Risks of introducing foot and mouth disease through the importation of beef from South America

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Summary
The safety of beef with respect to foot and mouth disease (FMD) is determined by the level of risk which the exporting region poses through disease prevalence, the reliability of the surveillance system of the region, the efficacy of the prevention and control measures, the efficiency of the Veterinary Services and the support of the private sector.
The South American continent has been regionalised in accordance with these criteria. Today there are approximately 90 million cattle in a territory of over 5 million km² comprising regions classified as having a very low to low level risk for FMD with regard to the export of animals and animal products. Another 50 million cattle live in regions classified as posing a moderate risk. These risk categories reflect varying levels of risk. The harvest of beef in the meat-exporting regions of South America includes a series of risk mitigation measures, from the origin of the source herd to the final packing of the beef. These measures reduce the unrestricted risk estimate by almost six orders of magnitude. Therefore, the final risk of FMD for the global trade of beef originating from the low risk regions in South America is extremely small.

Keywords

Introduction
Historically, livestock production has been one of the cornerstones of the economies of South American countries and the production of meat and meat products for export is an important economic activity of several countries. For the past ten years the mean annual exports of meat and meat products from the region is about 490,000 tons, representing a value of US$840 million (G. Davis and J. Leslie, personal communication). Figure 1 shows the location of the main cattle breeding and production systems of South America.
The southern region of the continent comprising the River Plate Basin area includes Argentina, Uruguay, Paraguay and the three southern states of Brazil (Rio Grande do Sul, Santa Catarina and Paraná). This region covers a territory of nearly 4 million hectares with 1,300,000 farms, and has a large livestock population consisting of 99 million cattle, 68 million sheep and 16 million swine (22).
The central region which encompasses the central states of Brazil (São Paulo, Mato Grosso do Sul, Mato Grosso, Minas Gerais and Goiás) and the eastern part of Bolivia (Beni and Santa Cruz) has an area of nearly 3 million hectares and a livestock population of 81 million cattle, nearly 1 million sheep and more than 11 million swine on about 660,000 farms (23).
The north-western region includes Colombia and the adjacent region of Venezuela (Zulia and Tachira) covering an area of 1,122,000 hectares and a livestock population of more than 8 million cattle, 1,700,000 sheep and 2,500,000 swine on 750,000 farms (23).

Historical perspectives
During the middle of the 19th century, improvements in the meat packing industry in South America led to a demand for
organise a campaign against FMD was Brazil, which launched a programme in Rio Grande do Sul in 1965. Paraguay and Uruguay initiated programmes in 1967, Chile in 1970 and Colombia in 1972. During the 1970s the national animal health services of each of these countries, with the assistance of international financial institutions, proceeded to restructure their animal health services, establishing the bases of many epidemiological surveillance and veterinary alert systems which are in operation today. In the 1960s, the percentage of cattle herds covered by FMD control programmes was only about 30%, which gradually increased to about 40% in the 1970s. In 1981 the figure reached 90%, but the control methodology adopted at the time did not take into consideration epidemiological differences of FMD in its spatial distribution resulting from economic-productive interactions. Rather, the strategies were based solely on mass vaccination of all susceptible animals, using inactivated saponin-hydroxide vaccines of questionable quality. For most of the continent, that policy served to maintain the epidemiological status quo and, at best, attenuated morbidity of the disease. The exception was Chile which, due to its distinctive geography and epidemiological conditions, was the first South American country to eradicate the disease using the mass vaccination strategy.

Influence of foot and mouth disease on South American economies

The more lucrative markets among FMD-free countries (such as the USA and Japan) were closed to imports of South American beef for a long period, due mainly to the presence of the disease on the continent. The Smoot-Hawley Tariff Act, adopted by the USA Congress in 1930, prohibited the importation into the USA of ruminants, pigs and meat and meat products of these animals from FMD-infected countries, except when those products were treated by heat and other methods which destroyed the FMD virus (8). Under this Tariff Act, countries were considered free from FMD when FMD had not occurred for at least one year and vaccination had not been practised. The Act stipulated that the importation of animals and their products had to be strictly regulated in the country of origin. All the countries of Central America, Mexico and Panama have regulations similar to those of the USA. Clearly, this situation placed South American meat exports at a competitive disadvantage. This zero-risk position, however, may be untenable with regard to articles 6.1 and 6.2 of the Agreement on the Application of Sanitary and Phytosanitary Measures of the World Trade Organisation (27) which states that a Member Country should recognise the concepts of low pest or disease prevalence, and should ensure that its sanitary and phytosanitary measures are
adapted to take into account the characteristics of regions from which products originate and to which products are destined. In doing so, the Member Country should take into account relevant geography, ecology, methods of surveillance and effectiveness of control systems (27). Thus, health requirements cannot be used as non-tariff trade barriers. Instead, international trade must be based on risk assessments and risk management.

