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Review on the Epidemiology and Economic Impacts of Foot and Mouth Disease in Ethiopia

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Abstract: Foot-and-Mouth Disease (FMD) is the most contagious, acute and economically important transboundary animal disease affecting cloven-hoofed wild and domestic animals. It is caused by a virus that belongs to the genus aphthovirus of the family picornaviridae. There are seven recognized serotypes of FMD (O, A, C, Asia1, SAT1, SAT2 and SAT3) which differ in distribution across the world. It becomes endemic in Ethiopia and leads a great economic loss in the livestock sector. The seroprevalence, temporal, serotype and regional distribution, topotypes present, the direct and indirect economic impacts of FMD in Ethiopia are reviewed in this seminar paper. Foot and mouth disease outbreaks are occurred in Ethiopia every year and reported from all regions of the country. However, most of the outbreaks are reported from Central, Southern and Southeastern part of Ethiopia associated with the movement of animals for trade, agroecology, animal density and production system of the community. These outbreaks of FMD results in huge economic loss directly due to production losses and indirectly due to export restriction, control and prevention costs. Therefore, the epidemiology of the serotypes present should be studied in detail. This helps to develop a vaccine which is effective to all the serotypes present in Ethiopia. Control of animal movement should be strengthened to limit spreading of serotypes.

Key words: Distribution · Economic Impact · Ethiopia · Foot And Mouth Disease · Seroprevalence

INTRODUCTION

Livestock is the mainstay of the livelihood of the majority of Ethiopians, providing draught power for crop production, source of meat and milk and cash income for farmers. Cattle are the most important ruminant species in terms of their contributes to the national economy, providing 54 billion birr per annum. It contributes 45% of Ethiopia's agricultural Gross Domestic Product [1].

Foot and mouth disease (FMD) is a highly contagious viral disease of cloven-hoofed animals and is one of the most economically important diseases of livestock [2]. Because of the highly contagious nature of the virus and severity of economic impacts associated with the disease, FMD is the most important disease limiting the trade of animals and animal products throughout the world [3]. The most direct economic impact of FMD in endemic countries is the loss or reduced efficiency of production, which lowers farmers' income. The impact of reduced productivity of animals can be prolonged and diseases can have lasting effects on livestock output in a number of 'hiddenways such as delays in reproduction leading to fewer offspring, resulting in a reduced livestock population. At the local level, FMD reduces farmers' income and food availability for consumption. At the national level, FMD slows economic growth by severely limiting trade opportunities [4].

Heavy losses occur in small scale mixed farming systems when outbreaks affect draught oxenduring cropping season. FMD causes considerable losses of milk yield and weight among dairy and fattening stock, respectively. Milk is important in the diet of sub-Saharan pastoralists [5]. For example, Borena in southern Ethiopia and the Turkana in northwest Kenya, milk accounts for 55% and 62% of their diet, respectively [6]. At household level, milk is particularly a portion of important food for pastoralists' children [7, 8]. FMD's role in contributing to the suffering and death of livestock, particularly when affected during periods of drought or atan early age by limiting their access to feed and water, can be significant. Furthermore, the FMD status of a country is an important

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determinant of international trade in livestock products and the existence of FMD is an effective barrier from the markets with the highest pricesfor these products. It also causes significant losses in agriculture and tourism due to restriction on human movement [9].

Foot and mouth disease (FMD) have been eradicated by many wealthy nations but remains endemic in most of the world. When FMD outbreaks occur in disease free countries and zones that produce livestock for export the economic impact is clear to see; however, the impact of the disease in endemic countries is more controversial, particularly when compared to diseases that cause greater mortality. In recent times there has been increased consideration of FMD control in endemic countries. Knowledge of disease impact is essential when deciding on the level of expenditure that can be justified by a disease control programme [10].

