Foot-and-Mouth Disease: 
Public Health Implications for Human Consumption of 
Pasteurized Milk

Consultation for Dairy Management Inc. (DMI)

Provided By:
University of Minnesota School of Public Health
University of Minnesota College of Veterinary Medicine,
Center for Animal Health and Food Safety

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EXECUTIVE SUMMARY:

Background:

Foot-and-mouth disease (FMD) is a viral infection that affects cattle, swine, and other cloven-hoofed ruminants. The United States has been free of FMD since 1929, but should the disease be reintroduced into domestic livestock populations, serious economic consequences could result.

Rarely will this disease infect humans, but given that some human cases have been reported throughout history, public health implications need to be addressed.

Dairy Management Inc. requested that the University of Minnesota conduct a literature review to assess the public health implications of human consumption of pasteurized milk in the event of an FMD outbreak. The ensuing report is an in-depth summary of the available scientific literature on the topic as an aid in developing risk communication messages.

Methods:

Over 500 published papers were accessed and reviewed. Relevant information was compiled and reported in the form of a literature review.

Findings:

FMD should be considered a rare zoonosis. The disease has been seen in humans, but its incidence is extremely rare. Since 1921, just over 40 human cases have been reported. All documented cases were acquired from close animal contact or through the consumption of unpasteurized milk. There have been no human cases acquired from the consumption of pasteurized milk or milk products.

It has been demonstrated that infected animals will shed FMD virus in the milk. Various methods currently exist for pasteurization. Scientific studies have demonstrated that current batch and continuous pasteurization methods will decrease and largely inactivate the amount of virus present in milk. These processing methods will significantly reduce the already low risk of human infection from consuming pasteurized milk. Studies assessing Ultra High Temperature (UHT) pasteurization methods have demonstrated a complete elimination of the virus in milk.
**Recommendations:**

Based on the review of the literature contained in this report, the researchers feel confident that the following statements/recommendations can be made:

1) FMD should not be considered a public health concern. There is virtually no risk of infection to the general public should an outbreak occur in livestock.

2) Current pasteurization methods using minimum required temperatures and times are sufficient to prevent human or animal infection with FMD as a result of consuming pasteurized milk. State quarterly inspections and pasteurization equipment checks along with dairy industry internal food safety and quality control programs should be maintained to ensure that appropriate processes are followed.

3) UHT methods eliminate the risk of infection, since studies have demonstrated the complete elimination of virus in milk using this technology.

4) Compliance with World Organisation for Animal Health (OIE) and Pasteurized Milk Ordinance (PMO) guidelines will ensure food safety in the event of an FMD outbreak.

5) Risk communication messages may need to be designed differently based on the stakeholders addressed. Suggested stakeholders are discussed in the review.
INTRODUCTION:

The following report has been developed by the authors as a consultation project for use by Dairy Management Inc.™ (DMI). DMI has been created as a representation of the American Dairy Association®, National Dairy Council®, and U.S. Dairy Export Council®, to help build demand for dairy on behalf of dairy producers and is dedicated to the success of the dairy industry. Information provided by this report will be used by DMI to disseminate information to dairy industry communicators.

The report was written to address the following specific questions posed by DMI:

1) What is the public health risk from foot-and-mouth disease (FMD)? Is there zoonotic potential? If there have been human cases, how did they manifest?

2) What effect does pasteurization have on FMD in milk? What are the food safety implications?

3) What prevention strategies / recommendations can we provide to the public?

To find answers based on scientific research, a literature review was performed to best address each portion of the questions. The methods section of this report defines the criteria used in the review, while the findings portion reports information accumulated during research of the topic. A discussion of limitations experienced in the research is followed by a conclusion of findings and recommendations for DMI.

METHODS:

Internet Reference archives:

Pubmed, a service of the US National Library of Medicine, was utilized to perform the following keyword searches and displays the breadth of information on the topic of FMD.

<table>
<thead>
<tr>
<th>Key words</th>
<th>All</th>
<th>Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot and mouth disease</td>
<td>3789</td>
<td>207</td>
</tr>
<tr>
<td>Foot and mouth disease, humans</td>
<td>863</td>
<td>121</td>
</tr>
<tr>
<td>Foot and mouth disease, man</td>
<td>58</td>
<td>8</td>
</tr>
<tr>
<td>Foot and mouth disease, pasteurization</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Foot and mouth disease, public health</td>
<td>1975</td>
<td>244</td>
</tr>
<tr>
<td>Foot and mouth disease, zoonosis</td>
<td>73</td>
<td>21</td>
</tr>
<tr>
<td>Foot and mouth disease, milk, public health</td>
<td>42</td>
<td>13</td>
</tr>
</tbody>
</table>
Articles listed for review were evaluated in some context ranging from abstract review to full review. With few exceptions, non-English publications were not reviewed.

An excellent bibliography was compiled in 1965 by B. Balassa to provide reference material for the research workers of the Plum Island Animal Disease Laboratory. The title is Bibliography of Foot-and-Mouth Disease in Man 1695-1965, and it lists 310 articles from the mentioned time period. Entries are arranged alphabetically with titles of papers rendered in the languages published. An additional supplement, Foot-and-Mouth Disease in Man A Bibliography 1966- September 1971 containing 45 more sources was provided in 1971 by R. Uskavitch. Copies of both of these sources were found at the University of Minnesota Veterinary Medical Library and articles of interest were located through the University of Minnesota library search engine.

Unbiased approach:

In order to preserve the academic integrity of this consult, all attempts were made to remain non-biased and approach the research from a balanced perspective. Neither the approach to disprove FMD as threat to humans nor the intent to prove it as a health risk was used. A great deal of references cited in accumulated articles were also collected and analyzed to determine the origins of information reported. This method allowed for a greater breadth of information and understanding on the topic of FMD. It should be noted, however, that some bias may be encountered when using the reference list of a specific article to find more articles of interest.

FINDINGS:

I. Introduction of Foot-and-Mouth Disease (FMD):

Foot-and-mouth disease (FMD) is a severe and highly contagious viral disease of cattle and swine with reported effects also recognized in sheep, goats, deer, and other cloven-hoofed ruminants (USDA, 2007). While some references were identified suggesting FMD is a zoonotic disease, it is generally accepted that humans are considered to be relatively non-susceptible to infection (Bauer, 1997). The United States has been free of FMD since 1929, when the last of nine U.S. outbreaks was eradicated.

The disease in susceptible animals is characterized by fever and blister-like lesions followed by erosions on the tongue and lips, in the mouth, on the teats, and between the hooves (USDA, 2007). Most affected animals recover, but the disease leaves them debilitated. Infection of young animals can result in death.

