

Research Article

Seroprevalence, Serotyping, and Associated Risk Factors of Foot and Mouth Diseases in Bovine in Western Amhara Regional State, North Western Ethiopia

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Abstract

Foot and mouth disease (FMD) is the most contagious disease of animals. The disease affects domestic cloven-hoofed animals, including cattle, swine, sheep, and goats, deer, and is characterized by fever, lameness, and vesicular lesions on the tongue, feet, snout, and teats. The study aimed to determine seroprevalence of FMD (Foot and Mouth Disease), to identify type of serotypes and to know associated risk factors. A total of 389 sera samples were collected from cattle in four districts of the north western Amhara region and subjected to a 3ABC enzyme-linked immune-sorbent assay. The overall seroprevalence of FMDV was 5.66% (22/389); (95%; CI: 3.34% to 7.98%). The 22 positive samples were subjected to solid phase competitive ELISA to identify specific serotypes. The occurrence of FMD was higher in Adet (OR= 12.8), greater in the semi-intensive than extensive production systems (OR=10.4) and highly occurred in the cross breed than local breed cattle (OR=3.56). Serotypes identified in the four districts were type O, SAT2, and A. This study revealed that FMD is a prevalent and endemic disease. Thus, awareness creation to the stakeholders on the control and prevention of a disease is required. Further epidemiological investigation and vaccine trials should be conducted.

Keywords

Foot and Mouth Disease, Risk Factors, Sero-Prevalence, Serotype

1. Introduction

The livestock sub-sector is an integral part of agriculture that provides food, milk, draft power, manure fertilizer for crop production and in turn, utilizes the crop residues as feed. Transboundary animal diseases (TAD) are one of the infectious diseases that have an impact on the livestock sector through decreased productivity, restricted international trade access, loss of entire herds, biodiversity loss, and the loss of

valuable genetic resources [22]. The important bottleneck for the development of the livestock sector includes infectious and non-infectious diseases, lack of food for animals, lack of appropriate disease control policy, lack of appropriate veterinary services, and lack of attention from the government [8]. The most important constraints are widespread endemic diseases including viral, bacterial, and parasitic infestation.

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Among the health constraints, infectious disease like Foot and mouth disease (FMD) is considered as one of the live-stock diseases which cause for the major socio-economic problem in Ethiopia.

Foot and mouth disease (FMD) is the most contagious disease of animals. It is a leading cause of high losses in susceptible cloven-hoofed animals and negatively affects the national economy of a country [6]. The virus has seven different serotypes (A, O, C, Asia1, South African Territories (SAT) 1, SAT 2, and SAT 3). All serotypes are clinically indistinguishable but immunologically distinct [15]. The disease has clinical signs of vesicular formation, and erosions of the epithelium of the mouth, nose, muzzle, feet, teats and udder, tongue, lips, and between the hooves [20]. The virus can be transmitted either directly via contact with an infected host or indirectly via contact with a contaminated environment. In addition to contact virus can transmit to a new susceptible animal either orally or via the respiratory tract [16].

Foot and mouth diseases (FMD) epidemiology is the study of the distribution of serotypes, prevalence rates, and risk factors that contribute to the occurrence of FMD. FMD is found all over the world and classified as a notifiable disease by the World Organization for Animal health [3].

FMD is endemic in Ethiopia, with complex epidemiological nature, wider geographical distribution, and broad host range. It has the ability to establish carrier status, and its antigenic diversity leading to poor cross-immunity, variant type of viral genes, and relatively short duration of immunity. The incidence of FMD is high in Ethiopia due to the presence of free animal movement, a high rate of contact among animals at commercial markets, the presence of communal grazing

areas and watering, poor diagnostic facilities, poor surveillance, and limited prevention and control strategies of the government [19].

The epidemiology of FMD should be studied on a regular basis in Ethiopia because of occurrence of foot and mouth diseases repeatedly recorded every year [14]. For prevention, control, mitigation, and eradication of the disease, baseline information about seroprevalence, serotype, and risk factors are essential. Therefore, the objectives of this study were to estimate the seroprevalence of foot and mouth disease in the study area, to assess risk factors associated with the disease and to identify serotypes of foot and mouth disease virus circulating in the study area.