Impact, together with the marginal returns for investing in disease control should be compared for different diseases, considering the cost of control measures and their likely effect. There is always a danger that conclusions on disease impact will be based on observations of affected individuals or farms, particularly if losses are dramatic. When considering the burden of a disease one must step back and consider its impact at the population level. To consider this as a function of losses in diseased individuals and the number affected is an over simplification; for livestock diseases and FMD in particular the full impact of a disease is far more complex. Although FMD is a disease of low mortality the frequency of outbreaks and the large numbers of animals and species affected in each outbreak results in a high and ongoing impact for FMD in endemic countries (Onono, *et al*., 2013). FMD endemic countries collectively contain three-quarters of the world's population [11, 12].

Livestock movements and trade play a key role in the spread of FMD. Hence, despite the significant economic losses involved [4], movement and trade restrictions at domestic and international level are fundamental to control [13]. Therefore, the objective of this study is to review the epidemiology and economic impact of FMD in Ethiopia.

Literature Review

Etiology: Foot and mouth disease virus (FMDV) was the first recognized viral pathogen and is the sole member of the genus Aphthovirus belonging to the Picornaviridae family. Seven immunologically different serotypes of the FMD virus are known, namely, A, O, C, Asia-1, South African Territories (SAT) -1, -2 and -3, which comprise more than 65 subtypes. Initially 2 types were named: type O for Oise in France and type A for Allemagne (Germany). Later type C was recognized as an additional type in Germany [14]. Some 30 years later, work at Pirbright laboratory in England demonstrated 3 novel serotypes of FMDV in sample collected from the FMD outbreak in South Africa and called SAT1, SAT2 and SAT3. The seventh serotype, that is, Asia 1 was first recognized in a sample from Pakistan [15].

In Ethiopia serotypes O, A, C and SAT2 were responsible for FMD outbreaks between 1974 and 2003 [16, 17], while serotypes O, A and C caused FMD outbreaks in cattle from 1957 to 1979 [18]. Antibodies to SAT2 were also detected in 1971 from cattle in North Omo, south-western Ethiopia [18, 19]. The recent study conducted byAyelet, *et al.* [20] on FMD samples collected between 1981 and 2007 throughout the country from different species of animals showed the presence of serotype O, A, C, SAT1 and SAT2.

Epidemiology

Transmission of FMDV: FMD is a directly transmitted disease with the predominant means of spread being direct or close contact between infected and susceptible animals. However, less frequently, transmission may occur indirectly through infection enabled by transporting healthy animals in vehicles which have previously transported infected livestock or through people handling healthy animals soon after being in contact with infected ones. Other mechanisms of local spread such as short-distance air borne transmission during outbreaks are suspected but unequivocal evidence is yet to be provided in this respect [21].

Much confusion has resulted from the finding in northern Europe that long-distance transmission has very rarely occurred through virus-containing aerosols being transported for many kilometers by air currents (i.e. air-borne spread). For this form of transmission to occur, a number of climatic and epidemiological circumstances need to prevail including a potent source of infection usually large piggeries suffering an explosive outbreak (because pigs excrete FMD virus more efficiently than other animals) high density of susceptible animals, cool temperature, often involving temperature inversion that prevents convection, gentle wind blowing in a constant direction and cattle as recipients of the aerosols, because cattle are more susceptible to aerosol infection than other species owing to their large inspiratory volume. In tropical/sub-tropical climates these requirements are seldom, if ever, met. A recent publication has postulated that aerosols may be derived from the skin of infected animals but that remains to be proven [22].

Among ruminants, cattle certainly, infection usually occurs via the respiratory tract and cattle may be infected by small numbers of infectious virions [21]. Conversely, large amounts of infectivity are required to cause infection by the oral route in cattle. In pigs by contrast, the oral route of infection is most common with infection resulting from the feeding of pigs with untreated swill being a common source of FMD outbreaks in Europe and Asia. There has only been one recorded case of this type of outbreak in southern Africa. It has been shown experimentally that animals infected with a FMD virus may excrete significant amounts of 'infectivity' for up to 3 days before obvious clinical signs develop and this has been considered epidemiologically important. Recently, however, it was shown in a series of experiments in cattle that the amounts of virus excreted before the development of clinical signs were insufficient to result in transmission; only about half a day after clinical signs developed did transmission occur [23].