FMD can cause severe losses in the production of meat and milk. FMD outbreaks not only disrupt animal trade, but also cause widespread economic and social impacts, both in the short and long term. These include: disruption or complete blockage of raw milk farm pick-up and delivery to dairy processing plants, as well as distribution of finished dairy products to wholesale and retail outlets; interruption of animal feed, veterinary pharmaceuticals and other supplies to dairy farms; and restrictions on travel / tourism-associated industries. Furthermore, concern has been raised about potential
terrorist organizations or rogue states that might target the $100 billion/year U.S. livestock industry by employing the etiologic agent of FMD. Such events would garner much media attention and could cause public concern over both the disease and food safety.

In response to these and other concerns, President George W. Bush signed into law the Public Health Security and Bioterrorism Preparedness and Response Act of 2002. The purpose of this Act is stated, "To improve the ability of the United States to prevent, prepare for, and respond to bioterrorism and other public health emergencies," (107th congress. public health security and bioterrorism preparedness and response act of 2002. public law 107-188.)

II. Broad Considerations for FMD:

1) Prevention and vigilance towards a FMD outbreak is crucial in today’s society as the majority of our nation’s population depends on someone else to provide food for them.

2) In the case of a biosecurity event (such as FMD), early detection would lead to an earlier response, which, in turn, would decrease economic damage and reduce expected volatility in agricultural industry commodity markets. Detection begins with animal producer, veterinarian and citizen awareness, and continues with technology to confirm any suspicions. Current monitoring systems supported by USDA that include disease detection training will help immensely, but personnel must be trained to use technology properly in a crisis situation.

3) Containing disease progression during an outbreak is important because the agriculture industry must be prepared to conduct business during and after a major FMD outbreak. Agricultural industry leaders, as well as the appropriate federal government agencies, must be properly trained to react in a crisis situation.

4) At all levels, a coordinated communication strategy must include the development of effective messages for government and industry groups that use risk management strategies in risk communication to the general population.

In the event of an outbreak of FMD, consumer confidence in the food supply may be undermined by the public’s perception that animal products might contain the virus, though not harmful to humans. Consumers may question the safety of all animal products (e.g., milk) on store shelves even those produced with pasteurized milk (Tomasula et al., 2007).

III. Causative Agent:

FMD is caused by a picornavirus; other members of this family of viruses include the swine vesicular disease virus, the human hepatitis A virus, and rhinoviruses.
Picornaviruses are 22 to 30 nanometers (nm) in diameter, naked (unenveloped), and display an icosahedral shape. The FMD virus belongs to the genus aphthovirus. The virus is a positive sense, single-stranded RNA virus. There are 7 immunologically distinct serotypes of FMD virus: FMDV-A, FMDV-O, FMDV-C, FMDV-ASIA1, FMDV-SAT1, FMDV-SAT2, and FMDV-SAT3. Also, more than 60 subtypes of the virus exist (AVMA, 2008).

Most picornavirus species are host-specific and are highly resistant to many disinfectants. The FMD virus is inactivated by sodium hydroxide (2%), sodium carbonate (4%), and citric acid (0.2%). Resistance has been noted in iodophores, quaternary ammonium compounds, hypochlorite and phenol, especially when organic matter is present (OIE - World Organisation for Animal Health, 2002).

IV. Significance to Public Health:

Due to media coverage of zoonotic diseases, such as bovine spongiform encephalopathy (BSE), tuberculosis, and E. coli 0157, public concern has been raised to the potential risks of contracting FMD from livestock sources. FMD infections in humans are very rare, with just over 40 cases (confirmed by virus isolation, or rise in antibody titers, or both) diagnosed since 1921. With this very low number of documented human cases, FMD is considered an unlikely zoonosis. In humans, vesicular lesions can be seen, but the signs are generally mild, and human patients usually recover a week after the last blister formation. FMD is not considered to be a direct public health threat, as it crosses the species barrier into humans with great difficulty and with little effect. Given the high incidence of the disease in animals, both in the past and in more recent outbreaks worldwide, its comparable occurrence in humans is very rare. (Prempeh, Smith, & Muller, 2001)

During the second half of the 19th century, many authors recorded cases of aphthous* diseases in man which appeared to have been acquired from animals affected by FMD (Hyslop, 1973). In one report, consumption of infected (raw) milk appeared to be the primary factor associated in 22 cases of human infection. This same author mentions that the authenticity of early documented cases is often a matter of speculation since coincidental appearances by diseases that appear similar in humans can occur during animal FMD outbreaks.

The circumstances in which FMD does occur in humans are not well defined; however, all reported cases have had close contact with infected animals. There is one report from 1834 of three veterinarians acquiring the disease and displaying clinical manifestations from deliberately drinking 250 ml of raw milk from infected cows for three consecutive days. However, reports documented before 1897, when Loeffler and Frosh discovered the virus for FMD, were not confirmed as FMD either by isolation of the virus or identifying immunoglobulins after infection (Bauer, 1997).

A well-documented human case of FMD in the United Kingdom occurred in 1967 during an outbreak. The farm worker affected was thought to have contracted FMD by
drinking virus-contaminated milk supplied by an infected cow on the farm (Mayor, 2001). Symptoms of the affected man included mild fever, sore throat, blisters on his hands, and wheals on his tongue. The patient described the lesions as uncomfortable and tingling, and his tongue as hot, tingling and sore. Traces of type O FMD were found in one tissue sample, but not in others, so speculation was that the man may also have been suffering from a skin condition of unknown origin. The man recovered within a few weeks and had no lasting health effects (Armstrong, Davie, & Hedger, 1967).

Table 1 is a representation of some of the documented human cases of FMD and virus type isolated (Berrios, 2007). Type O FMD is commonly referenced in these articles and exposure to virus from drinking raw milk is documented.