A good example of managed risk is the importation by Europe of meat from South American countries under controlled conditions. Following the extensive FMD outbreaks in Europe between 1967 and 1968, the European Community (EC) established standards and procedures for the import of deboned frozen meat. These standards were based on strict rules and controls concerning the source of the cattle and conditions practised at abattoirs. The standards also require maturing and preparation of carcasses, including the removal of bones, lymph nodes and large blood vessels from the meat. These measures have been largely effective, since deboned frozen meat from millions of cattle have been exported to European countries – even in periods of extensive outbreaks of FMD in South America – without resulting in the introduction of the disease. In addition, during the past twenty years more than a million tons of deboned frozen meat were imported by the United Kingdom (UK), the fully susceptible livestock population of which remained free of FMD (26).

The advances recorded in reducing disease incidence during the 1980s, as well as the General Agreement on Tariffs and Trade (GATT) Uruguay Round discussions on non-tariff barriers in the world trade of meat and by-products of meat, convinced the livestock industry of the need to eradicate FMD from the continent. This favourable social, political and economic climate led to the formulation of the Hemispheric Plan for FMD Eradication (22). This proposal was accepted by the Inter-Ministerial Meeting on Animal Health in 1987, with two main objectives: to eradicate FMD from endemic areas and to maintain and consolidate the status of those zones which were already free of the disease. One of the first concrete achievements of the plan was the endorsement, in June 1987, of the subregional project for FMD eradication in the Rio de la Plata Basin, comprising the most southern state of Brazil (Rio Grande do Sul), Mesopotamia of Argentina (Provinces of Misiones, Corrientes and Entre Ríos), the entire territory of Uruguay and, more recently, the eastern region of Paraguay. The guidelines of the project included inter alia the participation of the local community, regionalising strategies and reinforced participation at the local level.

**Foot and mouth disease surveillance on the continent**

Sound, reliable information is the basis for any disease control programme or risk assessment. In South America, information on FMD is generated by the Continental Vesicular Disease Surveillance and Information System, co-ordinated and maintained by PANAFTOSA (3, 4). The system was implemented in 1973. Operational units are the national disease surveillance systems which report epidemiological information to PANAFTOSA on a weekly basis. PANAFTOSA disseminates the information through weekly and monthly epidemiological bulletins. Communication is immediate in case of an emerging epidemiological problem. The national vesicular disease surveillance systems use the existing animal health infrastructure, including over two thousand local field units of the national FMD programmes in operation on the continent. The data from these units is reinforced by effective private-sector participation, particularly by the livestock industry. The geographical coverage of each field unit is represented by a quadrant of a map of the country according to geographical coordinates (3). Each quadrant has a numeric code and all epidemiological information is identified accordingly for horizontal communication with other units or with the central level of each country, as well as with PANAFTOSA. The Continental Vesicular Disease and Information System receives support from the Regional Vesicular Diseases Diagnostic Reference Laboratory at PANAFTOSA and through a network composed of the national diagnostic laboratories.

The Continental Vesicular Surveillance Information System has provided up-to-date epidemiological information on the behaviour of FMD in the field and has alerted veterinary authorities on the development of higher risk situations and emerging problems. The information collected has allowed timely evaluation and orientation of animal health strategies for more effective and efficient control and eradication of FMD (5).

**Advances in the control and eradication of foot and mouth disease**

In the 1960s and 1970s, the entire continent was affected by FMD, except for Guyana, Surinam, French Guiana and the Patagonian region of Argentina. Severe epidemics occurred periodically, often generated by immunological variants of the virus. The frequency of the disease ranged from 200 to 300 cases in cattle per 10,000 animals and from 13 to 20 herds affected per thousand. During the 1980s, morbidity rates fell to 24 to 40 cases per 10,000 cattle, with 5 to 8 herds affected per thousand. This progress was basically a result of significant advances in vaccine production technologies and the implementation of more efficient vaccine potency control programmes in most countries of the continent. In particular, the large-scale application of oil-adjuvant vaccines, developed by PANAFTOSA (7, 10, 11) and later produced by official and
private laboratories, proved to be extremely beneficial. These FMD vaccines afforded higher levels of protection of longer duration, which increased the confidence of the livestock community in the value of the vaccination strategies. Thus, the improved vaccines and the strategic use of those vaccines became major tools in the control and eradication effort.

