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REGULAR ARTICLES

Quantifying production losses associated with foot and mouth disease outbreaks on large-scale dairy farms in Rift valley, Kenya

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Abstract

Foot and Mouth Disease (FMD) is a contagious viral disease to which dairy cattle are highly susceptible. An outbreak of FMD in a dairy herds can cause a drop in milk yield, increase mastitis infections, and force culling. These production losses can be substantial, but farmers undervalue the magnitude of the loss that they incur. The study quantified the association of FMD outbreaks with milk yield, mastitis incidences, and culling rates. The data was from three large-scale dairy farms with a recent history (2008 to 2018) of FMD outbreaks in a region endemic for the prevalence of serotype C of the FMD virus since the mid-1980s in the Rift valley of Kenya. A total of 507 cows were monitored for three consecutive periods of six weeks before, during, and after FMD outbreaks. Relative to the period before and after the disease outbreak, production losses were marked during the outbreak. A disease outbreak was associated with up to 4.7% of the cows drying off ($n=24$) and milk production dropped by 16.1%. The incidence of mastitis increased from 5.4% to 21.5% (OR = 3.31, CI = 2.27, 4.83) and culling rates increased from 0.59% to 3.8% (OR = 6.71, CI = 1.99, 22.58).

Keywords Foot and Mouth Disease · Dairy Cow · Kenya · Rift Valley

Introduction

Foot and Mouth Disease (FMD) is a contagious viral disease that affects dairy cattle and cloven-hoofed ruminants (Pattnaik et al. 2012). The first symptoms in cattle are fever, dullness, anorexia, and a decrease in milk yield production. These symptoms are always accompanied by profuse salivation and drooling, severe nasal discharge, foot kicking or lameness, and vesicles on the lips and tongue (Rout et al. 2012). FMD has been investigated in various nations since the sixteenth century, and it has a negative influence on livestock productivity in places where the illness is endemic. An FMD outbreak typically lasts three weeks to one month. Production losses are varied during this time period, depending on animal genetics and management. The disease has been linked to production losses in dairy cattle due to a decrease in milk yield, culling, calf mortality, reduced fertility, or increased susceptibility to mastitis (Truong et al. 2018). Additional indirect expenditures associated with the FMD outbreak include sanitary measures and disease diagnosis. FMD diagnosis must be performed in specialized laboratories. ELISA identification of specific FMD antigens in epithelial tissue suspensions is typically used in the laboratory, and is frequently complemented by contemporaneous cell culture isolation. Trade restrictions are imposed as a result of the onset of FMD (Hayama et al. 2012). FMD's annual global impact has been calculated at $11 billion USD. Furthermore, an FMD outbreak has ramifications for agricultural households' and consumers' food nutrition and income security, as well as the threat to food supplies, security, and safety (Stenfeld et al. 2016).

Dairy production is a significant economic activity in Kenya, contributing to household security in terms of food, nutrition, income, and soil fertility. An FMD outbreak could lead to the company's demise due to significant direct and indirect production losses. Farmers, on the other hand, are prone to underestimate the degree of the loss, which could result in inefficient health response efforts.

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Materials and methods

The symptoms of foot and mouth disease are straightforward to be detected. These symptoms included an abnormally large amount of saliva production, sores on the teats and the hooves, and blisters around the mouth. A veterinary PCR test was ultimately used to confirm the presence of FMD. Cows that were considered under risk were the cows that were present in the herds during the outbreak of FMD. Mastitis was identified on the farms either through visual inspection of the udder for signs of inflammation and swelling or through analysis of the milk's color, smell, and production level; all these signs were later confirmed by using the Somatic Cell Count Penside Kit. When the SSC level in a cow exceeded 200,000, it was declared positive for mastitis. The cumulative number of cases recorded during the epidemic for cows diagnosed with mastitis for two or more consecutive weeks within or across periods represents the overall number of cases observed throughout the period. The three large-scale farms of the three breeds (Ayrshire, Guernsey, Friesian) which represent the herd in this study. The herd refers to the total numbers of cows that were in the farm before, during and after FMD outbreak. The farm effect was determined by taking into account the farm severely impacted during the FMD outbreak among the three farms selected for this particular research. The breed's impact is determined by which breed was most severely afflicted or affected the most among the three breeds (Ayrshire, Guernsey, Friesian) during the outbreak. Milk production is partitioned into three periods (three weeks before, during, and three weeks after the FMD outbreak). Milk production at herds level was measured for six weeks before the outbreak of FMD, six weeks during FMD, and six weeks after recovery from FMD from daily milk production daily records.