**Table 1. Articles on FMDV in Humans.** *(Translation from article written in Spanish) (Berrios, 2007)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Virus type</th>
<th>Country</th>
<th>Infection source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1929</td>
<td>Trautwein</td>
<td>A</td>
<td>Germany</td>
<td>Work related</td>
</tr>
<tr>
<td>1934</td>
<td>Von Scheltz</td>
<td>O</td>
<td>Germany</td>
<td>?</td>
</tr>
<tr>
<td>1938</td>
<td>Rinjard</td>
<td>O</td>
<td>France</td>
<td>milking</td>
</tr>
<tr>
<td>1938</td>
<td>Magnusson</td>
<td>O</td>
<td>Sweden</td>
<td>Ill animal</td>
</tr>
<tr>
<td>1938</td>
<td>Flaum</td>
<td>O</td>
<td>Sweden</td>
<td>milking</td>
</tr>
<tr>
<td>1941</td>
<td>Stenstrom</td>
<td>O</td>
<td>Sweden</td>
<td>milking</td>
</tr>
<tr>
<td>1950</td>
<td>Holm</td>
<td>O</td>
<td>The Netherlands</td>
<td>?</td>
</tr>
<tr>
<td>1951</td>
<td>Wahl</td>
<td>C</td>
<td>Germany</td>
<td>milking</td>
</tr>
<tr>
<td>1954</td>
<td>Czarnowski</td>
<td>C</td>
<td>Poland</td>
<td>?</td>
</tr>
<tr>
<td>1955</td>
<td>Geiger</td>
<td>C</td>
<td>Germany</td>
<td>laboratory accident</td>
</tr>
<tr>
<td>1959</td>
<td>Garbe</td>
<td>C</td>
<td>Germany</td>
<td>laboratory accident</td>
</tr>
<tr>
<td>1960</td>
<td>Maléndez</td>
<td>O</td>
<td>Chile</td>
<td>laboratory accident</td>
</tr>
<tr>
<td>1962</td>
<td>Pilz</td>
<td>C</td>
<td>Germany</td>
<td>laboratory accident</td>
</tr>
<tr>
<td>1962</td>
<td>Pilz</td>
<td>O</td>
<td>Germany</td>
<td>laboratory accident</td>
</tr>
<tr>
<td>1963</td>
<td>Schwann</td>
<td>C</td>
<td>Poland</td>
<td>milking</td>
</tr>
<tr>
<td>1964</td>
<td>Heinig</td>
<td>C</td>
<td>Germany</td>
<td>?</td>
</tr>
<tr>
<td>1964</td>
<td>Kobuclewitcz</td>
<td>C</td>
<td>Poland</td>
<td>raw milk ingestion</td>
</tr>
<tr>
<td>1965</td>
<td>Pilz</td>
<td>O</td>
<td>Germany</td>
<td>laboratory accident</td>
</tr>
<tr>
<td>1967</td>
<td>Salazhov</td>
<td>A</td>
<td>Russia</td>
<td>Milking/raw milk drank</td>
</tr>
<tr>
<td>1967</td>
<td>Elsner</td>
<td>C</td>
<td>Germany</td>
<td>Collecting environmental samples</td>
</tr>
<tr>
<td>1967</td>
<td>Armstrong</td>
<td>O</td>
<td>England</td>
<td>Ill animal</td>
</tr>
<tr>
<td>2001*</td>
<td>Bohn*</td>
<td>O*</td>
<td>England*</td>
<td>Ill animal*</td>
</tr>
</tbody>
</table>

*No literature found for the reference. (Mayor, 2001) reports that the last documented case in the U.K. was in 1967.

The virus type most often isolated in humans with FMD is type O followed by type C and rarely A. The incubation period in humans ranges from 2-6 days. Symptoms
displayed have mostly been mild and self limiting, mainly uncomfortable tingling blisters on the hands but also fever, sore throat, and blisters developing on the feet, in the mouth, as well as on the tongue. (Bauer, 1997)

Apthae forming in humans from FMD, range in size from that of a pin head to as large as 2 cm in diameter. Initially blisters are clear and yellowish in color, but soon become thickened. These blisters then dry up within two to three days and the skin is sloughed off showing the red basal epidermal layer. With care, the areas heal quickly by the body’s normal methods. Secondary blisters then may appear up to five days after development of primary blisters. Recovery is usually well advanced within a week after the last blister appears (Bauer, 1997).

Several other human diseases are characterized by formation of skin vesicles and clinical symptoms similar to FMD. Manifestation of the clinical signs associated with FMD in humans must be differentiated from the diseases listed in Table 2. Historically, in the event of a livestock FMD outbreak, coincidental appearances of the listed diseases can be misinterpreted by the general public as human FMD (Hyslop, 1973).

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An aphthous is defined as a small sensitive painful ulcer crater in the lining of the mouth and is more commonly called a canker sore. Aphthous ulcers are one of the most common problems that occur in the mouth. About 20% of the population (1 in 5 people) has aphthous ulcers at any given time. These ulcers typically last for 10-14 days and they heal without leaving a scar. There are many possible causes of aphthous ulcers and often the cause is unknown (Ulcer, aphthous definition - medical dictionary definitions of popular medical terms easily defined on MedTerms.)
Table 2. Differential diagnosis between foot and mouth disease and other viral diseases with similar clinical characteristics (Lopez-Sanchez, Guijarro Guijarro, & Hernandez Vallejo, 2003).

<table>
<thead>
<tr>
<th>Disease</th>
<th>Agent</th>
<th>Reservoir</th>
<th>Oral Manifestations</th>
<th>Systemic Manifestations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot and Mouth Disease</td>
<td>Picornavirus (RNA): Aphthovirus</td>
<td>Cleft hoof herbivores</td>
<td>Vesicles throughout the oral mucosa.</td>
<td>Fever, Malaise, Muscle pain, Diarrhea,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dysphagia</td>
<td>Vesicles affecting nasal mucosa and hands</td>
</tr>
<tr>
<td>Vesicular stomatitis</td>
<td>Rhabdovirus (RNA): Vesiculovirus</td>
<td>Cleft hoof herbivores and equine species</td>
<td>Vesicles throughout the oral and tonsillar mucosa. Dysphagia.</td>
<td>Fever, Malaise, Adenopathies</td>
</tr>
<tr>
<td>Hand, foot and mouth disease</td>
<td>Picornavirus (RNA): Enterovirus: Coxsackie, Echo</td>
<td>Humans</td>
<td>Vesicles throughout the oral mucosa.</td>
<td>Vesicles affecting hands and feet</td>
</tr>
<tr>
<td>Herpangina</td>
<td>Picornavirus (RNA): Coxsackie</td>
<td>Humans</td>
<td>Vesicles affecting the uvula, soft palate and tonsils. Dysphagia.</td>
<td>Fever, Vomiting, Abdominal pain</td>
</tr>
<tr>
<td>Primary herpetic gingivostomatitis</td>
<td>Herpes virus (DNA): Herpes virus hominis 1 and 2</td>
<td>Humans</td>
<td>Vesicles throughout the oral mucosa.</td>
<td>Fever, Malaise, Joint pain, Adenopathies</td>
</tr>
</tbody>
</table>

Another significant factor associated with an outbreak of FMD involves the psychosocial effects to the human population involved. Research in the United Kingdom was conducted to understand the health and social consequences of the 2001 FMD epidemic for a rural population in the most heavily affected North Cumbria region. Respondents' reports showed that life after the epidemic was accompanied by distress, feelings of bereavement, fear of a new disaster, loss of trust in authority and systems of control, and the undermining of the value of local knowledge. Distress was experienced across diverse groups well beyond the farming community (Mort, Convery, Baxter, & Bailey, 2005).
Key Points:
FMD rarely occurs in humans and disease manifestation (often mild and self-limiting) is most often associated with either consumption of unpasteurized milk or close contact with infected animals. Based on the published scientific literature, no human cases of FMD have been reported following consumption of pasteurized milk or milk products.

