Modeling FMD Viral Concentrations in Milk from Infected but Undetected Dairy Herds

Background:

In most diseases, there is a period of time when an individual is infected and able to spread the disease prior to showing clinical signs. This time period creates high risk for disease spread as animals and animal products may move while infected, prior to detection. As part of continuity of business planning efforts and development of the Secure Milk Supply Plan, two Pro-active Risk Assessments were conducted[1], focusing on the risk of moving raw milk from dairy herds that are infected with Foot and Mouth Disease virus (FMDv) but have not been detected.

To evaluate the risk of spreading FMD through raw milk movement, it is important to estimate the potential viral concentration in that milk. Studies have evaluated milk FMD viral concentrations from known infected cows and viral concentrations in bulk milk tank samples from infected herds. However, there is very little information on FMD viral concentrations in bulk milk tank samples early in the infection, before detection occurs. Furthermore, there are no studies examining how viral concentrations may change based on different U.S. dairy herd sizes. To address these data gaps and inform the risk assessments, a disease transmission model was developed to predict FMD viral concentrations in milk at the time of clinical detection under scenarios relevant to U.S. production systems.

Methods:

A stochastic disease transmission model was developed to simulate the spread of FMDv within a dairy herd (100, 500 and 1,000 head), estimating the number of cows in each disease state over time and the mean log FMDv titer within the bulk milk tank. Table 2 outlines the model parameters. Based on expert opinion, it was assumed that disease detection would occur when 5-10% of the herd are showing clinical signs. Model outputs included the number of cows in each disease state per time stamp, amount of milk in the bulk tank, FMD viral titer in the bulk tank and days to detection based on the percentage of cows showing clinical signs.

For each herd size, the number of days to detection post-infection at the 5 & 10% detection levels with mean (5th and 95th percentiles) are as follows:

Herd Size	5%	10%
100-cow herd:	4.8 days (3-8)	5.2 days (4-8)
500-cow herd:	5.2 days (4-8)	5.7 days (4-9)
1,000-cow herd:	5.4 days (4-8)	5.9 days (4-9)

Figure 1 shows how cows within a 1,000-cow dairy herd might progress from susceptible (uninfected), to latent (infected but not yet infectious), to preclinical (infected and able to spread the disease without clinical signs), to clinical (infected with clinical signs). On average, >50% of the herd is expected to become infected before disease is detected within the herd.

[1] Risk Assessment for Transmission of Foot and Mouth Disease via the Transport of Raw Milk Into, Within, and Outside of a Control Area during an Outbreak: http://hdl.handle.net/11299/176193
Risk Assessment with Implementation of Biosecurity Performance Standards: http://hdl.handle.net/11299/178987

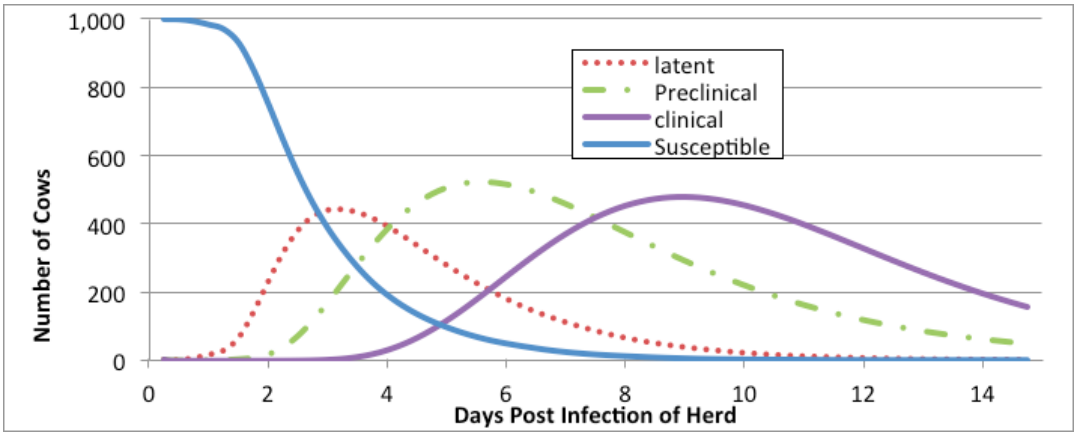

Figure 1. Mean number of cows in various disease states by days post infection in a 1,000-cow herd. The majority of the herd is expected to be infected by time of detection (approx. day 5). Model parameters are attached in Table 1.

