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ORIGINAL RESEARCH

Study on seroprevalence, risk factors, and economic impact of foot-and-mouth disease in Borena pastoral and agro-pastoral system, southern Ethiopia

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Abstract Cross-sectional serological study and questionnaire survey were conducted in Borana pastoral and agro-pastoral area to determine seroprevalence and risk factors associated with foot-and-mouth disease (FMD) infection and to assess community perceptions as to importance of the disease. A multistage random sampling was carried out to select cattle for seroprevalence and households for interviews. Totally, 768 sera were collected from 111 herds. The overall individual level seroprevalence of 23.0% (n=177) and herd level seroprevalence of 58.6% (n=65) were recorded using 3ABC ELISA test. The variation of individual level seroprevalence in districts were statistically significant ($P<0.05$) which was 29.9% in Arero, 24.0% in Yabello, and 15.7% in Teltele. From multivariate logistic regression analysis, herd size and age were seen to be significantly ($P<0.05$) associated with FMD seroprevalence. The result of the questionnaire survey based on 120 respondents indicated that, the daily milk yield of cows infected with FMD during outbreaks is reduced to an average of 0.5 L for 25.5 days while cows developing heat-intolerance syndrome after acute infection gave an average 0.67 L for 3.8 months and their calving interval prolonged about 12 months. The questionnaire survey in agro-pastoral area of Borena also indicated that FMD-infected oxen remained off-plough for one season when outbreaks occur in cropping time, whereas heat-intolerant oxen were no longer used for traction. These findings of the present study indicated that FMD is a highly prevalent and economically important disease in the Borana pastoral and agro-pastoral production systems which need effective control strategy for the disease.

Keywords Agro-pastoral and pastoral · Economic impact · Foot-and-mouth disease · Risk factors · Seroprevalence · Southern Ethiopia

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Introduction

Pastoralism is one of the oldest socio-economic systems in Ethiopia, which represents the major means of subsistence. Pastoralists constitute about 12–15% of the total population (Halderman 2004). The country possesses about 47.6 million cattle, 26.1 million sheep, 21.7 million goats, 1.0 million camels, and 7.7 million equines and 39.6 million chickens (CSA 2008). From the total livestock population of the country, pastoralists account for about 42%.

Several livestock production constraints lead Borana pastoralists to sub-optimal utilization of their cattle resources. Scarcity of water and pasture, recurrent drought, poor physical infrastructure, human population pressure, conflicts, and inappropriate pastoral policy are raised as main constraints for limitation of livestock production (Halderman 2004; Mussa 2004). This has also been worsened by high prevalent nature of livestock diseases and poor veterinary infrastructures and services in the area. Foot-and-mouth disease (FMD) has been among the most important prevalent livestock diseases in Borana area for long period of time (Coppock 1994; Rufael et al. 2008).

Foot-and-mouth disease is the most contagious animal disease affecting all cloven-hoofed animals and characterized by fever, loss of appetite, salivation, and vesicular eruptions on the feet, mouth, and teats (Bronsvoort et al. 2004). Morbidity is up to 100% in susceptible animal populations, but mortality is low in adults (Kitching 2002). The seven serotypes of FMD virus produce a disease that is clinically indistinguishable but immunologically distinct (OIE 2004). It is endemic with high prevalence in Africa, the Middle East, and Asia and is also present in parts of South America while industrialized countries are free from the disease (Rweyemamu and Astudillo 2002). However, it is a global problem since the result of increasing movement of human and livestock and livestock products (Perry and Rich 2007). From records of an outbreak investigations conducted by NVI between 1982 and 2000, serotype O, A, and SAT 2 FMD viruses were also identified (Gelaye et al. 2005). The recent study conducted by Ayelet et al. (2009) on FMD samples collected between 1981 and 2007 throughout the country from different species of animals showed that serotype O, A, C, SAT1, and SAT 2 were identified.