Distribution of Foot and Mouth Disease Virus: The serotypes of FMDV are not distributed uniformly around the world. The serotype O, A and C viruses have had the widest distribution and have been responsible for outbreaks in Europe, America, Asia and Africa. However, the last reported outbreak due to serotype C FMDV was in Ethiopia during 2005 [24] and so serotype C viruses may no longer exist outside of laboratories. The SAT1-3 viruses are normally restricted to sub-Saharan Africa. The current global burden of FMDV infection is maintained within three continental reservoirs in Asia, Africa and South America, which can be further subdivided into seven major virus pools of infection [24, 25]. Each of these contains at least three serotypes of virus and because virus circulation is mainly within these regional reservoirs, strains have evolved which are specific to the region and which often (in the case of type A and SAT viruses) require tailored diagnostics and vaccines for control [26].

In Africa, the FMDV serotypes are not uniformly distributed and each serotype results in different epidemiological patterns. The cumulative incidence of FMDV serotypes show that six of the seven serotypes of FMD (O, A, C, SAT1, SAT2 and SAT3) have occurred in Africa [27, 28]. Based on the genetic characterization of the virus and antigenic relationship of FMDV in Africa, the virus distribution has been divided into three virus pools: namely, pool 4 covering East and North Africa, the predominance of serotypes A, O, SAT1 and SAT2; pool 5 restricted to West and northern Africa, with serotypes O, A, SAT1 and SAT2; and pool 6 restricted mainly to South Africa, with SAT1, SAT2 and SAT3 serotypes. Recent studies in East and southern Africa have revealed genetic differences between viruses isolated at different times and places [29, 30].

Periodically, there have been incursions of types SAT1 and SAT2 from Africa into the Middle East, probably as a result of animal movement [27, 28]. The most recent reports include the spread of viruses of the SAT2 serotype to Yemen in 1990, to Kuwait and Saudi Arabia in 2000 and to the Palestinian Autonomous Territories and Bahrain in 2012 [31].

FMD is one of the major endemic trans-boundary livestock diseases of socioeconomic importance in Ethiopia and in other parts of the globe. The sero-prevalence of FMD in different regions of Ethiopia as indicated by different studies accounted that, the prevalence in Borena zone of Oromia Regional State was 53.6% [32]. The other studies also indicated that the prevalence of FMD in Eastern zone of Tigray, Yeka (Addis Ababa) and Guji zone of Oromia Regional State was accounted 41.5%, 32.7% and 30% respectively. Moreover, other studies indicated that the prevalence in Bale zone was 21.9% [33] in Somali was 14.05% and in around Dessie zuria and Koombolcha area was 5.59% [34, 35].

Overall, the geographic and genetic clustering of FMDVs suggest ecological adaptation and/or separation, but in many endemically affected areas, the temporal and spatial dynamics of infection still need to be much more accurately determined by analysis of host animal distributions and contact opportunities, serosurveys to estimate weight of infection and use of the latest available techniques in genetic tracing of FMDV incursions into disease-free regions [36]. Generally, many of these factors are driven by climatic factors and socioeconomic changes centered on human behavior. Also, findings regarding the epidemiology of FMD involving wildlife within a particular ecosystem of Africa may not be applicable to other ecosystems because of ecological, host and viral variability differences [37]. Understanding of how these risk factors are clustered and associated in space and time may assist in effective disease control planning [38, 39].

Table 1: Samples received in 2005 by the World Reference Laboratory for Foot-and-Mouth Disease at Institute of AnimalHealth, Pirbright (UK)

Country	Type O	Type A	SAT 1	SAT 2	C
Botswana	-	-	8	-	-
Cameroon	25	3	-	54	-
Ethiopia	22	9	-	-	4
Kenya	-	-	1	-	-
Mali	3	-	-	-	-
Sudan	3	-	-	-	-
Togo	4	1	-	-	-
Zambia	-	-	2	-	-

Table 2: Distribution of Foot and mouth disease virus in different parts of Ethiopia

