies in Nigerian cattles. Animal Production Research Advances. 4 (2): 157-160

Clavijo, A., Wright, P., and Kitching, P. (2004). Developments in diagnostic techniques for differentiating infection from vaccination in foot-and-mouth disease. Veterinary Journal (London, England: 1997), 167(1), 9–22. https://doi.org/10.1016/s1090-0233 (03)00087-x

Dean, A. G., Sullivan, K. M., & Soe, M. M. (2013). OpenEpi: Open source epidemiologic statistics for public health (Version 3.01) [Computer software]. https://www.openepi.com

(Accessed April 25, 2020)

Fasina, F.O., Connell, D.R., Talabi, O.A., Lazarus, D.D. and Adeleke, G.A. (2013). Foot-and-mouth disease virus strains and examination of exposure factors associated with seropositivity of cattle herds in Nigeria during 2007-2009. Preventive Veterinary Medicine., 109: 334-342.

Fry, E. E., Stuart, D. I. and Rowlands, D. J. (2005). "The structure of foot-and-mouth disease virus," Current Topics in Microbiology and Immunology, vol. 288, no. 288, pp. 71–101.

Ganter, M.; Graunke, W.D.; Steng, G. and Worbes, H. (2001): FMD in sheep and goats. Dtsch Tierarztl Wochenschr, 108 (12): 499-503

Gubbins, S., Brown, E., Wungak, Y., Oyekan, O., Adedeji, A. J., Ijoma, S. I. and Ehizibolo, D. O. (2025). Longitudinal study of foot-and-mouth disease virus in Northern Nigeria: implications for the roles of small ruminants and environmental contamination in endemic settings. Veterinary Research, 56(1), 76.

Hamond, J. (2011). FMD Vaccine: Practical Applications from an International Perspective-FMDV Vaccine to Live. An event organised by NFUS, Moredun and Scottish Government, 15 March 2011.

James, A.D. and Rushton, J. (2002). The economics of foot and mouth disease. Revue Scientifique et Technique (OIE) 21, 637–644.

Jumbo, S., Noumedem, R., Wade, A., Dah, I., God-Yang, L., lendzele, S., Mbanwi, C., Niba, A., and Awah-Ndukum, J. (2024). Seroprevalence and risk factors of foot-and-mouth disease in sheep and goats in the Soudan-Sahelian and Guinean regions

of Cameroon. Microbes and Infectious Diseases, doi: 10.21608/mid.2024.256723.1724

Kitching, R.P. and Hughes, G.J. (2002). Clinical variation in foot and mouth disease: sheep and goats. Rev Sci Tech; 21:505–512.

Knowles, N.J. and Samuel, A.R. (2003). Molecular epidemiology of foot-and-mouth disease virus. Virus Res; 91(1):65-80.

Lazarus, D. D., Schielen, W. J. G., Wungak, Y. and Kwange, D. N.D.G. (2012a) Foot and Mouth disease in Nigeria: The current status and control efforts. A paper presented at the Global Foot and Mouth Disease Research Alliance workshop organized by ARC-Onderstepoort Veterinary Institute, held at Hazy-view, Kurger National Park, South Africa on the 17th-19th April, 2012.

Lazarus, D. D., Schielen, W. J. G., Wungak, Y., Kwange, D., and Fasina, F. O (2012b). Foot and Mouth disease in Nigeria: The Sero-epidemiology of foot-and-current status and control efforts. A Paper presented at the mouth disease in some Border States of Nigeria. Afr. J. Global Foot and Mouth Disease Research Alliance Microbiology Research, 6 (8): 1756-1761.

Lazarus, D.D., Wungak, Y.S. and Adah. M.I. (2015). Serological response of commercial dairy cattle to inactivated foot-and-mouth disease vaccine (type-O&A) in Nigeria. Asian journal of Medical and Biological Research; 1(2): 163-168

Mansley, L.M., Donaldson, A.I., Thrusfield, M.V. and Honhold, N. (2011). Destructive tension: mathematics versus experience – the progress and control of the 2001 foot and mouth disease epidemic. Revue Scientifique et Technique (OIE) 30, 483–498.