V. Disease in Animals:

Although pigs are major producers of virus aerosols, cattle produce several magnitudes more of the virus in the epithelium of the tongue, which often sloughs off and is shed during clinical disease, as well as in saliva. The virus is also shed in urine, feces and milk. The 10–30 g of tongue blister epithelium, which a cow with FMD can discharge, may represent not less than one billion infectious units (IU). These enormous quantities of shed virus can contaminate the environment (boots, clothes, tires etc.) and, therefore, cattle are considered the main source of environmental contamination. FMD infection can be spread by an airborne route through the upper and lower respiratory tract, although it can also enter the new host through abrasions of the oral epithelium, hooves, and mammary tissue.

The peak of infectivity is just prior to or during the development of lesions. It is then greatly reduced 3–4 days after the lesions develop. Some virus strains are host adapted (Sutmoller, Barteling, Olascoaga, & Sumption, 2003).

Clinical Signs:

The clinical manifestations of FMD in animals usually are severe, and sequelae following initial recovery can seriously impair livestock productivity (Sutmoller et al., 2003).

The clinically visible lesions include rapidly rupturing vesicles filled with clear, straw-colored fluid. Vesicles vary in size from 0.5-10 cm in diameter and appear in areas subjected to pressure, irritation, or friction, on either skin or mucosal surfaces. These areas include interdigital spaces, heels, coronary bands, teats, oral mucosa, nostrils and rumen pillars. Ruptured vesicles may leave erosions or ulcerations, but begin as small blanched areas of epithelium that rapidly fill with fluid and eventually rupture. Epithelium will separate and slough leaving raw ulcers, tags of epithelial tissue, or erosions. These areas heal rapidly and leave discolored areas that fade until completely healed. Death is uncommon except in bovine neonates where cardiac and skeletal muscle necrosis may be evidenced upon necropsy (Kahrs, 2001).

Prolonged healing can cause marked weight loss and decreases in milk and meat production. Anorexia is caused by painful oral lesions, and lameness is due to painful digits. Commonly, animals will exhibit shifting of weight on feet, and secondary bacterial infections of the hooves frequently arise. Painful teat lesions may prevent nursing or milking. Mastitis of primary viral or secondary bacterial origin is a common effect (Kahrs, 2001).

FMD is clinically indistinguishable from vesicular stomatitis, and vesicle formation is preceded by a viremic stage consisting of fever, depression, anorexia,
listlessness, and occasional shivering. As vesicles form, animals display excess salivation, nasal discharge and classically in cattle, lip smacking (Kahrs, 2001).

Viral Transmission in Milk:

FMD virus is shed into the milk, blood, pharynx, rectum and vagina, before onset of clinical manifestations in infected cows. The virus can appear in the milk of animals exposed to it through contact with infected animals several days before clinical signs of the disease appear (Burrows, 1968). Experiments in which the bovine udder was inoculated with FMD virus showed that it is highly capable of producing large amounts of the virus (Burrows, Mann, Greig, Chapman, & Goodridge, 1971).

Information regarding the amount of FMD virus required to infect animals through various routes, including ingestion, has been compiled (Sellers, 1971). From previous data, it was determined that the amount of virus in infected milk may be up to $10^{5.5} \text{ID}_{50} \dagger$ per ml. Only 1 mL at a concentration of $10^5 \text{ID}_{50}$ per ml would be needed to infect a pig through ingestion. A normal daily intake of 0.5L of milk would be sufficient to initiate infection in a pig if the concentration were $10^{2.3} \text{ID}_{50}$ per ml. Calves consuming normal daily milk amounts at 0.5-9L, would need virus concentrations in the range from $10^{3.3} - 10^{2.05} \text{ID}_{50}$ per ml.

Key Points:

In order to ascertain if animals are affected by FMD, it is important to understand what clinical manifestations would be observed. Confirmation of an outbreak in animals would trigger appropriate risk communication messages to producers and processors to provide tools to address the spread of the disease and for consumers to assure them of the safety of the food supply. As virus can be excreted in milk prior to an animal demonstrating clinical signs, producers must be able to account for animals and products in the food chain once the disease is identified.

VI. Pasteurization / Food Safety:

“The terms "pasteurization", "pasteurized" and similar terms shall mean the process of heating every particle of milk or milk product, in properly designed and operated equipment, to one (1) of the temperatures given in the following chart and held continuously at or above that temperature for at least the corresponding specified time.”

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$\dagger \text{ID}_{50}$ (infectious dose) is the virus titer that will cause infection in 50% of individuals exposed.
**Table 3. Pasteurized Milk Ordinance (PMO) Temperature and Time Standards for Pasteurization**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>63°C (145°F)*</td>
<td>30 minutes</td>
</tr>
<tr>
<td>72°C (161°F)*</td>
<td>15 seconds</td>
</tr>
<tr>
<td>89°C (191°F)</td>
<td>1.0 second</td>
</tr>
<tr>
<td>90°C (194°F)</td>
<td>0.5 seconds</td>
</tr>
<tr>
<td>94°C (201°F)</td>
<td>0.1 seconds</td>
</tr>
<tr>
<td>96°C (204°F)</td>
<td>0.05 seconds</td>
</tr>
<tr>
<td>100°C (212°F)</td>
<td>0.01 seconds</td>
</tr>
</tbody>
</table>

*If the fat content of the milk product is ten percent (10%) or greater, or if the milk contains a total solids of 18% or greater, or if it contains added sweeteners, or if it is concentrated (condensed), the specified temperature shall be increased by 3°C (5°F). (Section 1. FF of PMO, 2007)

**Pasteurization Methods**

There are two basic pasteurization methods

1) Batch Method
2) Continuous Method (usually high temperature, short time (HTST))

**Batch Method**

The batch method (Figure 1) uses a vat pasteurizer, consisting of a vat surrounded by a jacket using a heating medium such as circulating water, steam or heating coils of water or steam. In the vat, the milk is heated and held throughout the holding period while being agitated. The milk may be cooled in the vat or removed hot after the holding time is completed for every particle. Some modifications include that the milk may be partially heated in a tubular or plate heater before entering the vat (Goff, 2007). However, the times identified above have to be met while the milk is in the vat.
Continuous Method

For most continuous processing, a high temperature short time (HTST) pasteurizer is utilized. The continuous process method has a few advantages over the vat method, the most important being time and energy saving. The actual heat treatment is accomplished using a plate heat exchanger, which consists of a stack of corrugated stainless steel plates clamped together in a frame (Figure 2). There are several flow patterns which can be used. Gaskets are placed to define the boundaries of the channels as well as to prevent leakage. The medium used for heating can be either vacuum steam or hot water (Goff, 2007)
HTST Milk Flow Overview
“Cold raw milk at 4° C in a constant level tank is drawn into the regenerator section of pasteurizer. Here it is warmed to approximately 57° C - 68° C by heat given up by hot pasteurized milk flowing in a counter current direction on the opposite side of thin, stainless steel plates. The raw milk, still under suction, passes through a positive displacement timing pump which delivers it under positive pressure through the rest of the HTST system.