2. Materials and Methods

2.1. Study Area

The research was carried out in the northwestern part of Ethiopia's Amhara regional state located between the latitudes of $8^{\circ}45' - 13^{\circ}45'N$ and the longitudes of $35^{\circ}15' - 40^{\circ}20'E$, covering an area of 157,127 km². The average annual rainfall in the region ranges between 598.3 mm and 1692 mm. Country side areas are home to 87.3% of the population, while urban areas are home to 12.7%. The region's main farming system is a mixed crop-livestock production system [15, 6]. Samples were collected from four districts (Adet, Banja, Simada and Ebenat) in western Amhara region. Figure 1 shows map of the four study districts in Amhara region, Ethiopia.

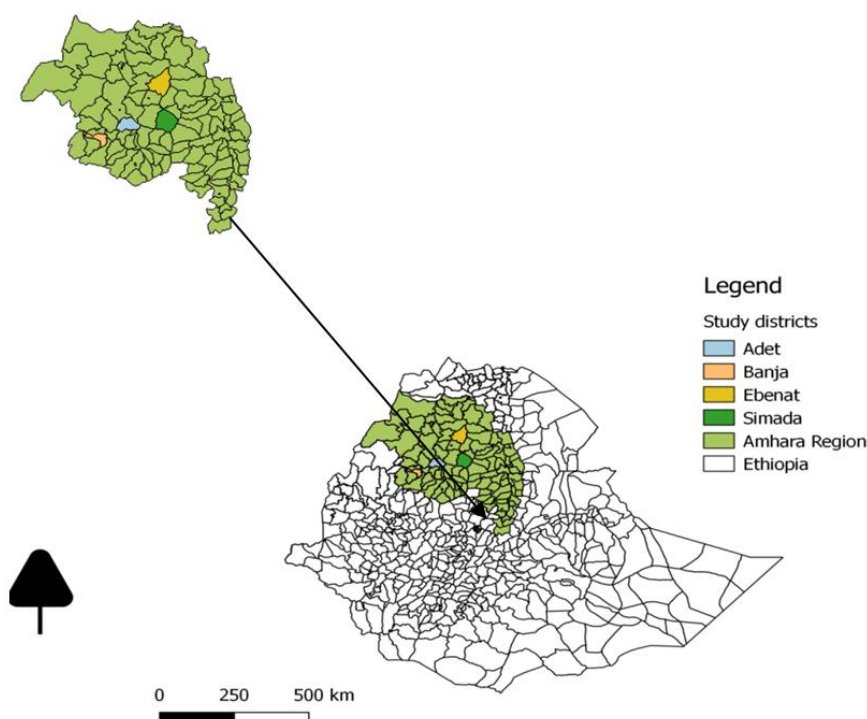


Figure 1. Map showing the study area; Source: Adopted by qGIS 2.18.

2.2. Study Population

The study population consists of cattle of various ages, sexes, herd sizes, and reared under various production systems and farming types. This region has a nearly similar population density with a mixed crop-livestock production system and similar animal management, except beef and dairy farms in the urban areas with intensive and semi-intensive production systems.

2.3. Study Design

A cross-sectional study was carried out with a multistage sampling method from region to individual animal level but within each stage, purposive, convenient, and random sampling method was applied. Study districts were selected due to accessibility and relatively good security but the peasant associations in the district were selected by considering agro-ecology. Half of the animals in one herd were used as sampling units, but if the owner had a small number of animals, all of them were included.

2.4. Sample Size Determination

The sample size was determined using a sample size formula based on the desired precision and previous prevalence in the study area [20]. According to the previous report of [11], the seroprevalence of FMDV in cattle in the area was 14.3%.

$$n = 1.96^2 \times P_{exp} (1 - P_{exp}) / d^2 = ((1.96)^2 \times 0.143 \times (1 - 0.143)) / (0.05)^2 = 188$$

Thus, a sample size of 188 was determined. However, it was maximized to 389 to increase precision and accuracy. Where $Z_{a/2}$ value of the critical region = 1.96, N = sample size, P_{exp} = expected prevalence, d = absolute precision used as a significance level, and 95% confidence interval. The sample size in each district was calculated using the disproportionate stratified sampling method, which divides the total sample size by the number of strata or districts, as well as a similar flow at the peasant association level.

2.5. Study Methodology

2.5.1. Sample Collection

Blood was drawn from the jugular vein of each animal using a 10 ml plain vacutainer tube. Each vacutainer tube was carefully inspected. During collection, the serum was carefully harvested and labeled for each individual animal before being placed in cryovials. The sera samples were kept at -19 °C until the laboratory investigation was completed. The research was carried out at the National Animal

Health Diagnosis and Investigation Center (NADIC) in Sebeta, Ethiopia.