In Ethiopia, outbreak of FMD frequently occurs in the pastoral herds of the marginal lowland areas of the country. This is mainly due to lack of vaccination, free livestock movement among different regions in the countries and across international borders, the existence of multiple FMD virus serotypes, and involvement of wildlife (Sahle 2004; Rufael et al. 2008). This might be exacerbated by genetic shift and drift (Haydon et al. 2001) of the FMD virus that may result in new antigenic variant of the virus and, consequently, may cause outbreaks of the disease. These indicate the presence of complexity and dynamic epidemiological situation of the disease in the area. Thus, continuous epidemiological studies are important to understand disease situation and to design appropriate control/prevention strategies in future.

The direct impacts of FMD vary markedly between developed and developing worlds and also among different livestock production systems in the later world (Perry and Rich 2007). Owing to the low productivity of pastoral herds as compared with commercial or semi-commercial diary units, FMD infection in pastoral areas is considered relatively as minor disease. However, pastoralists severely suffered by impact of the disease on milk yield since they rely more on milk as a subsistence food than any other population in the country (Rufael et al. 2008). Milk losses due to the disease are not clearly stated. The disease is also associated with abortion and mortality in calves in acute cases and “chronic FMD” cases showing heat intolerance, reduced fertility (Catley et al. 2004), and loss in draught power production in agro-pastoralists present in the area (Doel 2003). Therefore, the objectives of this study were to determine seroprevalence and associated risk factors of FMD and to assess economic importance of FMD infection in Borana Pastoral and agro-pastoral livestock production systems.

Materials and methods

Description of the study area

The study was conducted in selected districts (Arero, Teltele, and Yabello) of Borana zone of Oromiya Regional State, Southern Ethiopia (Fig. 1). The altitude of Borana rangeland lies at 970 m above sea level in the south, bordering Kenya to 1,693 m above sea level in the northeast. The rangeland represents a vast lowland area, covering about 95,000 km^2 (Coppock 1994). It borders with the republic of Kenya to the south, Somali Regional State to the east, and Southern Nation and Nationalities and People’s Regional State to the west, and Guji Zone to the north. The climate is semi-arid. The area exhibits a bimodal pattern of rainfall, with the main rains falling between March and May, and the short rains from mid-September to mid-November (Coppock 1994). A prominent feature of the Borana ecosystem is the erratic and variable nature of the rainfall, with most of the areas receiving between 238 and 896 mm annually (Angassa and Oba 2007), and the annual mean daily temperature varies from 19 C to 24 C with moderate seasonal variation.

The Borana pastoral system is dominated by savannah vegetation containing mixtures of perennial and woody bush land. The major sources of water are ponds and deep wells during rainy and dry periods, respectively (Angassa and Oba 2007). Livestock is an integral part of the Borana people that serve several purposes such as source of food, income generation, and social prestige (Angassa and Oba 2007).

Study designs, study population, and sampling method

Cross-sectional study

Study population was 450,000 cattle from purposively selected three districts of Borana zone, namely Arero, Teltele, and Yabello. The districts were selected based on accessibility, lack of seroprevalence information, presence of livestock markets activity, and socio-economic characteristics. Households or privately owned herds were the sampling units. A multistage sampling method was implemented to select the sampling units. The numbers of animals included in the study were distributed proportionally over the selected districts. First, about 20% of pastoral associations (PAs) from each district were randomly selected for this study. From selected PAs, about 10% of cattle herds from each selected PA were selected as primary sampling units. Eight cattle from the selected herds were randomly selected as secondary units. Accordingly, 13 PAs, 96 herds, and 768 cattle (248 from Teltele, 224 from Arero, and 296 from Yabello) were included in the study. This