Cows sold (voluntary culling) were based on farm management, but cow's death (involuntary culling) were based on farm management's failure to do routine health checks on the cows, which resulted in the death of some cows in the herds.

Study site

The study was conducted in Nakuru County within the Kenyan Rift valley. It has an altitude of 1,800 m above sea level, with temperatures ranging between 17.5 ˚C and 22 ˚C on average but can drop during the cold season. The average annual rainfall in the area is up to 895 mm (en.climate-date.org). Nakuru County was selected because it has been an endemic region for the prevalence of serotype C of the FMD virus since the mid-1980s and has a history of FMD outbreaks in recent years. Moreover, its geographical location also significantly influences the Maasai nomads that pass through the region once a year.

Data collection

Within Nakuru County, three large-scale dairy farms with regular herds daily recoding were chosen for this study. These three farms were selected due to the availability of detailed records for individual animals before, during, and after the FMD outbreak. In three farms, 507 exotic cows (Frisian, Ayrshire, Guernsey) were present before the outbreak. in farm 1, the number of cows were 205 (Frisian 40%, Ayrshire 20%, Guernsey 20%), farm 2, 130 cows (Frisian 25%, Ayrshire 30%, Guernsey 45%), and in farm 3, 172 (Frisian 44%, Ayrshire 26%, Guernsey 30%). When the FMD outbreak occurred, herd-level data was taken from each farm, including the number of positive and negative cases. The outbreaks occurred on the selected farms in 2014, 2015, and 2016. To account for the typical duration of the outbreak, the FMD outbreak was divided into three phases: six weeks before, six weeks during, and six weeks following. The information gathered included milk yield, mastitis incidents, the number of culled animals, and the associated financial implications.

Data processing and analysis

Data on milk production was partitioned into three distinct groups based on quartiles of production levels. The groups were: high producers with more than 75 kg/cow/week, average producers ranging from 23 to 75 kg/cow/week, and low producers with less than 23 kg/cow/week. This allowed us not only to monitor the production trends of the three groups of animals but also to relate them with the proportion of cows drying off due to the FMD outbreak. Hence, for ease of reporting for each period, we recorded cows at risk as the number of cows exposed to the disease within each period (before, during, and after). Distinct cases as the number of different cows that tested positive within each period. Repeated mastitis infections are the number of cows that tested positive for mastitis for two or more weeks within or across periods. Cumulative cases are the total number of positive cases reported within each period. Milk production and reported culled cases were used to compute economic losses.

We quantified the effect of the FMD outbreak on herd milk production using a general linear model (PROC GLM), fitting the period of a disease outbreak (six weeks before, during, and after), farm, and breed as independent variables to explain milk production at the herd level. The odds of mastitis occurrence and culling due to an FMD outbreak were assessed using logistic regression (PROC LOGISTIC), with the predictor being the periods (before, during, and after). The tests carried out in this study used a 0.05 level of significance. Descriptive statistics were used to compute economic losses.

Results

Effect of FMD outbreak on herd milk production

Table 1 shows effect of outbreak, farm and breed on herd milk production measured on weekly basis. The milk production before the outbreak (111,466.52 ± 2201.21 kg) dropped by 16.1% during the outbreak (93,476.32 ± 2181.65) and by 7.6% after the outbreak (102,952.05 ± 1993.02). Outbreak and farm had significant effect ($p < 0.05$). Farm 1 was significantly different from farm 2 and 3 respectively. while breed did not ($p > 0.05$) have effect on herd milk production.

Table 2 reports milk production change due to FMD outbreak for cows of different production levels. High milk producing cows reduced significantly milk production during the outbreak (61.7 ± 008 kg) while production showed an increasing trend after (76.0 ± 008 kg) the outbreak compared to before (98.5 ± 008 kg). Milk production for the average producers dropped (from 32 ± 45 kg) to 19.16 (± 0.36) Kg during and 24.49 (± 0.38) Kg after FMD outbreak. Incidences of cows drying off was higher during (9.4% and 4.8%) for average and low producers respectively than before and after (2.7% and 3.1% respectively).