As shown in Table I, FMD incidence rates stabilised at 4 to 8 cases for 10,000 cattle and 1 to 2 herds affected per thousand between 1982 and 1990. In the period following the initiation of the Hemispheric Plan for FMD Eradication, these values decreased further until morbidity rates reached levels of 0.68 cases per 10,000 cattle and 0.22 herds affected per thousand herds in 1996. The significance of these figures is underlined by the fact that there has not been an outbreak of FMD in the southern area of the continent since 1995 (Table II).

Table III illustrates the progress of FMD eradication in South America over the past two decades. After Chile, Uruguay was the second South American country to be acknowledged as free of FMD. No cases of FMD have been recorded there since June 1990. In 1993 the Office International des Epizooties (OIE) declared the country 'free of FMD with vaccination' because of the soundness of the surveillance and control systems which existed in Uruguay. In June 1995 the government suspended vaccination and subsequently Uruguay was recognised by OIE as 'free of FMD without vaccination'.

The Patagonian region of Argentina south of the 42nd parallel is free of FMD without vaccination, and has maintained that status through a special surveillance programme between that parallel and the Rio Colorado, situated further north. Presently (January 1997), Argentina is seeking recognition of 'free of FMD with vaccination' status.

Paraguay did not record any outbreak of FMD in 1995 or 1996. Authorities in Paraguay consider the western half of the department of Alto Paraguay and the northern half of the department of Boquerón free of FMD without vaccination. The country has enjoyed freedom from FMD for two years, and is planning a serological survey to substantiate a request for official recognition by the OIE as a country 'free of FMD with vaccination'.

Brazil is making significant progress in controlling FMD. Rio Grande do Sul and Santa Catarina recorded the absence of FMD for over two years and the states of Paraná, Mato Grosso do Sul and Goiás have not had outbreaks for over a year. Thus the best livestock producing areas of the continent, comprising a territory with more than 140 million cattle in 1.3 million herds, are currently free of FMD.

Foot and mouth disease risk regionalisation

In 1995, PANAFTOSA proposed a regionalisation of South America according to risk levels for FMD (6). The map in Figure 2 illustrates the present situation in relation to that
regionalisation. Major considerations in determining the risk level of a region are the duration of absence of clinical cases, the presence or absence of FMD viral activity, and whether or not FMD vaccination is used to control the disease.

In the A1 and A2 risk level regions (Fig. 2), FMD must not have occurred for at least five consecutive years and vaccine must not have been used for at least one year. An FMD prevention programme must be in operation and must include import controls. Furthermore, the FMD situation and effectiveness of FMD surveillance in surrounding regions, the existence of natural or man-made barriers must be taken into consideration. The south of Chile, Patagonia and Uruguay are in this lowest risk level (A1), because of the absence of FMD and the existence of a non-vaccinated, fully susceptible livestock population, which guarantees the absence of any occult viral activity. In the same risk category are Surinam and French Guiana, countries with small cattle populations which share borders with the relatively high-risk Brazilian Amazon region, but which are separated from Brazil by a dense rain forest without livestock. In the A2 regions, which also present a very low risk, are Guyana and the north of Chile, which have non-vaccinated, fully susceptible livestock populations, but which are situated adjacent to regions with a less favourable FMD situation. The Chocó region in the north-west of Colombia, also an A2 region, recently suffered an outbreak of FMD, but the disease was promptly eradicated.

In B1 and B2 risk level regions, vaccination is used for FMD control. B1 level regions must not have had FMD for at least two years and there must be sufficient evidence, by survey methods or otherwise, to demonstrate the absence of viral activity in the livestock population. In B2 level regions, clinical FMD must have been absent for 1-2 years. Presently, large parts of the South American continent with the majority of the best cattle-raising regions are in B risk regions. For instance, the low risk B1 region comprises Argentina (excluding Patagonia), Paraguay and the two southern states of Brazil (Rio Grande do Sul and Santa Catarina). In moderately low risk level regions (B2) are the Brazilian States of Paraná, Mato Grosso do Sul and Goiás.