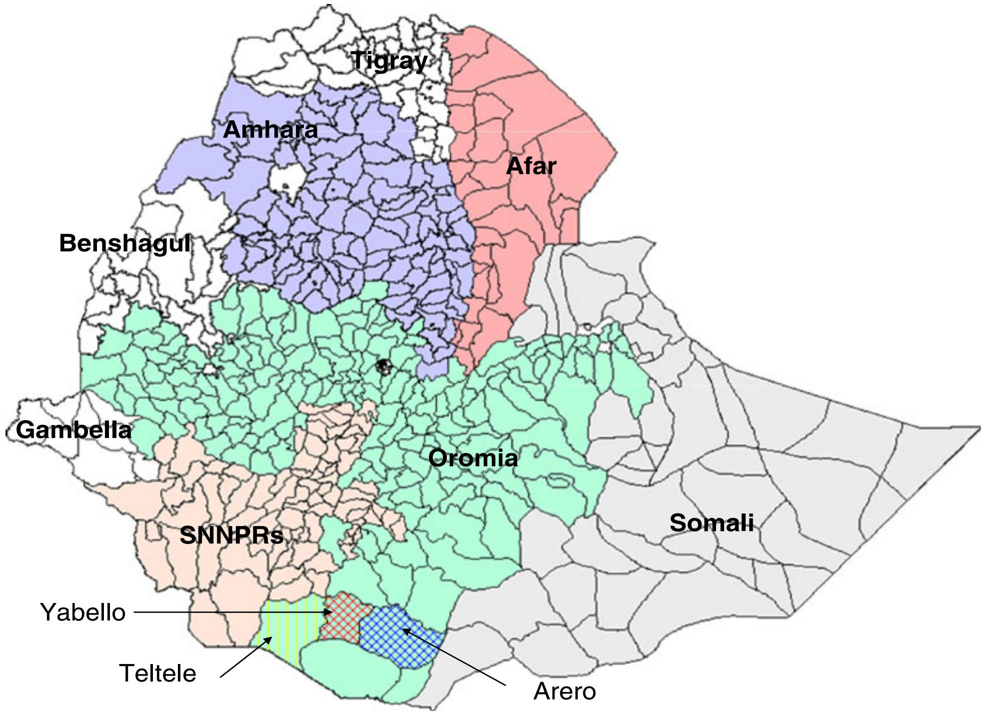

Fig. 1 Map of the study areas (Arero, Teltele and Yabello)

number was arrived at by first assuming the expected prevalence of 21% in cattle (Rufael et al. 2008) and 95% confidence interval and then an infinite population and multiplying the estimate sample by threefold for potentially large variation that can occur between clusters based on Thrusfield (2005).

$$n = \frac{1.96^2 * P_{\mathrm{exp}} * \left(1 - P_{\mathrm{exp}}\right)}{d^2}$$

Where, n=required sample size, P_{exp}=expected prevalence, and d^2=absolute desired precision

$$n = \frac{1.96^2 * 0.21 * (1 - 0.21)}{0.05^2} = 255\,\text{cattle}$$

Questionnaire survey

The survey was carried out in three purposively selected districts after serum collection had been finalized. Thirteen PAs which were selected for serological survey were included in the questionnaire survey to assess the implications of FMD infection in pastoral and agro-pastoral livestock production systems. Household having cattle were the sampling units for questionnaire survey. About 12.5% of these were randomly selected from the 13 PAs. Accordingly, households included from three districts in questionnaire survey were 46 from Yabello, 35 from Arero, and 39 from Teltele. A total of 120 households were interviewed using prepared semi-structured questionnaire. Group discussions with the pastoralists in each district were also conducted to capture the general production systems in the area.

Laboratory diagnosis

Serum sample collection

About 10 ml of blood sample was collected from the jugular vein of each animal using plain vaccutainer tube; the tubes were then kept protected from direct sun light in slant position until the blood clotted and sera were separated. The separated sera were transferred to sterile cryovials and kept in icebox at the field and thereafter transferred into refrigerator at −20 C. Finally, the samples were transported to the National Veterinary Institute (NVI) Laboratory for serological examination.