2.5.2. Serological Examination with Non-Structural 3ABC Competitive ELISA

Serum samples were subjected to non-structural protein (FMD NSP) Competition 3ABC ELISA (ID Screen ®, ID. Vet, and Montpellier France). A total of 389 sera were tested. A test was performed as per the manufacturer's instructions with series of procedures with 96 well micro plates. Positive results from non-structural 3ABC competitive ELISA was screened again for specific serotype antibody detection using a solid-phase competitive enzyme-linked immune sorbent assay (ELISA).

2.6. Data Management and Analysis

The serum data was entered into Microsoft (Ms) excel spreadsheet and coded for analysis. The overall seroprevalence and prevalence over each factor was analyzed by Stata software Version13 with chi-square statistical tools. Risk factors were analyzed by univariable and multivariable logistic regression analysis.

3. Results

3.1. Seroprevalence of FMD

The overall seroprevalence of FMDV was 5.66% (22/389) with (95%; CI: 3.34% to - 7.98%). Statistically significant (P -value = 0.001) higher seroprevalence was recorded in Adet 14.44% (n = 13) as compared to other districts as shown in Table 1. The districts in the south Gondar zone had relatively similar seroprevalence, 3.39% in Ebenat and 3.85% in Simada were recorded. In general, the prevalence of foot and mouth disease viruses varied among districts.

Table 1. The prevalence of foot and mouth diseases virus among districts.

Variable	No test	No positive test	χ^2	P value
Simada	104	4 (3.85%)	17.54	0.001
Ebenat	118	4 (3.39%)		
Adet	90	13 (14.44%)		
Banja	77	1 (1.30%)		

No test= number of animals tested, No positive= number of positive sample for FMD

3.2. FMD Prevalence Between Risk Factors

Seroprevalence was compared in various risk factors such as age group, gender, number of animals, production systems, and animal rearing practices. Even though higher seroprevalence was recorded in female 5.86% (n =15) than male 5.26% (n = 7), there was no statistically significant difference (p -value= 0.8). And also, age group was not statistically significant

(p -value= 0.37) in this study. It was higher in semi-intensive production system (28.57%) than intensive (17.65%) and extensive (3.4%) production systems. Significantly higher seroprevalence (P = 0.014), was also recorded in cross breed (15.15%) compared to local breed (4.78%) cattle. [Table 2](#) below showed more descriptions including the χ^2 value for each risk factor.

Table 2. Seroprevalence of FMD across corresponding risk factor.

Variable	Categories	No test	No positive	χ^2	P-value
Sex	Female	256	15 (5.86%)	0.058	0.8
	Male	133	7 (5.26%)		
Age	Adult	281	14 (5%)	0.8	0.37
	Young	108	8 (7.34%)		
Breed	Local	356	17 (4.78%)	6.09	0.014
	Cross	33	5 (15.15%)		
	Intensive	16	3 (17.65%)		
Production system	Extensive	353	13 (3.70%)	27.75	0.000
	Semi-intensive	20	6 (28.57%)		

3.3. Seroprevalence Across Herd Size, Farm Type and New Animal Added Per Year

Lower herd size had lower seroprevalence (5.06%) than higher herd size (6.06%), but the difference was not statistically significant. Seroprevalence was found to be significant-

ly (P = 0.003) higher in dairy farms (20.8%) than in small-holder farms (4.75%), and in beef farms with no prevalence. There was no statistical difference in seroprevalence among new animals added within a year or not (P = 0.79). Seroprevalence corresponding to risk factors is described in [Table 3](#) below.

Table 3. Seroprevalence of FMD across corresponding risk factor.

Factors	Categories	No test	No positive	χ^2	P-value
Herd size	Above 5 per herd	231	14 (6.06)	0.17	0.67
	Below 5 per herd	158	8 (5.06%)		
New animal added per year	no	347	20 (5.76%)	0.07	0.79
	Yes	42	2 (4.76%)		
Farm type	Small holder	358	17 (4.75%)	11.3	0.003
	Dairy farm	24	5 (20.8%)		
	Beef farm	-	-		

No test= number of test, No positive= number of positive, χ^2 =chi-square, CI= confidence interval

3.4. Logistic Regression Analysis

The occurrence of FMD seroprevalence was compared among districts using a univariable logistic regression analysis. The diseases occurred 12.8 times more frequently in Adet than in Banja, and it was statistically significant ($P=0.015$).