The remaining areas of the continent have higher levels of FMD risk. Regions with C risk levels only have sporadic cases of FMD and they must have advanced control programmes which aim at eradication. Regions classified as D risk are those in which FMD is endemic.

Risk mitigation measures

All levels of risk mentioned above refer to unrestricted risk; that is, the risk to the animal health of an importing country if animals or animal products were to be imported without the implementation of risk mitigation measures (1). Examples of risk mitigation measures include quarantine, diagnostic testing, inspections, processing and restricted use. For instance, the EC rules applied to the harvest of meat for export to the EC made this commodity apparently safe for importation under the conditions which existed at that time in Europe (14, 15). These risk mitigation procedures have been in use routinely for the past 20 years and have made an important contribution towards the development of a safe and highly technical meat industry. The EC standards for risk mitigation can be summarised as follows:

a) The region from which the source cattle for the meat shipment originate must have regular, officially controlled FMD vaccination programmes. This requirement was revoked for Uruguay when the vaccination programme ceased. Source animals must have remained in the region for at least three months before being slaughtered. Source cattle may not originate from herds within a radius of 25 km from premises
on which FMD occurred 60 days previously. The source animals are to remain in their holdings of origin for at least 40 days before departure to the abattoir.

b) Source cattle are to be transported directly to an EC-approved abattoir without passing through a market, and must be separated from animals which do not comply with EC requirements for meat imports. The trucks used to transport cattle must be cleaned and disinfected before loading.

c) The cattle must rest for at least twenty-four hours during which time they should pass ante-mortem inspection. At ante-mortem (and post-mortem) inspection there must be particular emphasis on examination of the mouth and feet.

d) The carcass should be matured for 24 hours at a temperature of 3°C-7°C, after which the acidity level should be measured in the middle of the longissimus dorsi muscle. A pH lower than 6.0 is required for export. Bones, bone fragments, superficial lymph nodes and large blood vessels must be removed from the meat.

PANAFTOSA, in co-operation with the Tuskegee University School of Veterinary Medicine in the USA, attempted to quantify the FMD risk posed to Caribbean countries by the importation of beef from Uruguay and selected regions in Argentina (25). The study indicated that for the Caribbean countries, the likelihood of transmission of FMD through meat imported from Uruguay and the region in Argentina would be very small. Based on a similar quantitative approach, the authors here attempt to evaluate more specifically the risk reduction resulting from the high technical standards of the regional meat industry in the context of the FMD risk regionalisation.

**Scenario pathway and computer simulation**

Quantitative risk analysis (QRA) techniques have been used for many years in engineering and economics (17, 20), but are relatively new to veterinary medicine (16, 18, 19, 21). Such studies make use of branches of science such as epidemiology, statistics, mathematics, virology and pathology, and in this case of meat technology. Scenario pathway analysis (17, 19) is one of the methodologies which may be used to evaluate the risks of animal product importation. A QRA commences with the identification of a disease hazard posed by the importation of animals or animal products. A pathway of events is then traced for the commodity concerned, from the point of origin to final destination, in which each event determines whether the pathogen remains hazardous. The probability of the outcome is assessed quantitatively for each event. The accumulation of the probabilities of the outcome of all the events in the pathway constitutes the total measure of risk related to the importation (17, 21).

Figure 3 shows the scenario pathway used for the present assessment. The initial hazard is the importation of meat from South America if an FMD-infected source herd were to be included (the probability of including an infected herd depends on the disease incidence and the tonnage of meat to be exported). The first event in the scenario is the detection of FMD, or not, in the infected source herd. If FMD is detected, the herd is disqualified for meat export. The next event is inspection of the cattle on the way to the abattoir. Other important risk mitigation events are the detection of FMD during ante- and post-mortem inspections. If FMD were still in the pathway at this point, it may then be eliminated by the maturation and deboning process or during freezing and storage of the meat. Table IV summarises the risk mitigation process, starting with E_initial, which is the export of meat from an FMD-infected source herd. Thus, the probability of the hazard occurring is 100% at this event (P_initial = 1). P_1-P_6 are the probabilities that Events 1-6 (E_1-E_6) occur. These probabilities are as follows:

P_1 is the probability that the animal health surveillance system fails to detect FMD in the infected source herd;
P_2 is the probability that transit controls fail to detect FMD in the herd en route to the abattoir;
P_3 is the probability that ante-mortem inspection fails to reveal FMD in the herd after arrival at the abattoir;
P₆ is the probability that post-mortem meat inspection fails to observe FMD lesions in one or more of the animals of the herd;

P₃ is the probability of maturing and deboning failing to destroy or remove all FMD virus;

P₄ is the probability of failure to destroy all FMD virus during freezing and transport of the meat.

\[ P_{\text{end}} = P_{\text{initial}} \times P_1 \times P_2 \times P_3 \times P_4 \times P_5 \times P_6. \]

For a first qualitative approximation, estimates can be made for each P according to a worst case scenario. However, the use of only one estimated value gives a very incomplete picture of the real risks involved, and ignores the fact that it is an estimate of only one potential outcome. In fact, a variety of values exist for each P which estimate the range (minimum and maximum) and a most-likely probability. Such values can then be used to simulate a so-called triangular probability distribution function (PDF) for each event in the scenario pathway. The PDFs which are generated for each event in the scenario tree can be combined by using computerised Monte Carlo simulation techniques. The authors used the commercially available @RISK® program to generate a cumulative PDF to represent the total risk mitigation from all events of the complete scenario.

For the product of \( P_{\text{initial}} \times P_1 \times P_2 \times P_3 \times P_4 \times P_5 \times P_6 \), evaluating the final probability (\( P_{\text{end}} \)) of occurrence of the hazard assumes that each P value is completely independent. However, if certain values are not completely independent, the @RISK® program allows for the introduction of a correlation factor. In the present work it was assumed that ante-mortem inspection (\( P_3 \)) and meat inspection (\( P_4 \)) have a certain degree of dependency (the level of detection efficiency at a given abattoir is related to the quality of local inspectors). However, simulations using high and low dependency between \( P_3 \) and \( P_4 \) only had a marginal effect on the final results.

### Probability values for each event in the scenario pathway

The values assigned to each of the probabilities in the pathway were similar to those used in an earlier study (25) for the quantification of the FMD risk for Caribbean countries through the importation of beef from Uruguay and selected regions in Argentina. However, some of the values were adjusted to reflect the present risk regionalisation. The estimates are based on arguments described below, on official records, and on well-informed estimates by the authors and specialists consulted. However, if there was any doubt, the worst case scenario was adopted rather than risk criticism for excessive optimism.

\( P_i \): probability that animal health surveillance system fails to detect foot and mouth disease

The livestock community is well aware of the socio-economic consequences of not reporting a suspicious vesicular disease. Of particular importance are the activities of the local commissions, in which there is a high degree of community participation. Certificates are issued for moving source animals, declaring their origin, the FMD vaccination status of the herd, the freedom of FMD of the herd and of the surrounding area within a 25 km radius for at least 60 days. Source animals remain in the region for at least three months and at their holdings of origin for at least 40 days before departure to the abattoir. Countries exporting beef maintain an active surveillance system to trace suspected cases of vesicular disease. For instance, 104 suspected cases were reported and investigated in Uruguay between 1991 and 1994. None of these proved to be FMD, but it is interesting to note that the majority of the notifications were made by private veterinarians or the owners and handlers of the animals. The time-lapse between notification and response of the Veterinary Services was a matter of hours (13). The authors assumed that under these conditions the probability that the surveillance system would fail to detect FMD in herds

### Table IV

Risk reduction scenario for the probability of exporting meat with foot and mouth disease (FMD) virus from South America, assuming that the herd of origin was infected