No	Area	Pervalence	Authors
1	Borena zone of Oromia	53.6%	[32]
2	Eastern zone of Tigray	41.5%	[33]
3	Yeka Addis Abeba	32.7%	[33]
4	Guji zone of Oromia	30%	[33]
5	Somalia region	14.05%	[34]
6	Dessie and Kombolcha	5.59%	[35]
7	South Nations Nationalities	5.6%	[40]
8	Afar	3.9%	[40]
9	Amhara	2.6%	[40]
10	Oromia	20.7%	[40]
11	Tigray	16.5%	[40]

Susceptible Livestock Population: FMD affects all cloven footed animals. Cattle, sheep, goats and pigs are the main domesticated species infected. The Water Buffalo (Bubalus bubalis) can become infected and may also transmit infection to other species *(www.reuters.com*). The World Organization for Anima Heath (OIE) code chapter on FMD includes the Camelidae as susceptible to FMD, similar to cattle, pigs, sheep and goat, but infection dynamics vary across a the species [41]. The two closely related camel species of Bactrian and dromedary camels posses noticeably different susceptibility to FMD virus [42]. Dromedary camels appeared to be susceptible with FMD serotype O, but they are unlikely to play any significant role in the natural epidemiology of FMD [43].

A wide range of wild cloven-footed animals contract FMD including deer and wild pigs. African buffalos play an important role in the maintenance of FMDV infection within National Parks in Uganda. Both SAT 1 and SAT 2 viruses were isolated and serological data indicate that it is also likely that FMDV serotypes O and SAT3 may be present in the buffalo population [44]. FMD is not considered zoonotic. Although clinical cases have been proven in human, these are extremely rare in relation to human exposure during outbreaks [45]. In the recent outbreaks during 2011 in different countries the majority of species affected are cattle, swine and sheep. Source of recent outbreak due to wild life species has been reported in South Africa and Namibia [41].

Pathogenesis: The pathogenesis of FMD has recently been reviewed in detail; these reviews not only reveal the complexity of FMD's pathogenesis but identify many gaps in the level of present understanding altogether 33 knowledge gaps are listed in the two papers, so a simple account of the pathogenesis of FMD is currently impossible [46]. The route of infection of cloven hoofed animals, other than in pigs where it is generally oral, is thought to be respiratory. In cattle the tissues most consistently infected during the pre viraemic phase of the disease are the epithelia of the nasopharynx and larynx [3]. It is therefore likely this is the primary replication site in ruminants. The tissues of the nasopharynx and FMD viruses have a complex relationship because not only does initial infection of ruminants take place there but the nasopharynx is also the site of viral persistence in chronically infected animals (so called carriers). Vesicle formation, cell lysis and significant inflammation occur at secondary replication sites (oral mucosa, skin of the horn hoof junction & skin of the teats) but not in the epithelium of the primary replication site. The cells which support viral replication are located in the basal layer of nasopharyngeal epithelium [46]. However, the mechanism by which viral replication occurs in the nasopharyngeal epithelium without causing cell lysis is unknown; nor is there an explanation as to why virus can be readily cultured from pharyngeal scrapings (obtained using probing cups) that, in recently infected animals, may contain high levels of antibody (mainly IgA) directed against the infecting virus. In pigs, delayed clearance of viral RNA from pharyngeal and lymphoid tissues has been observed but that has not been shown for infectious virus [46]. It is currently concluded that persistent infection of pigs does not occur or at least is not epidemiologically important. One or two days before the onset of clinical signs, cattle and pigs develop viraemia which may endure for up to 3 days.

The source of virus in the circulation remains a matter of conjecture (i.e. another knowledge gap) but viraemia ensures distribution of virus to all parts of the animal's body. In infected animals the vesicles which develop at the sites of secondary replication contain by far the highest levels of infectivity; however, high concentrations of virus can also be found in lymph nodes, myocardium, lungs and skin even in the absence of obvious lesions [47, 48, 49]. Virus may also accumulate in the spleen, liver, adrenals, myocardium, pancreas, thyroid and mammary glands. In mammary tissue and myocardium, however, viral replication occurs in secretory epithelial cells of the alveoli and myocytes respectively, resulting in clear microscopic lesions. There is an association between FMDV and dendritic cells in lymph nodes that results in localization of virus in germinal centres but the details of this association remain to be elucidated [3].