Effect of FMD outbreak on mastitis

Mastitis incidences increased from 5.4% before the outbreak to 21.5% (OR = 3.31, CI = 2.27, 4.83) during the outbreak then decreased to 2.5% after the outbreak (OR = 0.33, CI = 0.17, 0.64). The period during FMD occurrences was significantly different from the period before FMD outbreak ($P < 0.05$), where the cases of mastitis were higher during the outbreak compared to the period before FMD. while the period after the outbreak was also significantly different in regards to the period prior the outbreak ($P < 0.05$) where the mastitis cases were higher than the period before the outbreak (Table 3).

Effect of Foot and Mouth Disease outbreaks on culling

Farms purchased more cows before ($n = 4$) and after ($n = 5$) than during ($n = 1$) FMD outbreak. Among the cows present in the herd during outbreak, more cows dried off ($n = 24$) and were culled ($n = 19$) during the outbreak than before. Three pathways to culling were observed through cows drying off during the outbreak ($n = 9$) and through direct exit due to milk production decrease ($n = 10$) and through mastitis infections ($n = 4$).

Table 1 Effect of FMD outbreak on herd milk production

Period	Cows at risk (n)	AWMY*	MY* Mean ± SE**	Farm effect	Breed effect
Before	464	240.2	111,466.52 ± 2201.21[a]	3755.02***	0.45
During	436	231.9	93,476.32 ± 2181.65[b]	3452.12**	
After	433	215.9	102,952.05 ± 1993.02[c]	3351.11**	

** *AWMY*: Average weekly milk yield/cow, *MY**: Milk Yield, *Means with different letter superscript differ at 0.05 significance level*** $p < 0.0001$

Table 2 Milk production level before, during and after FMD of High, Average and Low production cows

Production level	Period	Number of cows	% Drying off	Milk/Cow Mean ± SE
High (> 75.5 kg/week)	Before	170	0	98.54 ± 0.008[a]
	During	170	0	61.67 ± 0.008[b]
	After	170	0	75.98 ± 0.008[c]
Average (23–75 kg/week)	Before	64	0	32.66 ± 0.38[a]
	During	58	9.4	19.16 ± 0.36[b]
	After	51	12.1	24.49 ± 0.38[c]
Low (< 22 kg/week)	Before	228	0	21.09 ± 0.13[a]
	During	217	4.8	11.78 ± 0.13[b]
	After	210	7.9	19.33 ± 0.13[c]

Table 3 Mastitis incidences before, during and after FMD outbreak

Period	Cows at risk (n)	Cows infected [a]	N	Prevalence (%)	Odds ratio (95% CI)
Before	504	Distinct cases	27	5.35	Reference
	504	Recurring infection	6	1.19	
	3024	Cumulative cases (cattle-week)	36	1.19	
During	483	Distinct cases	96	19.8	3.31 (2.27, 4.83) **
	483	Recurring infection	10	2.07	
	2898	Cumulative cases (cattle-week)	106	3.66	
After	480	Distinct cases	12	2.50	0.33 (0.17, 0.64) *
	480	Recurring infection	3	0.63	
	2880	Cumulative cases (cattle-week)	12	0.42	

*, **, *** Indicate level of significance at 0.05, 0.01 and 0.001 respectively *CI*, confidence interval. [a] refers to different levels at which infection rate was measured

Table 4 Culling rate before, during and after FMD outbreak

Period	Cows at risk (n)	Cows culled (n)	Herd culling rate (%)	Odd ratio (95% CI)
Before	507	3	0.59	Reference
During	504	19	3.76	7.45 (3.84, 14.46) ***
After	483	3	0.61	2.57 (1.26, 5.25)

*, **, *** Indicate level of significance at 0.05, 0.01 and 0.001 respectively *CI*, confidence interval

Result in Table 4 show that culling rate during FMD outbreak was higher compared to the period before FMD (O.R:7.45; 3.84–14.46), it was also higher after the outbreak than the period before FMD (O.R: 2.57; 1.26–5.25). Culling rate was significantly higher ($p < 0.01$) during the outbreak than the period before. Although the odds of culling were 2.57 times higher after the outbreak than before, the difference was not found significant ($p > 0.05$).