The raw milk is forced through the heater section where hot water on opposite sides of the plates heat milk to a temperature of at least 72° C. The milk, at pasteurization temperature and under pressure, flows through the holding tube where it is held for at least 16 sec. The maximum velocity is governed by the speed of the timing pump, diameter and length of the holding tube, and surface friction. After passing temperature sensors of an indicating thermometer and a recorder-controller at the end of the holding tube, milk passes into the flow diversion device (FDD). The FDD assumes a forward-flow position if the milk passes the recorder-controller at the preset cut-in temperature (>72° C). The FDD remains in normal position which is in diverted-flow if milk has not achieved preset cut-in temperature. The improperly heated milk flows through the diverted flow line of the FDD back to the raw milk constant level tank.

Properly heated milk flows through the forward flow part of the FDD to the pasteurized milk regenerator section where it gives up heat to the raw product and in turn is cooled to approximately 32° C - 9° C. The warm milk passes through the cooling section where it is cooled to 4° C or below by coolant on the opposite sides of the thin, stainless steel plates.

The cold, pasteurized milk passes through a vacuum breaker at least 12 inches above the highest raw milk in the HTST system then on to a storage tank filler for packaging.” (Goff, 2007)

HTST pasteurization is important to the dairy industry because of the operating efficiencies that it affords. Properly operated, these units allow a high volume of production in a minimum of processing space. The ability of HTST pasteurizers to assure a safe, finished milk or milk product hinges on the reliability of the time-temperature-pressure relationships that must prevail whenever the system is in operation (PMO, 2007).
HTST heating is the most commonly utilized method of pasteurization for fluid milk today. Milk is usually heated in a plate heat exchanger to a specified temperature followed by holding at that temperature in a pipe for a specified period of time (Tomasula & Konstance, 2004). Current Pasteurized Milk Ordinance (PMO, 2007) standards for HTST heating of milk require heating to a minimum of 72°C and a holding time of at least 15 seconds as seen in Table 1.

Additionally, higher temperatures are used in the following methods:
- Ultra-Pasteurization
- Ultra High Temperature/ Aseptic Processing

Ultra-Pasteurization (UP): The term “Ultra-Pasteurization”, when used to describe a dairy product, infers that such products shall have been thermally processed at or above 138°C (280°F) for at least two (2) seconds, either before or after packaging, so as to produce a product, which has an extended shelf-life under refrigerated conditions (PMO, 2007).

Ultra High Temperature (UHT), or Aseptic Processing: The term “Aseptic Processing”, when used to describe a milk product, infers that the product has been subjected to sufficient heat processing and packaged in a hermetically sealed container (PMO, 2007). The product is termed "shelf stable" and does not need refrigeration until it is opened.

FMD research regarding pasteurization methods:

A study was performed to determine whether continuous flow HTST pasteurization would be more effective than batch pasteurization methods in eliminating or reducing the infectivity of FMD in naturally infected milk. It also aimed to determine the temperature-time conditions, at temperatures <100°C, required for eliminating the virus in whole milk and 2% milk under flow conditions (Tomasula et al., 2007).

Specifically, the study aimed to determine whether HTST pasteurization simulating that of commercial operations would be effective in eliminating FMD from naturally infected whole and 2% milk. The study concluded that HTST pasteurization is more efficient than batch pasteurization methods in eliminating the FMD virus in whole and skim milk (Tomasula et al., 2007). The results of this study largely agree with those of (Hyde, Blackwell, & Callis, 1975) and (Blackwell & Hyde, 1976), who used the batch processing techniques to simulate HTST pasteurization of milk.

The above described studies indicate that the FMD virus encapsulated by milk fat has increased heat resistance. Modern milk-processing plants with efficient skimming operations and homogenization as part of pasteurization may release the residual encapsulated virus, ensuring its destruction during pasteurization, or may reduce residual virus to much lower levels than observed in this and previous laboratory-scale studies (Tomasula et al., 2007). Milk fat will be discussed in more detail later.
**Residual Virus:**

A series of pasteurization experiments using FMD were performed by researchers at the Plum Island Animal Disease Center at Orient Point, New York (Blackwell & Hyde, 1976; Hyde et al., 1975). HTST pasteurization was simulated using a batch type experimental model that heated milk to 72° C for a holding time of 15 seconds, which meets criteria of the 2007 regulations for time and temperature requirements of the Pasteurized Milk Ordinance (PMO, 2007). A $6 \log_{10}$ reduction in FMD was noted, however, inoculation of the pasteurized sample into steers demonstrated residual infectivity.

Steer inoculation has been deemed the most sensitive method to detect infectious FMD in naïve (previously unexposed) animals (Tomasula et al., 2007). Other methods that detect viral antigens (ELISA) or viral RNA (real time reverse-transcription PCR) exist, but fail to distinguish inactivated from infectious virus.

When the pasteurization time for whole milk was increased to 2 minutes at 72° C, steers inoculated with the milk developed FMD, but under identical conditions using skim milk, 1 of 3 steers inoculated with pasteurized skim milk samples developed FMD. When skim milk was heated at 72° C for 2 minutes, followed by evaporation of the initial volume by 50% at 65° C for 1 hour, the virus was eliminated. Whole milk samples pasteurized at 85° C for 15 seconds were infectious to steers, but under identical conditions using skim milk, only 1 of 5 steers inoculated with pasteurized skim milk samples developed FMD (Blackwell & Hyde, 1976).

In review of the these studies, increases in pasteurization temperature or holding time do not completely eliminate the virus in whole milk, but are effective in reducing, and in some cases eliminating, the virus in skim milk (Tomasula et al., 2007). Conclusions of (Blackwell & Hyde, 1976; Hyde et al., 1975) suggested that since FMD survives the evaporation of whole milk heated for expanded exposure periods but not that of skim milk receiving the same treatment; butterfat in cream of whole milk confers an even higher degree of protectivity during heating than the protein in skim milk.

It should be noted, however, that even though residual infectivity was observed with relatively large volumes of milk [(2 ml) directly inoculated intradermally (20 sites on tongue) and intramuscularly (4 sites in gluteals) into steers], the ability of this milk to infect by oral or other routes is unlikely (Tomasula et al., 2007).