Epithelial lesions at secondary replication sites are initiated by infection of single cells in the stratum spinosum [50]. Following infection of these cells, bullae develop either by lysis of cells swollen as a result of ballooning degeneration and the release of intracellular

fluid, or by the formation of areas of focal intercellular oedema. The bullae then coalesce, rupture or, more rarely, the fluid seeps away resulting in desiccation of the lesion. Development of characteristic vesicular lesions in FMD is dependent on persistent local irritation or friction. In transplantation studies in guinea pigs it was shown that epithelium from predilection sites grafted to other body areas lost that predilection and *vice versa* [51].

In various parts of the world including South America, East Africa and India/Pakistan, a heat-intolerance syndrome (sometimes referred to as 'hairy panters') has been associated with previous infection or 'chronic FMD', with a putative endocrine-related pathogenesis. The limited information available on this syndrome has been reviewed recently indicating that the extent of the syndrome's association with FMD remains speculative [46].

Clinical Signs: FMD is characterized by fever, profuse salivation, vesicles in the mouth and on the feet and a drastic reduction in milk production; sudden death in young stock may occur (Radostits, *et al*. 2006). Asequel to FMD frequently described in African cattleis the complex of clinical signs referred to as 'heat-intolerance syndrome(HIS). The condition is characterized by intolerance to heat and affected animals show pronounced panting, increased body temperature and pulse rate during hot weather and abnormal hair growth [3, 46, 52, 53].

Diagnoses: The accurate diagnosis of FMDV infection is of utmost importance for the control and eradication of the disease in endemic regions. The initial diagnosis of FMD is normally based on clinical signs, but this can easily be confused with other vesicular diseases [54]. Hence, it is vital that the recognition of signs of the disease by the farmer is promptly conveyed to the relevant veterinary authorities to verify clinical symptoms and suspect samples should then be sent to the reference laboratory for confirmation. Rapid and precise data generated by laboratories provide vital support to FMD control and vaccination programs. However, in many African countries, samples received by the laboratory can be of poor quality due to an ineffective cold-chain and long transport periods. These factors make laboratory diagnosis challenging and it is evident that sub-Saharan Africa requires diagnostic tools that are fit for purpose in these settings to allow for rapid diagnosis and the appropriate measures taken for control.

Existing diagnostic techniques for the detection of FMD are mainly based on the following principles:

- The identification of the infectious agent by virus isolation involving propagation on susceptible cell cultures [55].
- The detection of viral antigen by ELISA systems using FMDV-specific antibody or capturing reagents [56, 57].
- Molecular detection of viral nucleic acid by reverse-transcription polymerase chain reaction (RT-PCR) and the genetic analysis of the nucleotide sequence, mostly of the VP1-coding region [58].
- Detection of FMDV specific antibody in animals previously exposed to the virus. The VNT is usually used as a confirmatory test for sera found positive by ELISA [59].

These techniques are primarily suited for well equipped laboratories which are usually either national or regional reference laboratories [24]. The virus cell culture system, for example, requires careful handling of specimens to prevent environmental and cross contamination, trained personnel and a BSL3 (biosecurity level 3) laboratory. The success of virus isolation is dependent on the sample quality and requires special transport conditions from the sampling point to the laboratory [55]. Both the solid-phase competition ELISA and the liquid phase blocking ELISA for serological detection of FMDV specific antibodies against structural proteins are relatively simple procedures and easily implementable in diagnostic laboratories in endemic regions [60, 61].

Prevention and Control: The existing vaccines against FMD consist of complete, chemically inactivated virions combined with an adjuvant [62]. The adjuvant used in the vaccine formulation has undeniably a huge effect on the efficacy and potency of the vaccine and has been reviewed elsewhere [62, 63].

