Evaluating Environmental FMD Virus Concentrations from Infected but Undetected Dairy Herd

Background:

In most diseases, there is a period of time when an individual is infected and able to spread the disease, but is not showing clinical signs. This time period creates high risk as movements of animals and animal products during this period can potentially contribute to disease spread. As part of continuity of business planning efforts and development of the Secure Milk Supply Plan, two Proactive Risk Assessments[1] were conducted, 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.

An exposure pathway model was developed to evaluate ways FMD virus could spread from an infectious cow to another farm with susceptible livestock through routine raw milk movement to help inform the risk assessments. This model evaluates the risk from raw milk, along with the risk that the contaminated environment (manure, urine, saliva, leaked milk) may transfer to the milk truck or onto the driver and spread disease to another farm with susceptible species.

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. Based on expert opinion, it was assumed that disease detection would occur when 5-10% of the herd are showing clinical signs.

Model results indicated it will take an average of 5-6 days for FMD to be detected within a dairy herd and 50-60% of that herd will be infectious and shedding virus at that time. Table 1 demonstrates the numbers of pre-clinically & clinically infectious cows on the day of detection based on 5 or 10% of the herd showing clinical signs. All of these infectious cows will be contributing to the overall virus load within the environment.

Table 1. Number of preclinical and clinically infectious cows on the day of detection.

Parameter	100-cow Herd		500-cow Herd		1,000-cow Herd	
Number of cows (mean, 5th and 95th percentile)	Preclinical	Clinical	Preclinical	Clinical	Preclinical	Clinical
5% detection level	63 (54-72)	12 (5-21)	320 (298-339)	57 (27-95)	640 (605-670)	113 (54-190)
10% detection level	63 (55-71)	18 (10-28)	318 (296-339)	90 (53-134)	634 (598-667)	183 (106-265)

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

FMD virus can be found in most bodily fluids. Urine and feces contain lower viral concentrations compared to serum, nasal secretions, saliva, milk and pharyngeal fluids, shown in Table 2. Despite lower viral concentrations, Sellers and Parker (1969[2]) reported that from 2-5 days post infection, the environment may be significantly contaminated from virus levels in feces. FMD virus can remain stable in the environment for months and organic material, such as manure or milk can increase its ability to remain viable, or infectious. Once the environment is contaminated with infectious milk, saliva, urine and feces it can serve as a source of contamination for clothing, boots and tires, allowing FMD to spread to other areas.

Using a conservative detection level of 1% of the dairy herd showing clinical signs within the model, the amount of infectious manure produced prior and on the day of detection was calculated. A mean number of 616 infectious cows within a 1,000 cow herd producing 15-45 kg of manure / day was used, yielding a total of 9,240 - 27,720 kg of manure / day produced. The remaining, uninfected cows in this herd would be producing 5,760 - 17,280 kg of manure / day, which will dilute the infectious manure by about ⅓. The large amount of infectious manure produced still provides a serious risk for environmental contamination throughout the farm.

Using a cow milk production of 27.2 - 34 L / day, the 616 infectious cows within a 1,000 cow herd would produce 16,755.2 - 20,944 L / day. The remaining, uninfected cows would be producing 10,444.8 - 13,056 L / day. Within milk, FMD is excreted at significant levels 2-4 days prior to clinical signs and remaining high for another 4-5 days, similar to the general viremia profile. Virus loads carried in other fluids also decreases after 4-5 days of clinical signs.

Table 2. Calculated FMDv titers based on a 1% detection level in 1,000 cow herd

	Mean FMDv titer	Amount from infectious cows	Amount from uninfected cows	Log $TCID_{50}$ from infected cows	Proportion of viral load produced daily
Manure	2.15 $\log_{10}$ $TCID_{50}$/g	9,240 - 27,720 kg / day	5,760 - 17,280 kg / day	9.12-9.59	4.94 $\log_{10}$ $TCID_{50}$/kg
Milk	3.29 $\log_{10}$ $TCID_{50}$/ml	16,755.2 - 20,944 L / day	10,444.8 - 13,056 L / day	10.51-10.61	6.08 $\log_{10}$ $TCID_{50}$/L

These numbers and the associated environmental contamination only increase with less conservative and more likely detection levels of 5 - 10% of the herd showing clinical signs. In a 5% scenario, 753 cows would be infectious in a 1,000 cow-herd. These cows would produce between 11,295 - 33,885 kg of manure / day. The uninfected cows in that herd would only produce 3,705 - 11,115 kg of manure / day, decreasing the dilution effect and resulting in more concentrated viral concentrations throughout the environment.

2 Sellers, R.F., Parker, J., 1969. Airborne excretion of foot-and-mouth disease virus. J Hyg (Lond) 67, 671-677.

Though the milk viral load is larger than the manure viral load in this estimate, the manure has been directly contaminating the environment for an average of 5-6 days prior to disease detection. As the number of infected cows increases, so will viral loads that are shed into the milk and environment, making biosecurity and other preventive measures more important to decrease the risk of disease spread to other farms.

Table 3: Descriptive statistics on data retrieved from the literature on maximum viral titers in secretions and excretions from cattle (De Rueda et al., 2014[3]).

FMDv infection variables	Number of observations	Maximum titer average and range (log_{10} $TCID_{50}$/ml)
Blood	47	4.03 (0.95-6.20)
Upper Respiratory Tract (URT) (OPF swabs, saliva, and nasal discharge combined)	33	5.70 (1.25-8.50)
Nasal Discharge only	7	6.09 (2.75-7.85)
Probang sample	68	4.91 (2.20-8.65)
Milk	40	4.48 (2.15-7.35)
Feces	5	1.55 (1.50-1.75)
Urine	10	1.93 (1.00-3.80)
Semen	8	4.55 (2.10-6.20)
Airborne	9	4.33 (3.88-5.08)*
Non-clinical stage of disease	61	4.52 (0.95- 8.65)
Clinical stage of disease	123	4.62 (1.00-8.50)
Undetermined clinical stage	36	4.11 (1.15-7.15)

*Airborne concentration is in $TCID_{50}$/animal/day

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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

[3] Bravo de Rueda, C., Dekker, A., Eblé, P. L., & de Jong, M. C. M. (2014). Identification of factors associated with increased excretion of foot-and-mouth disease virus. *Preventive Veterinary Medicine*, *113*(1), 23–33. http://doi.org/10.1016/j.prevetmed.2013.10.005