The effect of breed indicates that FMD occurs 3.56 times more frequently in cross breed cattle than in local breed cattle, with a significant difference ($p=0.02$). FMD occurred 10.4 times more frequently in semi-intensive than in extensive production systems, with a significant difference ($P=0.000$) as shown [Table 4](#).

Table 4. Univariable logistic regression result.

Factor	Categories	OR	p-value	CI
District	Adet	12.8	0.015	1.63- 100.5
	Ebenat	2.66	0.38	0.29- 24.3
	Simada	3	0.32	0.33- 27.75
Breed	Cross	3.56	0.02	1.22- 10.37
	Semi-intensive	10.4	0.000	3.47- 31.14
Production system	Intensive	5.57	0.014	1.42- 21.8

OR= odds ratio, vs. versus; CI= confidence.

The occurrence of FMD seroprevalence among farm types showed that it was 5.3 times more frequently occurred in dairy farms than in smallholder farms and it was statistically significant ($P=0.012$). But there was no significant difference ($p\text{-value}= 0.67$) in herd size of number of animals per herd

above 5 or below 5 as shown in [Table 5](#). And also, new animals added within a herd in this study, did not show statistically significant difference ($P=0.7$) for the occurrence of FMD.

Table 5. Univariable logistic regression result.

Factor	Categories	OR	p-value	CI
New animal add with year	No vs. Yes	1.2	0.7	0.27-5.42
Farm type	Dairy	5.3	0.012	1.7-15.8
Herd size	Number of animals per herd above 5	1.2	0.67	0.49-2.45

From the risk factors included in this study, only districts and production systems showed a significant difference in the occurrence of FMD in multiple logistic regression analysis. Among districts, the FMD prevalence in Adet was 12.6 times higher than in Banja ($P=0.016$). It was 3.09 and 2.7 times more common in Simada and Ebinat, respectively, than in

Banja, but there was no significant difference. Foot and mouth diseases virus was 14 times more common in semi-intensive production systems than in extensive production systems, with a significant difference ($p=0.003$). For a more in-depth understanding, see [Table 6](#).

Table 6. With multi variable analysis on risk factors.

	Factors	OR	P value	CI
District	Adet	12.6	0.016	1.6-98.8
	Ebenat	2.7	0.38	0. 28-24.5

	Factors	OR	P value	CI
Production system	Simada	3.09	0.31	0.33-28.8
	Semi-intensive	14	0.0033	2.53-79.8
	Intensive	13.5	0.016	1.65-117.9

OR= odds ratio, vs= versus, CI= confidence

3.5. Serotype Identification

FMD virus serotypes O, A, and SAT 2 were identified as the causal serotypes from antibody detection in four districts. In Adet, 11 samples were serotype O and 3 samples were A. Three O and one SAT2 serotype samples were identified in Simada. O serotype was identified in Banja and Ebenat.

4. Discussion

Seroprevalence of FMD

Foot and mouth diseases virus was endemic in our country and found in all regions of Ethiopia, the prevalence and distribution varied across districts [7, 12], which could be attributed to differences in land scape, agro ecology, and animal movement within Ethiopia [10]. Prevalence varies from place to place with seropositivity that ranges from 5.6% to 42.7% in cattle. The overall seroprevalence of FMDV in the north western Amhara region was 5.66% in this study, but in another study [10], the overall prevalence in the entire Amhara region was 11.04%. Most of the districts chosen for this study had low prevalence compared with previous studies, Banja having a relatively low proportion of FMD prevalence of 4.2% [4] and in similar this district having a prevalence of 1.3% in this study. This could be due to the area being in a relatively central location, or it being a non-boundary area with less movement of animals. This may be due to exporting of animals than importing in the area. In south Gondar Zone districts, Tesfaye and his colleagues reported that the prevalence of the disease in the area was 9.6% [18]. However, it was 3.6% in the current study; this may be due to variation in selected peasant association. Another scholar, Abunna and his colleagues reported that the overall prevalence of FMD at Dire Dawa and its surroundings, Eastern Ethiopia was 8.01% [1]. This finding was in agreement with the present study. In this study, foot and mouth disease was present in all ecosystems. Cross-bred cattle had higher percentages of foot and mouth disease seropositivity than local breed cattle. It was 3.56 times higher in cross breed than in local breed cattle in the present study. Similarly, in previous studies, conducted in central Ethiopia, crossbred cattle were 2.79 times more likely than local cattle in seropositivity of the disease [14], and in another study from West Shewa Zone, Ethiopia, crossbred cattle were 6 times more likely than local cattle in seroposi-

tivity [2]. In this study, sex group was not statistically significant and it was in agreement with many previous studies [9, 12, 17].