Despite successful application in the developed world, the effective administration and optimal induction of protective immunity are hampered by several factors in developing countries. In addition to the vaccine-matching constraints that have been discussed in the previous section, some viruses are very difficult to adapt to cell culture, slowing the introduction of new vaccine strains, reducing vaccine yield and potentiating through prolonged passage the selection of undesirable antigenic changes [64, 65]. Vaccination does not induce sterile immunity and animals may still be able to infect non vaccinated animals and may also become persistently infected [62, 66].

The presence of contaminating non structural proteins in some vaccine formulations makes it problematic to distinguish between vaccinated and convalescent animals, impacting on the ability to export from FMD controlled regions. In addition, the hot climate in many African regions calls for vaccines with improved stability and which are less reliant on a cold chain. During production, the manufacturer also has to compensate for this instability by increasing the quantity of antigen per vaccine dose, which is expensive and reduces vaccine yield [66]. It is believed that unstable vaccines are less immunogenic due to degradation before and after inoculation. Therefore, FMD vaccines require frequent booster vaccinations in order to be effective. Lastly, the current vaccines are relatively expensive, especially for the small and subsistence farmer.

Vaccines used in the control of FMD in endemic regions are mostly used for mass prophylactic application. Such vaccines are multivalent to provide protection against multiple serotypes and should have a potency of at least 3 PD_{50} per dose [24]. Generally, prophylactic vaccines incorporate 146S particles combined with saponin alhydrogel or oil adjuvant [24]. Oil adjuvanted vaccines have been used successfully in FMD eradication campaigns in South America [13, 67, 68, 69]. A study evaluating different adjuvants for SAT vaccines has shown that a double water-in-oil-in-water adjuvant, ISA206, elicited protective antibody responses against SAT2 serotype in cattle [70]. Inactivated vaccines induce short lived immunity and it is recommended that naïve animals receive two initial vaccinations (a primary and secondary dose) 3-4 weeks apart, followed by re-vaccination every 4-6 months to prevent spread of disease within populations [70, 71].

However, in the African environment, this may differ for different manufacturers, depending on the potency of the vaccine and some manufacturers recommend five vaccinations per annum. There is a definite need to assess whether different adjuvants may enhance the duration of immunity against SAT antigens. For these reasons vaccination campaigns should be performed regularly, based on; - 1) the epidemiological circumstances and risk of disease spread, 2) the value and life expectancy of species and 3) the economic status of the country. The interval between vaccinations is critical to prevent a "window of susceptibility" and where the continuous or sporadic presence of virus in carrier animals is present [24]

The PCP is the strategy proposed by OIE and FAO to control and ultimately eradicate FMD from endemic countries. Different regions in sub-Saharan Africa are at different developmental stages of control and are thus facing unique challenges and priorities in terms of FMD control. In many African endemic countries, there are various knowledge gaps, such as disease occurrence and mechanisms of virus maintenance and transmission and therefore no routine vaccination campaigns are implemented (PCP Stage 1 countries). In other African endemic countries, even where surveillance is conducted to provide knowledge about high-risk populations, often implementation of effective, scheduled vaccination campaigns still does not take place (PCP Stage 2 countries). There are various reasons why governments do not subsidize FMD vaccines, leading to individuals needing to carry the cost and implement their own vaccine schedules. Additionally, individuals would need to source vaccines without knowledge of the current circulating strains in their region, leading to a poor vaccine match. This often leads to no or ineffective control in endemic African regions. The development of new vaccines against FMD in endemic countries in Africa should therefore take into account the ecosystem based synchronization as FMD control strategies employed in these regions [24].

Economic Impacts of FMD in Ethiopia: The impact of disease is not equal across all countries and livestock populations due to differences is not only FMD status, incidence and risk of incursion but also (a) the genetics of the national herd; (b) prevailing livestock management practices; (c) prevailing prices of livestock production inputs and outputs [72] and (d) their ability to supply livestock for export markets. Countries infected with FMD cannot trade live animals with FMD free countries. Typically the countries with the best meat prices are FMD free (i.e. EU, USA and Japan) [4] where prices are typically 50% higher [73]. The trade of livestock products is also restricted. If regular outbreaks occur only processed, tinned products can be exported to free countries; if FMD is effectively controlled with vaccination by a competent veterinary service able to detect outbreaks then deboned meat can be exported. Also, trade of fruit and vegetables can be affected by FMD status. Even if a country is FMD free, if it trades with FMD infected countries it will experience trade restrictions [4].