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† Inactivated virus are unable to produce evidence of growth or cause damaging effect on tissues but still cause antibody production. An infectious virus is able to cause infection, growth and damaging effect to tissues.
Homogenization:

Modern processing plants homogenize and clarify (remove solid impurities from milk) prior to heating, which helps break down the milk fat globules and removes debris. This process may be of benefit in exposing FMD virus encapsulated in milk fat and cells, which is then either destroyed by heat or removed in association with debris (Tomasula & Konstance, 2004).

Homogenization is defined as the mechanical treatment of the fat globules in milk brought about by passing milk under high pressure through a small orifice. This results in a decrease in the average diameter and an increase in number and surface area, of the fat globules (Goff, 2007). As mentioned above, this process allows better access to virus encapsulated in the milk fat.

Milk pH:

Milk pH is an important variable that allows the virus to become more stable as the value rises. Cows infected with FMD tended to have a more alkaline milk output (Tomasula et al., 2007) where FMD infected milk had a pH of 7.1 compared to 6.7 prior to infection. Similar results were reported previously (Hyde et al., 1975). Earlier studies of the virus found it most stable at a pH between 7 and 7.5 and the time to reduce viral titers was decreased if pH was 6.7 as opposed to 7.6 (Tomasula et al., 2007).

Dilution effects:

An important variable not represented in the studies conducted by (Blackwell & Hyde, 1976; Hyde et al., 1975; Tomasula et al., 2007) is that commercial milk and milk product-processing operations blend massive quantities of milk from various dairy farms. In an FMD outbreak event, milk tankers arriving at a plant, with products from farms with cows not yet exhibiting clinical signs, would be mixed in holding tanks with milk from non-infected farms. The blending of infected and non-infected milk would display a dilution effect of virus particles and lower the pH of the bulk quantity. Milk pasteurization was demonstrated to be much more effective in virus inactivation when pH of milk is closer to the normal (uninfected by FMD) levels of 6.7 (Tomasula et al., 2007).

It was estimated that if 10% of a lactating dairy herd became infected, the produced infected milk would be diluted in the farm bulk tank by a 10-fold dilution (Donaldson, 1997). The milk truck tank would further dilute (5-fold dilution), followed by further mixing in the processing plant, removal of coarse particles by filtration (10-fold reduction in virus), and followed by HTST pasteurization (71.7°C, 15 s) which would produce a $10^5$ reduction in virus. This would result in a virus concentration of $10^{1.9} - 10^{2.9} \text{ID}_{50}/l$. It was further estimated that for a single calf to have a high probability of obtaining an infectious dose from pasteurized milk, 1,250–12,500L (330-3302 gallons) would need to be consumed. A single pig would need to consume 125-250L (33-66 gallons) for an infective dose (Donaldson, 1997). Calves normally consume 0.5-9L and pigs consume 0.5-4.1L of milk daily (Sellers, 1971). If a calf inhaled some of the milk as
it was drinking, the likelihood of infection would be increased as a much lower infectious dose is required to infect cattle by the respiratory route as compared to the oral route.

**Key Points:**

After dilution factors and pasteurization have been accounted for, scientific studies have shown that cattle and swine consuming pasteurized milk are highly unlikely to contract an infection since it is physically impossible to ingest the liquid amount calculated to infect the animals. This result could plausibly be extrapolated to humans, although there have been no studies specifically looking at infectivity in humans. **Particular attention should be paid to time, temperature, homogenization, and pH during processing to further ensure a decreased risk of infection from pasteurized milk consumption.**

**Other Dairy products:**

A review of animal products and the effect of processing to reduce FMD titers has been written (Ryan, Mackay, & Donaldson, 2008). The results are described and referenced below:

**Milk powder:** Milk and skimmed milk used to produce milk powder are heated to 80–90°C for 30 s, which produces a $10^{5.4}–10^{6} \text{ID}_{50}$ decrease in infectivity. Subsequent roller- or spray-drying should further inactivate any residual virus.

**Cream:** Cream has a higher concentration of fat globules than milk. FMD virus survived in cream heated at 93°C for 16 s, with up to $10^{3.5}$ pfu/ml detected in cell culture after this treatment. This temperature is higher than commercial cream pasteurization.

**Cheese:** Virus survival is dependant on the manufacturing conditions and pH of the cheese concerned, and so the data for one cheese cannot be extrapolated to another. See Table 4 for results.

**Yogurt:** No data is available on FMD virus survival but it is speculated that the low pH involved in manufacturing should inactivate the virus.

**Table 4. Detection of Viruses in Dairy Sources (Ryan et al., 2008)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Amount of virus present or longest detection time</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpasteurized bottled milk</td>
<td>$10^{4.0} \text{MID}_{50}/\text{ml}$</td>
<td>Hedger and Dawson (1970)</td>
</tr>
<tr>
<td>Milk (65°C, 64-min pasteurization)</td>
<td>Virus detected by cattle inoculation (CI)</td>
<td>Hyde et al. (1975)</td>
</tr>
<tr>
<td>Product</td>
<td>VT Detection</td>
<td>Notes</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Milk (HTST pasteurization)</td>
<td>$10^3.0$ pfu/ml</td>
<td>Hyde et al. (1975)</td>
</tr>
<tr>
<td>Milk (UHT pasteurization)</td>
<td>Virus not detected</td>
<td>Cunliffe et al. (1979)</td>
</tr>
<tr>
<td>Milk powder*</td>
<td>Decrease in infectivity of $10^{5.4}$ to $10^{6.0}$ ID$_{50}$</td>
<td>Donaldson (1997), Bekkum and Leeuw (1978)</td>
</tr>
<tr>
<td>Cream (93°C, 16 s)$^\dagger$</td>
<td>$10^{4.5}$ pfu/ml</td>
<td>Blackwell (1978a)</td>
</tr>
<tr>
<td>Butter$^\ddagger$</td>
<td>Detected by CI at 30 days</td>
<td>Blackwell (1978a)</td>
</tr>
<tr>
<td>Butter oil$^\ddagger$</td>
<td>Detected by CI at 45 days</td>
<td>Blackwell (1978a)</td>
</tr>
<tr>
<td>Cheddar cheese (raw milk)$^\S$</td>
<td>Detected by CI at 60 days</td>
<td>Blackwell (1976)</td>
</tr>
<tr>
<td>Cheddar cheese (heated milk, 67°C, 60 s)$^\S$</td>
<td>Detected by CI after preparation, before curing</td>
<td>Blackwell (1976)</td>
</tr>
<tr>
<td>Camembert cheese (pasteurized milk, 72°C for 16 s)$^\P$</td>
<td>Detected by CI at 21 days</td>
<td>Blackwell (1976)</td>
</tr>
<tr>
<td>Mozzarella cheese (pasteurized milk, 72°C for 16 s)</td>
<td>Virus not detected</td>
<td>Blackwell (1976)</td>
</tr>
<tr>
<td>Emmentaler cheese (raw milk)**</td>
<td>Virus detected during manufacturing, not detected during curing</td>
<td>Kihm et al. (1979)</td>
</tr>
<tr>
<td>Sweet whey</td>
<td>Detected by CI</td>
<td>Blackwell (1978b)</td>
</tr>
<tr>
<td>Acid whey</td>
<td>Virus not detected</td>
<td>Blackwell (1978b)</td>
</tr>
<tr>
<td>Lactose, α- and β-lactalbumin</td>
<td>Virus not detected</td>
<td>Blackwell (1978b)</td>
</tr>
<tr>
<td>Casein from HTST milk</td>
<td>Virus detected by CI</td>
<td>Cunliffe and Blackwell (1977)</td>
</tr>
</tbody>
</table>