<table>
<thead>
<tr>
<th>Event</th>
<th>Description of event</th>
<th>No risk pathway*</th>
<th>Risk pathway</th>
<th>Probability (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eᵣᵣᵣᵣ</td>
<td>Export of meat from an infected source herd</td>
<td>Yes</td>
<td>No</td>
<td>( P_{\text{initial}} = 1 )</td>
</tr>
<tr>
<td>E₁</td>
<td>Animal health surveillance system detects FMD in the infected source herd</td>
<td>Yes</td>
<td>No</td>
<td>( P_1 )</td>
</tr>
<tr>
<td>E₂</td>
<td>During transit controls FMD is detected in the herd en route to the abattoir</td>
<td>Yes</td>
<td>No</td>
<td>( P_2 )</td>
</tr>
<tr>
<td>E₃</td>
<td>At ante-mortem inspection FMD is detected in the herd</td>
<td>Yes</td>
<td>No</td>
<td>( P_3 )</td>
</tr>
<tr>
<td>E₄</td>
<td>At post-mortem meat inspection FMD lesions are observed in one or more of the animals of the herd</td>
<td>Yes</td>
<td>No</td>
<td>( P_4 )</td>
</tr>
<tr>
<td>E₅</td>
<td>FMD virus survives maturing and deboning</td>
<td>No</td>
<td>Yes</td>
<td>( P_5 )</td>
</tr>
<tr>
<td>E₆</td>
<td>FMD virus survives freezing and transportation of the meat</td>
<td>No</td>
<td>Yes</td>
<td>( P_6 )</td>
</tr>
<tr>
<td>E₇</td>
<td>Contaminated meat exported from South America</td>
<td></td>
<td></td>
<td>( P_{\text{end}} = P_{\text{initial}} \times P_1 \times P_2 \times P_3 \times P_4 \times P_5 \times P_6 \times P_7 \times P_8 \times P_9 )</td>
</tr>
</tbody>
</table>

* The "No risk pathway" assumes that action is taken to stop the entire shipment once evidence of FMD is discovered in even one animal in the shipment.
designated for the export of beef was remote. However, failure to detect FMD could occur in areas with high vaccination coverage and low morbidity, or if all the source cattle were still within the incubation period. A conservative estimate of the probability that such conditions would occur was assumed to be in a range of 1%-10%, with a likely value of 5%.

**P₂:** probability that foot and mouth disease is not detected during transit

Source cattle are transported directly to the approved abattoir without passing through a market. They do not come into contact with animals which do not comply with the EC meat import requirements. All people involved in the transportation of livestock have an obligation to report any disease sign which might suggest FMD. If clinical cases of FMD are present, those probably would be observed and reported. However, people involved in transit controls are probably less efficient than those working with the animal health surveillance system. In addition, FMD could still be in the incubation stage. The assumed range of 5%-50% and a most-likely value of 20% reflect this situation.

**P₃:** probability that foot and mouth disease is not detected during ante-mortem inspection

Upon arrival at the abattoir, all documents are reviewed by a Veterinary Services official before the animals disembark. If everything is in order, the cattle move into a reception pen for ante-mortem inspection. At this point, individual animals are identified with the identification number and the herd number of the producer. Only animals belonging to the same herd are kept in the same resting pen. These pens are well lit and the cattle remain there for at least 24 hours, but not longer than 72 hours. Since FMD has a short incubation period, infection of the animals either at the farm of origin or in transit would probably be visible, with lesions on at least a few animals. It would be difficult to miss the feverish, salivating or lame animal and, therefore, the probability that the inspection process fails to detect at least one FMD animal is low. The detection of one animal with FMD would cause the cancellation of all meat exports from that abattoir or region. The probability of failing to detect at least one animal with signs of FMD was estimated to be 1%-10%, while the most-likely probability was estimated to be 5%. These values are very conservative and may be too pessimistic.

**P₄:** probability that foot and mouth disease is not detected during post-mortem inspection

After at least 24 hours of rest, the animals are moved as a herd for slaughter. The basis for dealing effectively with the detection of FMD at post-mortem inspection is the identification system of each individual animal. As the skin is being removed, the initial identification numbers are printed on each quarter. In addition, each half carcass, the head, organs and intestines are all given the same number to facilitate retrieval of parts if any pathology were observed during post-mortem inspection. Of particular importance is the identification of the head and feet of each individual animal. Meat inspection technicians inspect the carcass after removal of the skin. If a pathology is observed, the area of concern is tagged and the entire animal is placed aside to await judgement of a veterinary officer. The tongue, oral mucosa, muzzle and feet of all cattle are inspected individually for acute or recovered vesicular lesions. It would be difficult for an inspector to miss developing vesicles or acute lesions. If the herd was infected shortly before leaving the farm or during transport, it is likely that at least a few of the animals would have developed lesions by this stage. Healing lesions of the convalescent animal are also very characteristic and would probably be found in more than one animal of the herd. As in the entire inspection process, any FMD foot lesion or any tongue lesion would cause an immediate interruption of all meat export operations from that abattoir (and in a low risk area from that region).