Ethiopia has the largest cattle population in Africa; in 2006 there were >43 million cattle with slightly fewer sheep and goats [74]. Large numbers of ruminants are exported; in the Ethiopian financial year (July 2010–July 2011), meat and livestock export revenue was $211.1 million, mostly from live animal trade with the Middle East (>472, 041 heads of live animals, 70% of which were cattle) [75].

However, production costs are high compared to other meat exporting nations, such as Australia or Brazil, limiting the potential for export market access regardless of FMD status. Difficulties in meeting export Sanitary and Phyto Sanitary standards results in greater numbers of livestock being purchased by traders for export through unofficial channels where prices are lower. Due to the presence of FMD and other OIE listed trade limiting diseases the export of live cattle and their products to FMD free countries is an unlikely prospect [74]. This raises the case for investment in veterinary service infrastructure to improve the control of all trade limiting diseases for international market access. Having an economy that is highly dependent on smallholder and animal based agriculture, including the widespread use of beasts of burden, the direct impacts of FMD are substantial in Ethiopia. In agro-pastoral areas, FMD infected oxen are unable to work for the entire season when affected at cropping time. Pastoralists are particularly vulnerable to FMD as their living depends entirely on their livestock [76]. By reducing the supply of milk FMD impacts on food security, particularly when outbreaks occur during times of the year when other food sources are limited and dependency upon milk is greatest [53].

Direct Economic Impact

Visible Losses: Production losses due directly to FMD include reduced milk production [76], affecting both the humans and calves that depend on it. This can account for 33% of losses in endemic settings [77]. Not only crucial to commercial dairy operations, milk is an important source of nutrition for many pastoralists, particularly for children [53]. Although FMD typically has a short term affect on an animal's health, chronic FMD typically reduces milk yields by 80% [53, 76].

Livestock growth rates are also suppressed and mortality amongst young stock is typically 2-3% [78] although occasionally much higher [53, 79]. Loss of traction power where draught animals are used is particularly damaging if it occurs during harvest [80, 81]. FMD can result in abortion, the cost of which is high as the farmer will have to pay to keep the cow without it producing anything for another year or more, or cull the animal. Visible production losses are most prominent in pigs in intensive production systems and dairy cattle. These two systems are key sources of animal protein in poor countries and their importance continues to grow [82].

Invisible Losses: A compound effect of fertility problems due to abortion and reduced conception rates is a need to have a greater proportion of breeding animals in a population for a given output. This invisible loss means that for every kilo of meat or milk produced there is an additional fixed cost to maintain more breeding stock [72].

Indirect Economic Impacts

Control Costs: The cost of control carried out by the state veterinary services (e.g. vaccination, outbreak control, culling and compensation) is borne by the tax payer. In addition significant amounts are spent by the private sector. These costs are enormous with an estimated 2.35 billion doses of FMD vaccine administered in the world every year [83] at a cost of $0.4-3 or occasionally $9 per dose including delivery and application [13, 53, 84]. Due to the short duration of immunity induced by FMD vaccines, ongoing control programmes vaccinate cattle one to five times a year and sheep and goats once a year; limiting resources available to combat other diseases.

Wildlife is sometimes kept out of FMD free zones with fencing which is both costly and affects wildlife ecology [85]. Even if a country is FMD free there are ongoing costs due to efforts to prevent disease introduction, including import controls and sometimes vaccination. In addition, maintaining FMD early detection and control capability, including vaccine banks, is costly. Other costs include FMD related research and permanent restrictions on the livestock sector (such as post movement standstills and bans on feeding swill). The cost of surveillance are significant, including proving disease freedom after an outbreak; >3 million serum samples were tested after the UK 2001 outbreak [59] in addition to approximately 3.5 million sera tested during the outbreak.