There was no statistically significant difference among age groups in this study and it is congruent with the report of from Bale Zone, Oromiya regional state, Ethiopia [16]. However, studies conducted from different parts of the country showed that age groups were statistically associated with disease occurrence [7, 12, 17]. The difference could be attributed to age delegation among researchers. The prevalence of FMD in the semi-intensive production system was 28.57%, while the prevalence in the extensive production system was 3.57%. This difference may be due to animal density variation, as the semi-intensive production system had a higher density of animals in a fixed area than the extensive production system. FMD prevalence had increased in densely populated than scattered one, so ventilation and animal density may cause for variation in occurrence and distribution of the disease.

The occurrence of foot and mouth disease in dairy farm was 5.3 times more than occurrence of the diseases in small holder farms ($p=0.012$). There was no sero prevalence in beef farm, this may due to unavailability of animals constantly in the farm for a long period of time. In this study, serotype A, O, and SAT2 were identified and similarly Sulayeman and his colleagues from central Ethiopia reported that the same type of serotypes were detected [16]. Serotype O to be the most prevalent and dominant serotype in Adet, causing the majority of outbreaks in the Amhara region [13]. In agreement to this Serotype O was also identified in Adet, Simada, Ebenat and Banja in this study. Serotype O considered as the most widely studied and common FMD serotype in the world [21], and in this study, serotype O was the most dominant serotype. Another scholar indicated that it was the most prevalent in central Ethiopia [5, 18]. The three serotypes, O, A, and SAT2 were found in the central part of the country, Debre Birhan, Debrezyiet, and Addis Abeba [19]. And those serotypes were identified in the current study areas. SAT2 was also the cause for FMD outbreak in Afar Region, Ethiopia [7].

5. Conclusion and Recommendations

The present study indicated that Foot and mouth disease is more prevalent and endemic disease in in north western Amhara region on rural communities as well as dairy and beef farms because of free movement of livestock in different regions and

ineffective control measures. The seroprevalence of foot and mouth diseases varies among districts with a minimum prevalence of 1.3% in Banja to a maximum prevalence of 14.4% in Adet. The average prevalence in this study is 5.66%. In addition different Serotypes were identified. As a result, livestock owners should be aware about the clinical and economic consequences of FMD and try to control and prevent their animals. Vaccine trials, more work on serotypes, and detailed epidemiological investigations should be conducted.

Ethics Approval

Animal research ethical review Committee of Addis Ababa University, College of Veterinary Medicine and Agriculture was check on ethical issues for sample collection and preservation with Reference No: VM/ERC/07/04/13/2021.

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Authors' Contributions

B.Y. Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing— original draft, Writing—review&editing, Y.J. Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, A.M. Conceptualization, laboratory work, review & editing.

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Data Availability Statements