On account of the thorough individual inspection of each carcass, the authors assumed that the post-mortem inspection process would be at least five times more sensitive than the ante-mortem inspection.

**P₅:** probability that foot and mouth disease virus survives maturation and deboning

After 24 hours of maturing at a temperature of 3°C-7°C, the acidity level is measured and a pH value of lower than 6.0 is required, since at that level FMD virus rapidly disintegrates. However, the effectiveness of the maturation depends on the amount of glycogen in the muscle at the time of slaughter, which in turn is influenced by the general health and the resting period of the animal. In addition, the desired pH is not always reached within lymph nodes, bone marrow or the contents of large blood vessels (12). These parts therefore are removed, but human error cannot be completely ruled out in the reading of pH measurements and during the deboning operation. For instance, blood clots, bone chips and pieces of large vessels or parts of lymph nodes might not be removed completely.

No data are available on the kinetics of virus inactivation in meat at a pH of 6.0. In the absence of such information, it is difficult to estimate the amount of FMD virus which might survive in the meat of a matured, deboned carcass from a viraemic animal. For the above-mentioned reasons, the authors arbitrarily selected 10% as the most-likely probability for carcasses of viraemic cattle to yield contaminated meat. The probability level was assumed unlikely to be less than 1% and not more than 30%. However, these figures may be overestimated, because experience with the importation of large quantities of deboned meat by Europe during epidemic periods supports the notion that the maturation process of the carcass is very effective.

**P₆:** probability that foot and mouth disease virus survives freezing and transport

Since FMD virus resists freezing and survives in frozen meat, the probability of virus survival was assessed as being close to 100%.
Results of computer simulation

The above-estimated values were entered in an Excel®/RISK worksheet (Table V) for the simulation of the probability that FMD virus might remain in the chain of events.

Table V
Excel®/RISK worksheet for estimating effects of risk mitigation for foot and mouth disease (FMD) during harvest of meat from South America

<table>
<thead>
<tr>
<th>Event</th>
<th>Probability of failure of risk reduction measures and survival of FMD virus in meat from infected herd</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$ FMD not detected in source herd at origin</td>
<td>0.01 0.05 0.1</td>
</tr>
<tr>
<td>$P_2$ FMD not detected by transit control</td>
<td>0.05 0.2 0.5</td>
</tr>
<tr>
<td>$P_3$ FMD not detected during ante-mortem inspection</td>
<td>0.01 0.05 0.1</td>
</tr>
<tr>
<td>$P_4$ FMD not detected during meat inspection</td>
<td>0.002 0.01 0.02</td>
</tr>
<tr>
<td>$P_5$ Survival of FMD after maturing and deboning</td>
<td>0.05 0.1 0.3</td>
</tr>
<tr>
<td>$P_6$ Survival of FMD during freezing and transport</td>
<td>0.9 0.95 0.99</td>
</tr>
</tbody>
</table>

Figure 4 shows the resulting PDF. The same data are presented as an ascending cumulative graph in Figure 5.

The expected result that meat still contains FMD virus at the end of the chain is represented by the midpoint of the PDF, which is $10^{-6.1}$, meaning a chance of slightly more than one in a million. The cumulative graph predicts, with a 95% probability, that this risk will not exceed $10^{-5.5}$ or one in 700,000. Even with the rather crude estimates used, which probably favour a worst case scenario, it is clear that a very large risk mitigation factor is obtained by adhering to strict standards for the harvesting of the beef for export to the EC as practised in South America.

Discussion and conclusions

Risk evaluation or risk assessment has been used ever since the spread of animal diseases was contained by such measures as quarantine and control of animal movements. These assessments were mostly qualitative, were often both intuitively and scientifically based and were usually quite effective. Risk assessments, whether qualitative or quantitative, must be consistent, transparent and well documented (17, 19, 21). The information and conclusions on the risks involved must be presented clearly and in such a manner that the results can be readily understood by decision-makers and can help them choose a course of action. When new information becomes available, a risk assessment must be easy to update and to revise. The risk regionalisation for FMD presented by PANAFTOSA clearly fits these criteria. The method is derived from a much more comprehensive proposal made by the United States Department of Agriculture (2), but with the specific objective of regionalising risk levels for FMD. It is supported by epidemiological information provided by the Continental Vesicular Disease Surveillance and Information System and a network of national diagnostic laboratories co-ordinated by the Regional Diagnostic Reference Laboratory for Vesicular Diseases at PANAFTOSA. When new epidemiological information is generated, or when the disease status of a region changes, an updated risk regionalisation can be prepared and published.