*Milk and skimmed milk used to produce milk powder is heated to 80–90°C for 30 s then roller- or spray-dried (Bekkum and Leeuw, 1978; Donaldson, 1997).

$^\dagger$Cream was heated for 16 s at 93°C after storage for 18 h at 4°C (Blackwell, 1978a).

$^\ddagger$Butter was made from cream heated for 16 s at 93°C. The pH of these samples was 5.4 (Blackwell, 1978a).
Virus was detected in cheddar cheese made from raw milk after 60 days of curing but not 120 days. This is in excess of the minimum curing time for this cheese. Virus was detected in cheese made from heated milk (67°C for 60 s) after preparation but not after 30 days of curing (Blackwell, 1976).

Virus was detected in cheese made from pasteurized (72°C for 16 s) milk after 21 days of curing but not 35 days. Twenty-one days is the normal curing time (Blackwell, 1976).

**The cheese is stored after manufacturing for at least 4 months at pH 5–5.6 (Kihm et al., 1979).

Extended form of resources used in Table 4 are located in Appendix A for use as reference.

(Ryan et al., 2008)

Strategies and Recommendations for Milk Processing:

**HTST**

United States processing plants typically use HTST pasteurization to process milk at temperatures ranging from 72°C to 81°C, with holding times consistent with the Pasteurized Milk Ordinance (see Table 1) and including time ranges up to 40 seconds. This is consistent with recommendations discussed below for inactivating FMD in the event of an outbreak.

**UHT**

In the United States, ultrapasteurized milk, sold in aseptic packages, is processed at temperatures that range from 137-143°C with holding times of 2 to 3 seconds. This process results in complete destruction of FMD virus in both whole and skim milk (Walker, de Leeuw, Callis, & van Bekkum, 1984).

The current International Animal Health Code recommendations issued by the World Organisation for Animal Health (OIE) to inactivate FMD in the event of an outbreak are as follows:

**Milk and cream for human consumption:**

For the inactivation of viruses present in milk and cream for human consumption, one of the following procedures should be used:

1) A sterilization process applying a minimum temperature of 132°C for at least one second (ultra-high temperature [UHT]), or

2) If the milk has a pH less than 7.0, a sterilization process applying a minimum temperature of 72°C for at least 15 seconds (high temperature - short time pasteurization [HTST]), or
3) If the milk has a pH of 7.0 or over, the HTST process applied twice.

Article 3.6.2.6. (Terrestrial animal health code - 2007)

These recommendations are based on findings of the scientific community to reduce FMD in milk.

Double HTST pasteurization could be implemented most efficiently by increasing the pasteurization temperature. In the event of an outbreak, however, it is unlikely that milk in the bulk tank would exceed a pH of 7 due to dilutional effects (Tomasula et al., 2007).

**Milk for animal consumption:**
For the inactivation of viruses present in milk for animal consumption, one of the following procedures should be used:

1) The HTST process applied twice, or

2) HTST combined with another physical treatment, e.g. maintaining a pH of 6 for at least one hour or additional heating to at least 72°C combined with desiccation, or

3) UHT combined with another physical treatment referred to in point 2 above.

Article 3.6.2.7. (Terrestrial animal health code - 2007.)

Lowering the pH of milk to 6 for one hour after HTST pasteurization is difficult to implement practically, however (Tomasula et al., 2007).

**DISCUSSION:**

The intent of this consultation was to explore public health risks associated with FMD, zoonotic potential of the virus, review documented human manifestations of disease, and discuss the effects of pasteurization on the virus. With the information addressing the mentioned queries, prevention strategies and recommendations can be made by Dairy Management Inc. (DMI) to address to the public.

Limitations experienced by the author in compiling an extensive database of historical research on FMD include that much of the information is accessible only in the original published language. Many articles are published in European languages other than English, making access to the entire FMD research database impossible for those (author of this document included) limited by language barriers. Information displayed in Table 1 regarding human FMD cases, type, and exposure sources was translated from an
CONCLUSIONS AND RECOMMENDATIONS:

It is of considerable epidemiological importance that FMD can be excreted in the milk of cattle, and most likely other milking animals such as goats and sheep, for several days before the clinical signs of disease become apparent. Once the disease has been recognized in a herd, however, the implementation of control measures and biosecurity ‘codes of practice’ for treating milk that is potentially infected should prevent further spread by that means (Donaldson, 1997).

Control measures including feeding animals only pasteurized milk, and careful handling of raw milk on the farm, in the milking parlor, at the bulk tank, and in transport (pick up and delivery) to the processing plant are paramount to prevent spread of FMD among animals and farms in the event of an outbreak.

As discussed, there are studies that demonstrate methods to reduce or eliminate FMD in milk and milk products. These studies provide adequate guidelines for appropriate milk and milk product processing to ensure food safety. Unfortunately, there are no published studies that fully quantify d- and z-values for FMD in food products. The d-value (decimal reduction time) is a measure of the heat sensitivity of a virus; defined as the length of time it takes for the quantity to decrease 10-fold at a given temperature. From measuring d-values at different temperatures, the thermal death time, which is the time it takes for virus levels to reach $10^0$ at a given temperature, can be calculated. The z-value is the temperature increase necessary to decrease the thermal death time 10-fold (Ryan et al., 2008). One study measured a thermal death time curve in milk derived from FMD-infected cows through plotting virus inactivation points against temperature and time (Walker et al., 1984), but further research to establish these parameters for FMD in a greater range of products would be very useful. This would enable a more accurate risk assessment posed by certain products (Ryan et al., 2008).

Overall Recommendation:

Although there are scientifically authenticated reports of human FMD infections, humans are generally considered to be non-susceptible to infection by the virus. If recommendations of the OIE and PMO are followed in processing and milk handling, DMI can relay the message that milk consumption is not a public health threat. Significant research accumulated by the scientific community and discussed in this document supports this statement on transmission and risk of exposure.
Key Points:

- Humans are generally considered to be non-susceptible to infection by FMD, rendering the disease an unlikely zoonosis.