Market Access: Countries infected with FMD cannot trade live animals with FMD free countries. Typically the countries with the best meat prices are FMD free (i.e. EU, USA and Japan) [4] where prices are typically 50% higher [73]. The trade of livestock products is also restricted. If regular outbreaks occur only processed, tinned products can be exported to free countries; if FMD is effectively controlled with vaccination by a competent veterinary service able to detect outbreaks then deboned meat can be exported [4]. Even if a country is FMD free, if it trades with FMD infected countries it will experience trade restrictions [4].

Table 3: Different impacts of foot and mouth disease

Direct impacts	Indirect impacts		
Visible losses [76]	Invisible losses [72]	Additional costs [59]	Revenues forgone [4]
Loss of milk production	Fertility problem	Vaccine and Vaccine delivery	Use of suboptimal breeds
Loss of draft power	Change in herd structure	Movement control	
Loss of weight gain	Delay in sale of animals		
	and / or animal products	Diagnostic tests	Denied access to markets both local and international
Dead animals		Culled animals	

FMD is highly contagious, affects many species and is not easily contained within one farm or one population. The presence of FMD creates problems to all livestock owners who are connected to populations where FMD is present. This connection may be geographical or via market chains. Therefore, FMD creates what economists call externalities. If an outbreak occurs because one farmer did not protect his animals others may suffer. Conversely when a livestock owner protects their animals from FMD infection they will generate a positive externality as they are less likely to become infected and transmit the pathogen to other farms [81].

The positive and negative impacts of FMD on different players in a dynamic market are complex; when FMD outbreaks create increased demand for vaccines, pharmaceutical companies benefit. When a free country experiences an outbreak poultry prices may increase due to public reluctance to consume products from FMD susceptible species, particularly if through ignorance there is a reluctance to eat products from FMD vaccinated animals. Where externalities exist there is a need for public investment as one farmer's actions create costs and benefits for others. These externalities are not equally shared amongst different livestock sectors with production losses being particularly severe for commercial dairy farms. Even when individuals reap positive returns from successful FMD control there is less of an incentive to undertake such a programme if there is a high risk of reinfection from those that do not attempt FMD control [81]. Effective control of infectious diseases with vaccination often requires high levels of vaccine coverage to develop herd immunity; with a sufficient proportion of immune animals outbreaks will tend to die out due to a lack of susceptible hosts. If left in the hands of individual farmers a lack of action by those less visibly affected by FMD will result in pockets where control is poor, undermining the entire control programme. Impacts on the livestock producer have ripple effects along the entire market chain, impacting on other players, such as markets, abattoirs and dairies to mention a few [86].

FMD control can be both an externality, with benefits not captured by the market and a regional or global public good, as the reduction in risk of FMD is also experienced by countries other than ones controlling the disease; external funding and cooperation is therefore required [84].

CONCLUSION AND RECOMMENDATIONS

Foot and mouth disease (FMD) is a highly contagious viral disease of cloven-footed animals and is one of the most important economic diseases of livestock. The disease is characterized by fever and vesicular eruptions in the mouth, on the feet and teats. It is caused by a virus of the genus Aphthovirus, in the family Picornaviridae, of which there are seven immuno-logically district serotypes; O, A, C, South African Territories (SAT) 1, SAT2, SAT3 and Asia1. FMD is the most important disease limiting the trade of animals and animal products throughout the world.FMD is one of the major endemic trans-boundary livestock diseases of socioeconomic importance in Ethiopia. The most direct economic impact of FMD in endemic countries is the loss or reduced efficiency of production, which lowers farmers' income. The impact of reduced productivity of animals can be prolonged and diseases can have lasting effects on live- stock output in a number of ‘hidden’ ways such as delays in reproduction leading to fewer offspring, resulting in a reduced livestock population. At the local level, FMD reduces farmers' income and food availability for consumption.. From the above conclusion the following recommendations are forwarded:

- Strict control program should be applied to mitigate economic losses.
- There is a lack of studies that examine the full economic cost of FMD in endemic countries particularly considering indirect losses at the national level; therefore, further studies on examining the full economic cost of FMD in endemic countries particularly considering indirect losses at the national level should be performed.

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