Serology

The SVANOVIR™ FMDV 3ABC-Ab ELISA test was used to differentiate serological positive and negative animals. Controls and test sera were first diluted in 1:40 concentrations using buffer. The odd columns' wells of the microplate were coated with FMDV 3ABC viral antigens while the even columns' wells were coated with control antigens. Duplicates of 50 µl of diluted controls and test sera were dispensed into wells. The plates were sealed with lids and incubated for 30 min at 37°C. The incubated microplates were rinsed three times by filling the wells with about 300 µl per diluted phosphate-buffered saline (PBS) Tween buffer at 1:20 concentration using distilled water. A bottle of lyophilized horseradish peroxidase (HRP) conjugate was reconstituted with 6 ml PBS–Tween buffer and after 1 min, 50 µl of the reconstituted HRP conjugated anti-bovine IgG were added into the wells of the microtiter plates. The plates were then covered and incubated for 30 min at 37 C. After washing the plates, 50 µl of substrate solution were dispensed into wells of the microtiter plates and incubated for 30 min at room temperature in a dark place. The reaction was stopped by adding 50 µl of stop solution to each well of the plate, and the content was mixed thoroughly. Finally, the optical densities (OD) were measured using air as blank at 405 nm in a microplate photometer and simultaneously, the OD value results of each well of the plates were printed out.

Calculations of the results were done in two steps as follows:

1. The OD values in wells coated with FMDV 3ABC viral antigens were corrected by subtracting the OD values of the corresponding wells containing the control antigen.

   $$\mathrm{OD}_{NSP\,3ABC} - -OD_{control} = \mathrm{OD}_{Corr}$$

2. All corrected OD value for the test sera as well as the negative control (Neg C) were related to the corrected OD value of the positive control.

   $$\mathrm{PP} = \frac{\text{Test sera or Neg C}(\mathrm{OD}_{\mathrm{Corr}})*100}{Positive\ control(OD_{Corr})}$$

The interpretation was conducted by cut-off value provided by the manufacturer. Based on this,

- $PP_{test\ sera}<48$ were taken as seronegative and
- $PP_{test\ sera}\geq 48$ were seropositive.

Data management and analyses

Data entry and management was made using Microsoft Excel. Data analysis was made using SPSS-12 software. Descriptive statistics was performed to summarize reproductive and production performance and seroprevalence. The χ^2 test and logistic regression were used to assess risk factors. In all the analyses, confidence levels at 95% were calculated, and a $P\leq 0.05$ was used for statistical significance level.

Result

Seroprevalence

From 111 herds examined, 65 (58.6%) contained at least one positive cattle. The herd level seroprevalence recorded was 67.6% (n=34) in Arero district, 62.5% (n=40) in Yabello district, and the lowest was found in Teltele district (45.9%, n=37). The herd seropositivity was found to be statistically not significant (P>0.05) among the studied districts.

Regarding to PA basis, the highest herd level seroprevalence was observed in Bobela (100%), Surupa (87.5%), Didyabello (70.0%), and Alona and Afura (66.7%). But, the lowest was recorded at Cherri (28.6%), followed by 33.3% at Ebissa, 40.0% at Sabba, and 44.4% at Bulegorma. However, there was no statistically significant (P>0.05) difference in herd seropositivity among the PAs included in the study.

Out of 768 sera collected from the three districts of Borana zone, overall seroprevalence of 23.0% (177) were recorded. A proportion of 15.7% recorded in Teltele District was the lowest seroprevalence, followed by seroprevalence of 24.0% in Yabello and 29.9% Arero District (Table 1). The respective seroprevalence recorded in the three districts were shown statistically significant difference (P<0.05).

A total higher seroprevalence of 28.4% (50/176) was recorded in three PAs (Didyabello, Surupa, and Didhara) of Yabello district with focal grazing place and high livestock trade activity and lower total seroprevalence of 17.5% (21/120) in two PAs (Cherri and Harwayu) of the same district without those factors. These risk factors was significantly associated (P<0.05, χ^2=4.657) with the disease seroprevalence.

On the other hand, the highest seroprevalence at PA level was found at Bobela (43.8%, n=48) of Arero district while the lowest was at Ebssa (12.5%, n=48) followed by Billa (13.9%, n=64) of Teltele district, and Cherri (14.7%, n=48) of Yabello district (Table 1). The highest prevalence recorded at Bobela PA was shown significant difference from other PAs.