Presently, a large area of the continent with excellent cattle-raising areas is included in low to moderate risk regions. As is the case everywhere else in the world, it is possible that FMD might be reintroduced into those regions. However, the chances of this happening become less likely with the progressive advances made in disease eradication in the remaining, higher risk areas of the continent. The national veterinary surveillance systems in the low-risk regions maintain active surveillance of possible vesicular disease cases and appear well prepared to deal with an eventual
reappearance of FMD. Chile has experienced an outbreak twice (in 1984 and 1987), and has successfully eradicated the disease on both occasions. Similarly, in 1993 the southern states of Brazil (Santa Catarina and Rio Grande do Sul) suffered an outbreak of FMD following the movement of infected swine, after a period of two years without clinical disease. Here again the disease was successfully eradicated. The high level of technology of the meat industry in beef-exporting regions of the continent, which includes the control of the commodity from the premise of origin to the final product, provides an additional risk reduction factor of the order of a 1/700,000 to one in a million. The combination of low regional risk levels and very efficient risk mitigation determines the ultimate safety of South American beef for the international market.

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Risques de fièvre aphteuse liés à la viande bovine en provenance d'Amérique du Sud

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Résumé

Pour une région productrice de viande bovine, la sécurité de ses exportations au regard de la fièvre aphteuse dépend du niveau de risque déterminé par la prévalence de la maladie dans la région, de la fiabilité de son système de surveillance, de l'efficacité des mesures de prévention et de contrôle, de l'efficacité des Services vétérinaires et de la collaboration du secteur privé. Sur la base de ces critères, l'Amérique du Sud a été divisée en différentes régions. Actuellement, les régions présentant un risque défini comme très faible ou faible au regard de la fièvre aphteuse lors d'exportation d'animaux et de produits d'origine animale représentent plus de 5 millions de km² avec environ 90 millions de têtes de bétail. Les régions classées comme présentant un risque modéré comptent, quant à elles, 50 millions de bovins. Ces catégories correspondent à des niveaux de risque différents. La filière de la viande dans les régions exportatrices d'Amérique du Sud met en œuvre une série de mesures de diminution des risques, depuis le troupeau d'origine jusqu'au conditionnement final. Ces mesures permettent de diviser par six les risques précédemment évalués. Par conséquent, le risque de fièvre aphteuse lié au commerce mondial de viande de bœuf en provenance des régions à faible risque d'Amérique du Sud est, in fine, extrêmement réduit.

Mots-clés

Riesgos de fiebre aftosa en la carne vacuna de origen sudamericano

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Resumen
El grado de seguridad que ofrece la carne de vacuno en cuanto a su posible contaminación por el virus de la fiebre aftosa viene determinado por diversos factores: el nivel de riesgo asociado a la prevalencia de la enfermedad en la región exportadora; la fiabilidad del sistema de vigilancia de dicha región; la eficacia de las medidas de control y prevención; la eficiencia de los Servicios Veterinarios; y el grado de colaboración del sector privado.

El continente sudamericano ha sido subdividido en regiones con arreglo a estos criterios. Hoy en día existen alrededor de 90 millones de cabezas de ganado vacuno en regiones calificadas de bajo a muy bajo riesgo de fiebre aftosa en lo que a la exportación de animales o productos animales se refiere. Ello representa un territorio de más de 5 millones de km². Otros 50 millones de cabezas de ganado vacuno viven en regiones clasificadas como de riesgo moderado. Estas categorías reflejan varios niveles de riesgo. En las regiones exportadoras de Sudamérica, el sector productor de carne aplica una serie de medidas encaminadas a reducir los riesgos desde el rebaño de origen hasta la preparación final de la carne. Estas medidas reducen en casi seis órdenes de magnitud el riesgo en relación al riesgo no limitado. Por ello, el riesgo final de transmisión de fiebre aftosa por los intercambios internacionales de carne vacuna procedente de regiones sudamericanas de bajo riesgo es, de hecho, ínfimo.

Palabras clave

References