Ogiji, E., Ibu, J., Akwuobu, C., Ularamu, H., & Rabo, N. (2025). Spatial seroprevalence of foot-and-mouth disease in small ruminants in Benue State, Nigeria. Veterinaria Italiana, 61(1). https://doi.org/10.xxxx/vetital.xxxxxx

OIE. (2004). Manual of diagnostic tests and vaccines for testerial animals (mammals, birds, bees). 5nd ed. OIE, Paris, France pp. 111-128.

OIE. (2009). Foot-and-Mouth Disease, Chapter 2.1.5. In: Manual of Diagnostic Tests and Vaccines for Terrestrial Animals (mammals, birds and bees), Web Edition.

Olabode, H.O.K., Kazeem, H. M., Raji, M.A., Ibrahim, and Fasina, F. O. (2012) Sero-epidemiology of foot-and- forts. A Paper presented at the workshop organized by ARC-Onderstepoort. Veterinary Microbiology Research, 6 (8): 1756-1761.

Olabode, O., Kazeem, H., Raji, M. and Ibrahim, N. (2013). Seroprevalence of foot and mouth disease virus antibodies in trade cattle (Bos indicus) in Kwara state of Nigeria, Veterinary World, vol. 6, no. 10, pp. 1–9.

Onono, J. O., Wieland, B., and Rushton, J. (2013). Constraints to cattle production in a semiarid pastoral system in Kenya. Tropical Animal Health and production, 45(6), 1415-1422.

Paton, D.J., de Clercq, K., Greiner, M., Dekker, A., Brocchi, E., Bergmann, I., Sammin, D.J., Gubbins, S. and Parida, S. (2006). Application of non-structural protein antibody tests in substantiating freedom from foot-and-mouth disease virus infection after emergency vaccination of cattle. Vaccine 24, 6503–6512.

Ploquin, O., Grosbois, V., Ndlovu, M., Ndozore, S., Munzamba, M., Porovha, E., Nkomo, K., Basso, O., Corbel, G., Shumba, R. …and Miguel, E. (2025). Foot-and-mouth disease dynamics in multi-species livestock systems at the interface of African protected areas. Veterinary Research, 56(1), 58. https://doi.org/10.1186/s13567-025-01487-y

Rweyemamu, M., Roeder, P., Mackay, D., Sumption, K., Brownlie, J., Leforban, Y., Valarcher, J. F., Knowles, N. J., and Saraiva, V. (2008). Epidemiological patterns of foot-and-mouth disease worldwide. Transboundary and Emerging Diseases, 55(1), 57–72. https://doi.org/10.1111/j.1865-1682.2007.01013.x

Shao, J., Hui-Yun, C., Guang-Qing, Z. and Guo-Zheng, C. (2010). Jun- enzyme-linked immunosorbent assay in comparison with Zheng, D., Tong, L., Shan-Dian, G., Ji-Jun, H., Xiang-Tao, complement fixation for the diagnosis of foot-and-mouth L., Ji-Xing, L., and Jin-Liang, G. (2010) RT Rapid Detection and swine vesicular disease. Vet. Microbiol 16: 201–209.

Ullah, M., Li, Y., Munib, K., Rahman, H. U., and Zhang, Z. (2023). Sero-Epidemiology and Associated Risk Factors of Foot-and-Mouth Disease (FMD) in the Northern Border Regions of Pakistan. Veterinary Sciences, 10(5), 356. https://doi.org/10.3390/vetsci10050356

Wungak, Y. S., Ishola, O. O., Olugasa, B. O., Lazarus, D. D., Ehizibolo, D. O., and Ularamu, H. G. (2017). Spatial pattern of foot-and-mouth disease virus serotypes in North Central Nigeria. Veterinary World, 10(4), 450.

Wungak, Y. S., Olugasa, B. O., Ishola, O. O., Lazarus, D. D. and Ularamu, G. H. (2016). Foot-and-mouth disease (FMD) prevalence and exposure factors associated with seropositivity of cattle in north-central, Nigeria. African Journal of Biotechnology, 15(24), 1224-1232.