Risk factors of foot-and-mouth disease

Sex difference in the present study recorded a higher seroprevalence of 26.0% in females than 16.5% in males (Table 2). These proportions were statistically significantly (P<0.05) different. The other intrinsic factor of the investigation was age by categorizing into three groups. The highest seroprevalence of 32.6% was obtained in animals aged at least 4 years old, followed by 18.2% and 8.5% in animals aged between 2 and 4 years old, and less than 2 years old, respectively (Table 2). The respective seroprevalence in three age categories significantly (P< 0.05) varied. High seroprevalence of 30.6% was recorded in animals in large herds, whereas low seroprevalence of 16.4% was found in animals in small herds (Table 2). These seroprevalence significantly (P<0.05) varied.

Table 1 Seroprevalence of foot-and-mouth disease at the level of Peasant Associations (PAs) in the study of three districts

PAs	No. of tested sera	No. of positive sera	Prevalence (%)	95% CI
Teltele				
Sabba	64	13	20.3	9.8–30.8
Bile	72	10	13.9	5.4–22.4
Bulegorma	64	10	15.6	6.5–24.5
Ebissa	48	6	12.5	3.1–21.9
Yabello				
Didhara	48	13	27.1	14.5–39.7
Cherri	48	7	14.6	5.3–23.9
Harwayu	72	14	19.4	10.2–28.5
Didyabello	72	20	27.8	17.5–38.2
Surupa	56	17	30.4	18.3–42.5
Arero				
Afura	48	15	31.3	18.2–44.4
Fulduwa	64	16	25.0	14.4–35.6
Alona	64	15	23.4	13.0–33.8
Bobela	48	21	43.8	29.8–57.8
Overall	768	177	23.0%	20.0–26.0

Questionnaire survey

All the respondents ($n=120$) from the three districts indicated that they milked cows twice a day (at morning and evening). This study indicated that Borana cows daily produce on average 1.87 L of milk, excluding the milk suckled by the calf, for about 8 months. It was also showed that heifers delivered first calves on average of 4.8 years of age. Thereafter, they gave an average 8.1 calves with 16.2-month intervals in their productive life (Table 3).

The present questionnaire survey indicated that FMD-infected (*Oyaalee*) Borana cows dropped milk yields for an average of 25.5 days. A proportion of 78.3% of respondents informed that they could get on average only half a liter of milk per day during FMD outbreaks. Moreover, cows having chronic FMD (*Gaandilee*) did not have any milk for

Table 2 Summary of OR, *p* value, and 95% CI (OR) of risk factors associated with FMD prevalence using multivariate logistic regression analysis

Risk factors	No tested	No positive	Sero-prevalence (%)	SE	*P* value	OR	95% CI (OR)
District							
Teltele	248	39	15.7	–	–	–	–
Yabello	296	71	24.0	0.230	0.028*	1.658	1.056–2.604
Arero	224	67	29.9	0.237	0.001*	2.261	1.420–3.601
Age							
<2 years old	252	21	8.5	–	–	–	–
2–4 years old	280	51	18.2	0.327	0.010*	2.323	1.226–4.417
>4 years old	236	77	32.6	0.301	0.000*	4.864	2.695–8.778
Sex							
Female	526	137	26.0	–	–	–	–
Male	242	40	16.5	0.221	0.419	0.836	0.542–1.290
Herd size							
<50 cattle/herd	256	42	16.4	–	–	–	–
50–100 cattle/herd	264	59	22.3	0.233	0.055	1.565	0.990–2.473
>100 cattle/herd	248	76	30.6	0.226	0.001*	2.101	1.350–3.272
Constant				0.363	0.000	0.042	

*Significant ($P<0.05$)

an average of 12 days. After these days, they could only give 0.67 L of milk in a day for an average 3.8 months.