All relevant data are within the paper and its supporting information files.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Abunna F, Fikru S, Rufael T. Seroprevalence of Foot and Mouth Disease (FMD) at Dire Dawa and Its Surroundings, Eastern Ethiopia. *Global Veterinaria*. 2013; 11(5): 575-8.
- [2] Ahmed B, Megersa L, Mulatu G, Siraj M, Boneya G. Sero-prevalence and associated risk factors of foot and mouth disease in cattle in West Shewa Zone, Ethiopia. *Veterinary medicine international*. 2020 Mar 31; 2020.
- [3] Aman E, Molla W, Gebreegizabher Z, Jemberu WT. Spatial and temporal distribution of foot and mouth disease outbreaks in Amhara region of Ethiopia in the period 1999 to 2016. *BMC veterinary research*. 2020 Dec; 16: 1-8.
- [4] Ayelet G, Gelaye E, Negussie H, Asmare K. Study on the epidemiology of foot and mouth disease in Ethiopia. *Rev Sci Tech*. 2012 Dec 1; 31(3): 789-98.
- [5] Ayelet G, Soressa M, Sisay T, Belay A, Gelaye E, Jembere S, Skjerve E, Asmare K. FMD virus isolates: the candidate strains for polyvalent vaccine development in Ethiopia. *Acta tropica*. 2013 Jun 1; 126(3): 244-8.
- [6] Duguma M, Jibril Y, Issa A, Hunde A. Sero-prevalence of foot and mouth disease of cattle in Bale Zone, Oromiya regional state, Ethiopia. *Global Veterinaria*. 2013; 11(1): 59-64.
- [7] Gelaye E, Ayelet G, Abera T, Asmare K. Seroprevalence of foot and mouth disease in Bench Maji zone, Southwestern Ethiopia. *Journal of Veterinary Medicine and Animal Health*. 2009 Jul; 1(1): 005-10.
- [8] Jemberu WT. Bioeconomic modelling of foot and mouth disease and its control in Ethiopia (Doctoral dissertation, Wageningen University and Research).
- [9] Mazengia H, Taye M, Negussie H, Alemu S, Tassew A. Incidence of foot and mouth disease and its effect on milk yield in dairy cattle at Andassa dairy farm, Northwest Ethiopia. *Agriculture and Biology Journal of North America*. 2010; 1(5): 969-73.
- [10] Mesfine M, Nigatu S, Belayneh N, Jemberu WT. Sero-epidemiology of foot and mouth disease in domestic ruminants in Amhara Region, Ethiopia. *Frontiers in Veterinary Science*. 2019 Apr 30; 6: 130.
- [11] Minale AS, Rao KK. Hydrological dynamics and human impact on ecosystems of Lake Tana, northwestern Ethiopia. *Ethiopian Journal of Environmental Studies and Management*. 2011; 4(1).
- [12] Mohamoud A, Tessema E, Degefu H. Seroprevalence of bovine foot and mouth disease (FMD) in Awbere and Babille districts of Jijiga zone, Somalia Regional State, Eastern Ethiopia. *African Journal of Microbiology Research*. 2011 Oct 9; 5(21): 3559-63.

- [13] Negussie H, Ayelet G, Jenberie S, Minda S, Tesfaw L. Molecular epidemiology and vaccine matching study on foot-and-mouth disease virus circulating in Ethiopia. *African Journal of Microbiology Research*. 2013; 7(44): 5101-6.
- [14] Sulayeman M, Dawo F, Mammo B, Gizaw D, Shegu D. Isolation, molecular characterization and sero-prevalence study of foot-and-mouth disease virus circulating in central Ethiopia. *BMC veterinary research*. 2018 Dec; 14(1): 1-0.
- [15] Tadesse B, Molla W, Mengistu A, Jemberu WT. Transmission dynamics of foot and mouth disease in selected outbreak areas of northwest Ethiopia. *Epidemiology & Infection*. 2019; 147.
- [16] Tadesse B, Tesfahun A, Molla W, Demisse E, Jemberu WT. Foot and mouth disease outbreak investigation and estimation of its economic impact in selected districts in northwest Ethiopia. *Veterinary medicine and science*. 2020 Feb; 6(1): 122-32.
- [17] Tesfaye A, Mengistu A, Rufael T. Sero-prevalence status of foot and mouth disease in the North Western Amhara Regional State, Ethiopia. *Ethiopian Veterinary Journal*. 2016; 20(2): 43-53.
- [18] Tesfaye Y. Isolation, molecular characterization and vaccine matching of foot and mouth disease virus circulating in Ethiopia (Doctoral dissertation, MSc Thesis, Addis Ababa University, Faculty of Veterinary Medicine, Bishofu, Ethiopia).
- [19] Thrusfield M. *Veterinary epidemiology*. John Wiley & Sons; 2018 Apr 30.
- [20] TIKUYE YALEW SH. Antigen detection and molecular characterization of foot and mouth disease virus from outbreak cases in Ethiopia (Doctoral dissertation, ADDIS ABABA UNIVERSITY).
- [21] Wubshet AK, Dai J, Li Q, Zhang J. Review on outbreak dynamics, the endemic serotypes, and diversified topotypic profiles of foot and mouth disease virus isolates in Ethiopia from 2008 to 2018. *Viruses*. 2019 Nov 18; 11(11): 1076.
- [22] Yirgalem M, Dawo F, Gizaw D, Mamo B, Bilata T, Shegu D. Phylogenetic And Sequence Variability Analyses Of Vp1 Protein Of Foot And Mouth Disease Viruses In Cattle In Amhara Region Of Ethiopia.