Dynamical Analysis of Transmission Model of the Cattle Foot-and-Mouth Disease

Feng Li[1,2], Zhen Jin[3,*], Juan Zhang[3], Michael Y. Li[4] and Youming Wang[5]

[1] *North University of China, Taiyuan, Shanxi 038507, China.*
[2] *Shanxi Agricultural University, Taigu, Shanxi 030801, China.*
[3] *Complex Systems Research Center, Shanxi University, Taiyuan, Shanxi 030006, China.*
[4] *The Laboratory of Animal Epidemiological Surveillance, China Animal Health & Epidemiology Center, Qingdao, Shangdong 266032, China.*
[5] *Department of Mathematics, University of Alberta, Edmonton, Alberta, T6G 2GL, Canada.*

Abstract. The epidemic of foot-and-mouth disease (FMD) in cattle remains particular concern in many countries or areas. The epidemic can spread by direct contact with the carrier and symptomatic animals, as well as indirect contact with the contaminated environment. The outbreak of FMD indicates that the infection initially spreads through the farm before spreading between farms. In this paper, considering the cattle population, we establish a dynamical model of FMD with two patches: within-farm and outside-farm, and give the formulae of the basic reproduction number R_0. By constructing the Lyapunov function, we prove the disease-free equilibrium is globally asymptotically stable when $R_0 < 1$, and that of the unique endemic equilibrium when $R_0 > 1$. By numerical simulations, we confirm the global stability of equilibria. In addition, by carrying out the sensitivity analysis of the basic reproduction number on some parameters, we reach the conclusion that vaccination, quarantining or removing of the carrier and disinfection are the useful control measures for FMD at the large-scale cattle farm.

---

*Corresponding author. *Email address:* `jinzhn@263.net` (Z. Jin)

1   Introduction

Foot and mouth disease (FMD) was the first disease which the World Organization for Animal Health (OIE) established official status recognition. It is a highly contagious and economically devastating viral disease of cloven-hoofed animals, such as cattle, pigs, sheep, goats and deer. The typical clinical sign is the occurrence of blisters (or vesicles) on the muzzle, tongue, lips, mouth, between the toes, above the hooves, teats and potential pressure points on the skin. The earliest written records of FMD was in 1546, but the pathogenic agent was not discovered by two former pupils of Robert Koch until the late nineteenth century. FMD is notorious as a perennial threat to ruminants for centuries. FMD outbreaks have occurred in most countries containing the FMD virus (FMDV) susceptible animals. Australia, New Zealand and Indonesia, Central and North America and Western Europe are currently free of FMD. However, FMD is still prevalent in Africa, the Middle East, Asia, and South America. Depending on the epidemiological situation of the FMD, the control strategy is implemented varying from country to country. The FMD free countries or areas prefer to control epidemics by slaughtering infected animals, rather than using vaccination as the control strategy. In many FMD infected countries or areas, vaccination remains an alterative part of an effective control strategy, such as in China, Mongolia, Korea and India. But the decision on whether or not to use vaccination lies in national authorities [25].

FMD is transmitted by multiple routs. Susceptible animals may become infected by contact with infected animals or contaminated objects, and indirect contact with an infected environment [20, 29]. In addition, animals are considered to be carriers of FMDV if the virus or viral genome can still be isolated from the esophageal pharyngeal fluid more than 28 days after infection. The carrier state in the cattle usually does not persist for more than 6 months, although in a small proportion it may last up to 3 years. The carrier animals hold a high level of neutralizing antibody within their sera, but retain the live virus, meanwhile, excrete low-level of FMDV [16, 30]. A study quantifies the transmission rate of FMDV infection from carriers to susceptible animals [33]. The carrier animals are one of the possible sources, which may be occasional cause of new outbreaks [32, 34]. Therefore the model of FMD transmission should take into account the carriers, especially in many countries which use vaccination against FMD.

Dynamic models play the significant role in estimating transmission size and evaluating transmission intensity as well as the control measures. Numerous models studied the mechanisms of the disease transmission between farms, and the epidemiological unit of analysis was the individual farm. These models made predictions with different types of control measures that were taken prevent the epidemic from spreading [2, 5, 6, 8, 10, 11, 14, 21–23, 28]. These models were based on the unit of the farm, which considered that all the animals at the farm are infected when one case is found, as a consequence, many uninfected animals were culling. In addition, the infection will initially spread through the farm before spreading between farms [15, 26]. The within-farm transmission of FMD is module simulating a farm outbreak and modeled local control