Some 91.6% of interviewees responded that they observed abortion in FMD-infected pregnant cows. The aborted cows became pregnant and gave birth after 12 months of abortion. In addition, respondents indicated that cows mostly delivered unhealthy and weak calves if they were infected at advanced stage of pregnancy. Regarding chronic FMD suffering cows, the average calving interval was found to be extended to 29.3 months. The average culling times of these animals from herds were estimated at 5 years after they developed the chronic syndrome (Table 4). The respondents raised low daily milk yield, unable to feed their calves for the first 2 weeks, long calving interval, and their vulnerability to dry hot weather situations as main reasons for culling of these animals.

The agro-pastoralist respondents (74/120) informed that oxen infected with acute phase of FMD did not plough for one crop season and chronic FMD developing oxen were not used for ploughing any longer.

Discussion

The overall seroprevalence of 23% obtained in this study was in close agreement with the previous seroprevalence record of 21% in the Borana pastoral area (Rufael et al. 2008) and 26.5% in the country (Sahle 2004). The highest seroprevalence of 29.9% was recorded in Arero District. This might be attributed to the presence of extensive livestock movements in search of pasture and water. There was severe scarcity of pasture and water due to lack of rain in the year 2008 long rainy seasons. Therefore, these extensive livestock movements during severe shortage of pasture and water might have enormous impacts on the disease epidemiology, since serum samples were collected immediately after rain started. This study is in agreement for the role of livestock movements in dissemination of the disease and causing of frequent outbreaks of FMD in pastoral areas of Africa (FAO 2007). Similarly, the lower seroprevalence of 15.7% in Teltele District compared to the seroprevalence in Yabello district (24.6%) might be attributed to the relative limited livestock movement in searching of grazing and watering points in the area as well as low livestock trade activities in that district.

A high herd level seropositivity of 58.6% recorded might be attributed to more than 50% cattle having the carrier state and remaining as seropositive after infection for about 3 years (Clavijo and Kitching 2003; Moonen et al. 2004) together with frequent outbreaks (Sahle 2004) in the pastoral production system. The presence of seropositive herds in all PAs could also be in support of herd level endemicity of FMD in the Borana area (Rufael et al. 2008). Nevertheless, there was also variation of PA level seroprevalence with the maximum prevalence of 43.8% at Bobela in Arero District and minimum prevalence of 12.5% and 13.9% at Ebssa in Teltele District, respectively. Similarly, variations in the district-specific seroprevalences were observed.

Moreover, the significant difference between overall seroprevalence of 28.4% in three PAs and 17.5% in the other two PAs in Yabello District recorded might be associated with frequent contacts of animals during high livestock trade activities, thus having livestock frequently mix with animals coming from different area. In contrary, Cheri and Harwayu PAs' cattle migrate during severe shortage of pasture towards comparatively low FMD seroprevalent Teltele district. This finding revealed that 10.9% of seropositivity in the Didyabello, Surupha, and Didhara PAs' and 4.4% of all seropositive cattle in the Yabello District was attributed to the accumulated effect of these mentioned factors.

The age-specific seroprevalence study revealed an increasing prevalence as the age increases, and this finding is in agreement with report of Gelaye et al. (2009). This might be result of cumulative experience of exposure of the cattle population with the agent older cattle. On the other hand, the relatively low seroprevalence in age group less than 2 years may be indicative of prevailing passive maternal immunity and low frequency of exposure (Coppock 1994). The maternal immunity level drops as age increases. The other intrinsic host factor, sex, appeared to have a significant effect on seropositivity in univariable analysis, but it had no significant association with FMD seropositivity using multivariable logistic regression analysis. This might have resulted from confounding effects by other variables like age.