Figure 2 shows the variation in milk viral load during the initial 5 days post-infection simulated in the model, prior to when a herd would be likely to be detected with FMD. This variation is illustrated by the wide range between the 5th and 95th percentile and occurs due to differences between farms in the early disease spread stages.

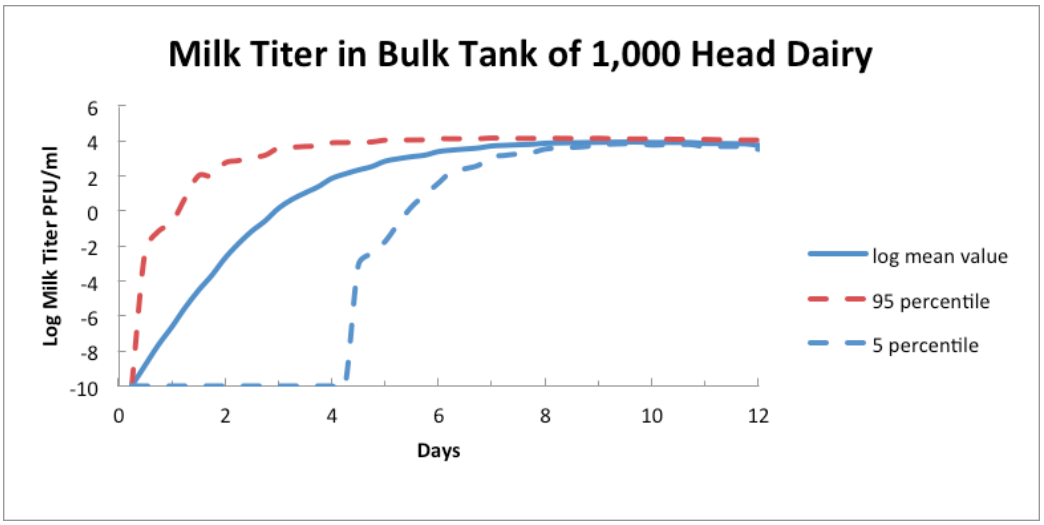

Figure 2. Variation in FMDv titer (log PFU/ml) in a bulk milk tank by day post-infection for a 1,000-cow milking herd with a 5% detection level.

2-4 days prior to clinical signs, viral titer levels in milk can reach high levels and remain elevated up to 4-5 days after clinical signs develop, similar to the overall viremia profile. The mean log titer of FMDv in the bulk milk tank on the day of detection ranges from 2.64 (100 head, 1% detection level) to 3.60 (1,000 head, 10% detection level) $\log_{10}$ PFU/ml for all 3 dairy sizes and detection levels considered. This model found that mean titers for FMDv in milk are one to two orders of magnitude greater than the lowest doses reported to cause disease via inhalation, indicating there is a potential risk of infection if susceptible species are exposed.

Table 1. FMDv titer in the bulk tank on the day disease is detected by dairy size and detection level

FMDv Titer in Bulk Milk Tank log_{10} PFU/ml (mean, 5th and 95th percentiles)	100-cow Herd	500-cow Herd	1,000-cow Herd
1% detection level	2.64 (0.67-3.70)	3.08 (2.22-3.73)	3.14 (2.33-3.75)
5% detection level	3.26 (2.33-3.86)	3.43 (2.86-3.90)	3.44 (2.88-3.91)
10% detection level	3.47 (2.83-3.96)	3.59 (3.12-3.97)	3.60 (3.15-3.99)

Based on 5-10% of the herd showing clinical signs prior to disease detection, all three herd sizes could be infected, shedding virus, but undetected for about 5 days. With each day, the possible FMD viral concentrations in raw milk are increasing, creating a risk of spreading disease through raw milk movement. The second proactive risk assessment considered heightened biosecurity performance standards to mitigate this risk and allow continuity of business in the face of an outbreak. Finally, though FMD virus is present in milk prior to detection, it is important to note that viral concentrations are greater and remain high for a period of time after detection, creating increased risk of disease transmission if susceptible species are exposed.

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Comments
Please send comments or suggested edits for improvement to: umnsf@umn.edu

Additional Resources
The Secure Milk Supply website has additional resources available at: www.securemilksupply.org