Economic losses due to FMD outbreak in the selected commercial farms

Economic losses included two components milk production and culled cows as indicated in Table 5 below. Only 3 cows were culled before and after outbreak, while 19 cows were during the outbreak of FMD, leading to a 210,000 Ksh loss considering sale of 1 cow to cost 70,000 KSh. During the outbreak losses increased to 1.4 Million KSh for culled cows and 629,667.5 KSh for decrease in milk production. Losses for milk production reduced to 298,007.5 KSh after the outbreak.

Discussion

Effect of FMD outbreak on milk production

The study evaluated milk production, cows exiting the herd, and mastitis incidence in three successive periods of six weeks before, during, and after the occurrence of the FMD outbreak between 2008 and 2018 of three large-scale dairy farms with 507 total number dairy cows. The goal was to find out how much farmers may be underestimating when it comes to production loss.

This study found that milk production of the total heard (Frisian, Ayrshire, Guernsey) in the three farms combine dropped by 16% during the FMD outbreak. This reduction in milk production was expected because during the FMD outbreak, the affected cows, especially those in mid and late lactation, dry off (Singh et al. 2013). Furthermore, we found that average and low milk-producing cows have a higher drying off rate (12 and 8%, respectively) than high-producing cows that only recorded a drop-in milk yield. A milk reduction due to acute FMD can arise from two situations. First, a lactating cow affected by FMD reduces or stops milk production during the period of infection. This is because, in

Table 5 Economic losses due to FMD outbreak in the selected farms

Loss item	Before		During		After	
	Quantity	Value (KSh)	Quantity	Value (KSh)	Quantity	Value (KSh)
Milk (Kg)	0	0	17,990.5	629,667.5	8514.5	298,007.5
Culled cows (n)	3	210,000	19	1,330,000	3	210,000
Total loss (KSh)		210,000		1,959,667.5		508,007.5
Loss in USD		1981.1		18,487.4		4,792.5

that period, infected cows stop eating due to the pain caused by the sores on the mouth and the lip as well as the tongue, reducing feed and water intake, hence lowering energy levels, impacting negatively on milk production, lactating cows also dry off due to the stress caused by FMD (Ferrari et al. 2014). The current study recorded an overall reduction in milk production during the outbreak period, with a higher rate of cows drying off during the outbreak.

Secondly, more cows ($n = 20$) exited the herd (Frisian, Ayrshire, Guernsey) in the three farms during the outbreak and milk was discarded from quarantined cows during the period of FMD infection (Nampanya et al. 2015). If the FMD outbreak in the farm lasted more than four weeks, it could lead to an increase in milk loss in the herd if the necessary biosecurity measures were not implemented. A study conducted in Ethiopia reported a 75% loss in daily milk production during an outbreak of FMD that lasted longer than 4 weeks (33.6 days).

Farmers experience large economic losses during FMD outbreaks because to a drop-in milk yield, which affects milk sales (Baluka 2016). These milk sales have a negative impact on the farmer's ability to make a profit. The decrease in milk production of 16% during an FMD outbreak suggests a large loss of KES 113,320 per animal when milk is sold at a price of 40 KES per liter during outbreaks that occur in the dry season. This evidence is in line with the findings that were reported by Ansari-Lari et al. (2017), who discovered a decrease in milk output of approximately seventy percent during the FMD outbreak in Iran. The loss in milk output could lead to a significant drop in household income, particularly in rural areas where the majority of people make their living from milk production. This would be especially problematic in areas where milk production is the primary source of income. According to Ferrari et al. (2014), even though the majority of mature cows recover within three to four weeks after an epidemic, it may take longer for livestock output to restore to its normal level. The farmer will be forced to spend more money on feeding and treatment expenses, but he or she will not profit from the sick cows.