Table 3 Result of reproductive and productive performance of Borana cows as per the respondent responses

Parameters	Mean ± SD	Minimum	Maximum
Age at first birth (year)	4.8±0.4	4.0	6.0
Calving interval (month)	16.2±2.1	12.0	24.0
No. of calves born in lifetime	8.2±2.3	5.0	12.0
Daily milk yield (L/day)	1.87±0.3	1.0	2.7
Lactation length (months)	8.1±1.3	3.0	13.0

Table 4 Production and reproduction performance of Borana cows infected with FMD virus as per respondents responses

Parameters	Mean ± SD	Range
Acute FMD		
Daily milk yield (L/day)	0.5±0.27	0–1
Milk reduction/loss duration (days)	25.5±5.3	7–40
Chronic FMD		
Complete milk loss duration (days)	12±4.1	3–15
Daily milk yield after complete milk loss (L/day)	0.67+0.27	0–1.5
Lactation length (months)	3.8±2.2	2–6
Calving interval (months)	29.3±6.2	12–36
Culling year after developing chronic FMD	5.2±5.6	2–11

Even though there was an increment of seroprevalence found with an increase in herd size, multivariate logistic regression analysis revealed the presence of significant effect of herd size difference on seropositivity animals belongs to small and large herd size categories only. However, the present study indicated the importance of herd size in epidemiology of the disease. This could be attributed to direct contacts and mode of transmission (Seifert 1996) due to the contagious nature of the disease. Large herd sizes can cause crowding of animals that facilitates frequency of contacts and hence, enhances chances of transmission.

The present finding of 1.87 L of milk per day found was comparable with medium-producing cows of 1.68 L milk per day (Coppock 1994). The results of other parameters were also in agreement with study of Tolera and Abebe (2007) findings of 4.7 years at first calving, 15.9 months of calving interval, and 8.3 months of lactation length and with study of Coppock (1994) findings of 4.5 years at first calving, 15 months of calving interval, and 8.2 months of lactation period.

This study revealed that acute phase of FMD infection resulted in reduction of about 1.37 L of milk per day per lactating cow for 25.5 days. This loss of milk was accounted about 73.3% of milk which was supposed to be produced within those days but only 7.7% of total milk production of a lactating cow per lactation period. This high temporary loss of milk possibly exacerbated the shortage of milk production during dry seasons in which mostly outbreaks were occurred. Moreover, up to 12.8% of acute FMD cases in Borana cattle later developed signs of chronic FMD or heat-intolerance syndrome (Rufael et al. 2008) which only produce about 0.67 L of milk per day for 3.8 months. This showed about 83.2% of milk lost from these animals per a lactation period. This was comparable with 78.0% milk production loss reported in chronic FMD suffering cows in pastoralist areas of Afar region (Tadesse 2003). Large proportions of cows might be infected in an outbreak because the morbidity of the disease reaches up to 100% (Seifert 1996), thereby loss of milk production from the systems could be significantly large amount in both acute and chronic cases. This implies that FMD infection has a considerable impact on Borana communities' diet since milk accounted for 55.4% of their diet during a "normal" year and 52.2% of the diet during a drought year, and the disease also has reduced income of households of which 22–37% income is from dairy sale (Coppock 1994).

The questionnaire survey in agro-pastoral areas of Borena also showed that FMD-infected oxen remain off-plough for one season when outbreaks occur in cropping time, whereas heat-intolerant oxen are no longer used for traction. Thus, agro-pastoralists were compelled to borrow from their clan members freely or rent oxen or plough a day for owner of oxen for 1 day to work with them.

In conclusion, the present study indicated that foot-and-mouth disease is a highly prevalent livestock disease in Borana pastoral and agro-pastoral areas. Livestock mobility has been a strategy of Borana communities to mitigate shortage of pasture and water during prolonged dry seasons and drought periods and to access better livestock markets. Nevertheless, the livestock movement has been a major risk factor for spreading and frequent outbreak occurrences of FMD through mixing of different herds from different areas and subjecting cattle to movement stresses. Age and herd size categories have significantly associated with FMD seropositivity. The disease is an important factor causing temporary reduction of daily milk yield, abortion, loss of traction power, and death of calves during outbreaks. Permanent daily milk yield reductions, prolongation of calving interval, and vulnerability for drought are the consequences of developing heat-intolerance syndrome after recovery of proportion of cattle from acute-phase FMD infection.

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