- Humans have contracted the disease from close contact with animals, exposure to environments containing the virus, and drinking unpasteurized milk.

- Humans do not contract the disease from drinking pasteurized milk. No cases have been documented.

- In the event of a FMD outbreak, milk pasteurized in accordance with the Pasteurized Milk Ordinance is safe for human consumption. The process inactivates and can destroy the FMD virus. The current International Animal Health Code recommendations issued by the World Organisation for Animal Health (OIE) to inactivate FMD in the event of an outbreak should be utilized.

- It is recommended that individuals not drink unpasteurized milk from any animal, whether FMD infected or not, since the risk of infection by pathogens other than FMD remains.
References


Prempeh, H., Smith, R., & Muller, B. (2001). Foot and mouth disease: The human consequences. the health consequences are slight, the economic ones huge. *BMJ (Clinical Research Ed.)*, 322(7286), 565-566.


Appendix A. Bibliography of Sources utilized for generation of Table 4 (Ryan et al., 2008)

These articles may be of use in further review of FMDV

Bekkum, J. G. V., and P. W. D. Leeuw, 1978: Some Aspects of FMDV in Milk. 6th International Congress Veterinary Science, La Plata, Argentina


Appendix B: Stakeholder Information

Stakeholders:
This list of stakeholders represents the main groups involved in the questions posed by DMI in relation to FMD. Recognition of the roles that the stakeholders play is of paramount importance when developing materials that can be dispersed to various audiences. Each stakeholder’s relation to FMD prevention, control, and communication will be identified and their relevance to the topic briefly discussed.

University of Minnesota: School of Public Health and College of Veterinary Medicine:
- Communicators of risks.
- Influence economic implications due to value of product:
  Our perception of risk can influence how consumers view dairy products due to our influence on public perception of risk.
- Dairy product processing methods development. Methods design and improvement can take FMD control measures into account.

Dairy Industry Communicators:
- Communicators of risk.
- Inform public on standardized product – processing methods control and regulations.
- Responsible for relaying information to consumers on dairy products and food safety considerations.

Dairy Industry at all levels from farm to table:
- Evaluate and regulate product processing methods.
- Provide quality product to consumer.
- Economic implications due to value of product and loss of productivity.
- Psychosocial:
  Farmers would be directly impacted if fear of FMD in milk caused a decrease in milk value and resulted in economic hardship. Depopulation and quarantine of herds in a crisis situation would have psychosocial effects beyond just the loss of productivity.

Veterinarians:
- Economic implications due to value of product and loss of productivity.
- Can influence economic implications due to value of product:
  Their perception of risk can influence how consumers view dairy products due to their influence on public perception of risk.
- Communicators of risks.
- Ensure product processing methods are controlled.
- Responsible for relaying information to people regarding dairy products and production. Veterinarians are often the first source of information related to diseases such as FMD.
Milk Consumers:
- Influence the value of dairy products due to their perception of risk. Actions of all of the stakeholders involved will in some way influence the decisions of the milk consumer to continue or discontinue consumption.
- Need to be provided with safe, quality-assured product.

State Departments of Agriculture and USDA /APHIS:
- Communicators of risks.
- As representatives of the agricultural industry, they are responsible for relaying information to consumers regarding dairy products.
- Product processing methods control and regulation.
- Can influence economic implications due to value of product:
  Their perception of risk can influence the consumer’s view of dairy products due to their influence on public perception of risk.
- They are responsible for detection and control of disease outbreaks, and managing a crisis situation. This division would coordinate local, State, and Federal response and eradication efforts, coordinate interagency planning, and implement national communication and information-sharing strategies, as well as maintain contact with U.S. trading partners.

State Departments of Health and Human Physicians:
- Communicators of risks, especially in times of disease outbreaks and food safety concerns.
- Can influence economic implications due to value of product:
  Their perception of risk can influence the consumer’s view of dairy products due to their influence on public perception of risk.

Consumer Watchdog Groups / Non government organizations:
- Serve as unofficial communicators of risks.
- Can influence economic implications due to value of product:
  Their perception of risk can influence the consumer’s view of dairy products due to their influence on public perception of risk.

Recognizing the Role of Stakeholders Involved:

Dairy industry communicators are responsible for relaying information to consumers regarding pasteurized dairy products and reinforcing that FMD is an animal disease and not a public health threat. Milk and other dairy products are still safe to consume during an FMD outbreak. Persons in this field can have a positive economic impact on the value of milk if information is properly dispersed.

The Dairy Industry at all levels, from farm to table, can also serve to maintain the value of milk. Farm workers and managers are responsible for maintaining sanitary milking conditions and bulk storage of the product. As the product is transferred into the milk processing line, conditions specified by the PMO need to be followed and monitored.
on a continuous basis to ensure for destruction of FMD and other pathogens. These
groups would be directly impacted if fear of FMD in milk caused a decrease in milk
value and resulted in economic hardship. Depopulation and quarantine of herds in a crisis
situation would have psychosocial effects beyond just the loss of productivity.

Veterinarians are viewed as an expert opinion to clients, media, and general
public audiences. They are responsible for relaying information to people regarding dairy
products and discussing that FMD is an animal disease and not a public health threat
when consuming pasteurized milk. Veterinarians not involved in agricultural venues
would need to be informed of the current findings in the scientific community regarding
FMD and pasteurized milk as a non-risk to humans. Persons in this field can also have a
positive economic impact on the value of milk if information is properly dispersed.

State Departments of Agriculture and USDA /APHIS represent the agricultural
industry. They are responsible for detection and control of disease outbreaks, and
managing a crisis situation. As mentioned earlier, this division would coordinate local,
state, and federal response and eradication efforts, coordinate interagency planning, and
implement national communication and information-sharing strategies, as well as
maintain contact with U.S. trading partners. Their actions can have a positive economic
impact on the value of milk if information is properly dispersed and they ensure that milk
is properly processed.

State Departments of Health and human physicians are viewed as expert opinion
to clients, media, and general public audiences. Persons in this field can have a positive
economic impact on the value of milk if information is properly dispersed. Depopulation
and quarantine of herds in a crisis situation would have psychosocial effects on their
patients beyond just the loss of productivity and planning to address this should be
considered.

The dairy product consumer is influenced by information from all of the
stakeholders mentioned in this review. By properly dispersing information about FMD,
all other stakeholders can ensure the consumer of the scientific community’s findings
that, although humans have been documented as contracting FMD, the likelihood of
contracting the illness is very low and that pasteurization significantly decreases the
likelihood of infection to a point where FMD is not a public health threat.