Effect of FMD outbreak on mastitis incidences

The odds of having mastitis were higher (OR: 3.31, CI: 2.3–4.8) and lower (OR: 0.33, C.I.: 0.2–0.7) during and after the FMD outbreak, respectively (Reference). Mastitis incidences were higher before FMD than they were after the outbreak, probably because farmers failed to distinguish the distinct signs of mastitis due to their similarities with FMD (Yoon et al. 2012; Chakraborty et al. 2014). These findings were published in Yoon et al. 2012 and Chakraborty et al. 2014. We identified an overall mastitis prevalence of 19.8% during the FMD outbreak, and 20% of cows that were being processed for exit tested positive for mastitis. This is because FMD causes lesions on the teats, which may make them more susceptible to bacterial infection in the future (Lyons et al. 2015). Coagulase-negative According to De Vliegher et al. (2012), staphylococci are the most common cause of inflammatory illness and subclinical mastitis in dairy cattle. Staphylococcus aureus and environmental pathogens account for only a tiny fraction of instances of inflammatory illness and subclinical mastitis. Mastitis is frequently associated with foot and mouth disease because the mammary gland tissue is the sole area where the FMD virus can survive for 3–7 weeks. As a result, vesicles form in the teats, and when the teat orifice is involved, severe mastitis develops (Sharma 2010). Furthermore, bacterial mammary gland infection raises the somatic cell count in cow's milk.

Mastitis' economic repercussions are not limited to milk production at the farm level, but can extend further. During the outbreak, 20% of cows were diagnosed positive for mastitis 17% of dry cows tested positive for mastitis. This reinforces earlier research findings of a strong link between mastitis and FMD, which could be a justification for culling (Jingar et al. 2014; Lyons et al. 2015; Reshi et al. 2015). Sinha et al. (2014) did a study on the economic losses caused by mastitis in dairy and discovered that the disease is responsible for 48.53% of milk losses. Sharma et al. (2016) observed that mastitis lowered milk production by up to 40.77% because mastitis impacts both milk quality and quantity.

Effects of FMD outbreak on culling rates

Cows exit the dairy herd for a variety of reasons, including death, sale, disease, infertility, or low production. In this study, the proportion of cows that exited the herd during FMD was higher (3.76%) than before the outbreak (1%). The exits occurred through three direct pathways: productive cows (50%), dry cows (35%) and mastitis positive cows (15%). This finding is consistent with the findings of Lyons et al. (2015), who reported that during the FMD outbreak, the total number of animals that exited the herd was 166% higher than the period after, with 76 leaving for a variety of reasons, including disease, death, or low production. Reduced fertility could also be the result of mastitis, which is an illness that affects the mammary glands of cows and can cause ovarian follicular responses to be impaired, leading to decreased fertility. because of this, dairy cows are good candidates for being slaughtered.

The variation of culling (voluntary or involuntary) in farms is based on the decision-making of farm management in terms of voluntary and the delay of regular checkup of the cows' health, with regard to involuntary culling (Booth et al. 2004). The epidemiological features of foot and mouth disease strain determine optimal culling. (Tildesley et al. 2009). In the event of culling that is associated with foot and mouth disease, farmers encounter economic losses. According to Gohin and Rault (2013), the economic burden of foot and mouth disease in Brittany raised the debt by 500.92 million euros due to the culling of sick animals.

The effect of foot and mouth disease on culling was observed even after the FMD outbreak, because the percentage of cows that exited after the outbreak was almost half of the cows that exited the herd during FMD (Table 4). This can explain the long-term effects of the disease, which include severe lameness caused by FMD, poor reproductive performances and death. Furthermore, there is a ban on the sale of meat or dairy products during the outbreak that may cause the farmers to postpone culling and only sell after the outbreak (Olechnowicz et al. 2011). Knight-Jones and Rushton (2013) indicated that during FMD outbreaks farmers are often confronted with the decision to cull the cows of low fertility. It can be costly to the farmer to replace the cows that were culled for any of the reasons listed above.

Conclusions

a. Milk production drops substantially during an outbreak of Foot and Mouth Disease and recovery is slow following the outbreak.
b. Mastitis incidences increase during an outbreak of Foot and Mouth Disease.
c. Cows exits, both voluntary and involuntary increases during and after the outbreak of FMD

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable

Declarations

Consent for participation Not applicable

Consent to publish Not applicable

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