The potential risks to animal health from imported sheep and goat meat

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Summary
Alerted by outbreaks of foot and mouth disease and the swine fevers which have been attributed to international trade in meat, regulators have tended to adopt conservative policies with respect to the importation of meat. However, for disease introduction to occur as a result of meat importation, a number of criteria must be satisfied.

A qualitative assessment of the risks posed by sheep and goat meat leads to the conclusion that, with the possible exception of foot and mouth disease, there is little likelihood that Office International des Epizooties List A or List B diseases would be spread through trade in adequately matured meat obtained from animals which have passed veterinary ante-mortem and post-mortem inspections.

Keywords
Foot and mouth disease - Goat diseases - Goat meat - Imports - Risk analysis - Risk assessment - Sheep diseases - Sheep meat - Trade.

Introduction
The discipline of risk analysis has only relatively recently been applied to the importation of animal products such as meat (30). The incentives to develop a structured, objective, repeatable and transparent process of risk analysis have followed the establishment of the World Trade Organisation (WTO) and the promulgation of the Agreement on the Application of Sanitary and Phytosanitary Measures (51). This agreement (the so-called 'SPS Agreement') requires WTO members to remove barriers to trade in agricultural products, except in situations where such trade can be demonstrated to jeopardise the animal, human or plant health in the importing country.

Risk, as it relates to the importation of animals or animal products, is a measure of the probability of the introduction of disease and the seriousness of such an outcome. Risk analysis is a blend of inductive and deductive reasoning and judgement (31).

The process of risk analysis is considered to comprise risk identification, risk assessment, risk management and risk communication. Risk assessment is the process of estimating, as objectively and transparently as possible, the probability that an importation would result in the introduction of disease. It takes into account the prevalence of pathogens in the source population, the probability of those pathogens surviving in the product during processing, storage and transport, the probability of the pathogen coming into contact with local livestock after importation and the repercussions of such contact. There is a substantial body of information on the survival of pathogens in many animal products, such as meat. The intention of this paper is to provide qualitative assessment of the risk that sheep and goat meat could serve as vehicles for a number of diseases of livestock.

The approach used in this paper has been to examine the potential risks in a way that is, it is hoped, useful to the regulator. A qualitative, rather than quantitative, approach was chosen because it serves little purpose to attempt to quantify the risks in any generic sense, as a useful risk assessment will be based on a number of important variables which are specific to both the exporting and importing countries. This is not to say that a quantitative risk assessment cannot be conducted for specific imports and, indeed, such assessments may well be warranted when considering specific import proposals (36).

Meat as a vehicle for livestock diseases
For meat or meat products to serve as vehicles for the introduction of animal disease, a number of criteria must be met (29):
- the disease must be present in the country of origin
- the disease must be present in the particular animal
slaughtered (or the carcass must have become contaminated during the butchering process)

- the diseased meat must pass inspection procedures
- the pathogen in the meat must survive storage and processing and be present at an infectious dose
- the pathogen must be present in the tissues traded
- the pathogen must be able to establish infection by the oral route
- scraps of the meat product must find their way into a susceptible animal of the appropriate species in the importing country.

The likelihood of each of these criteria being met will be different for each pathogen and country of origin. However, with one or two exceptions, the probability that all criteria will be met for any one disease is low.

One further criterion must be fulfilled before a disease poses a risk to the livestock industry of the importing country, namely: if the agent establishes infection in a susceptible host in the importing country, local conditions must be such that the disease could spread and become endemic.

This criterion is particularly relevant for those diseases which are transmitted by arthropod vectors which are not present in the importing country.

With the exception of pathogens which can survive the processes involved in the manufacture of meat-and-bone meal, for a disease carried in sheep or goat meat to be introduced into an importing country, the pathogen must be one that can infect a dog, cat, pig or other meat-eating animal. Sheep and goats are unlikely to be infected directly by pathogens carried in meat.

An important safeguard against introducing many exotic virus diseases is the drop in the pH of meat which accompanies rigor mortis. Provided that meat is matured to a pH below 6.0, the more important viruses, if present, are likely to be inactivated. However, the ultimate pH of meat is affected significantly by the physiological condition of the animal prior to slaughter (35). In animals with low muscle glycogen reserves, as can occur when the animal has been stressed prior to slaughter, an ultimate pH greater than 6.0 is not uncommon. Adequate resting prior to slaughter is important to ensure that muscle pH falls below 6.0 and, for this reason, slaughtering practices should be considered when conducting a risk analysis.

Diseases considered

An earlier review (29) examined all the Office International des Epizooties (OIE) List A and List B diseases, the Food and Agriculture Organisation (FAO) List C diseases, and various miscellaneous diseases of livestock and poultry and concluded that only 53 diseases warranted detailed consideration for possible carriage in meat. Reasons for removing pathogens from the list included:

- the pathogen is not present in edible tissues
- carnivorous or omnivorous species are not susceptible to infection
- infection does not occur by the oral route
- transmission of infection requires an arthropod vector.

The current paper examines OIE Lists A and B diseases of sheep and goats discussed in the earlier review, as well as Rift Valley fever, sheep pox and goat pox, Mycoplasma species and Maedi-Visna (Table I).

Foot and mouth disease

Foot and mouth disease (FMD) is one of the most contagious diseases of domestic animals. It is an acute viral disease which affects a wide variety of domesticated and wild cloven-hoofed animals including cattle, sheep, goats and pigs. FMD is characterised by the formation of vesicles and erosions of the mouth, nose, feet and teats, but infections in sheep and goats are often subclinical (18).

Meat as a vehicle

Many outbreaks of FMD have been traced to waste food being fed to pigs (18). The outbreak which occurred in the United Kingdom in 1967 was attributed to the importation of sheep carcasses from South America which contained virus in the bone marrow.

Most of the research on the survival of FMD virus (FMDV) in meat has involved beef or pork and one might assume that the
findings are applicable to sheep and goat meat. In beef and pork, the drop in pH to between 5.5 and 6.0 which usually accompanies rigor mortis ensures that FMDV is inactivated. Minced meat contains the virus, a core temperature of 93°C is required to ensure complete inactivation (4). The OIE International Animal Health Code (37) recommends thorough cooking (Article 4.3.2.1) and specifies that after deboning and defatting, the meat should be heated to maintain a core temperature of 70°C or greater for at least 30 minutes. However, recent studies have suggested that higher core temperatures or longer cooking times may be necessary to ensure complete inactivation of FMDV (27, 32, 38).

High salt concentration does not inactivate FMDV in meat products. In products in which the meat has matured before being salt-cured, the virus does not survive in muscle tissues (because of the pH changes) but may persist in lymph nodes, large blood clots, bone fragments and fat. The mincing and mixing processes used in the manufacture of sausages and similar products reduce the chances of FMD virus survival. However, FMDV can survive for prolonged periods in high salt concentrations such as those used to preserve sausage casings (14).

At pH 6.0, FMDV is inactivated at a rate of 90% per minute. At pH 5.0, the rate of inactivation is 90% per second (46). Böhm (11) demonstrated that infected intestines could be freed of FMDV by washing in 0.5% citric or lactic acid for 5 minutes. This is the basis for recommending that sausage casings be treated with 0.5% to 2.0% lactic or citric acid, or a citric acid buffer system (pH 5.3), for 8 to 10 hours.

The low pH of lactic-cured sausages such as salamis, which may contain sheep meat, ensures that FMDV is inactivated within a week, even if such products are made with the meat of viraemic animals (39).

The risk of introduction

There is a risk that the pH changes associated with rigor mortis may not be sufficient to inactivate the virus in muscle of sheep slaughtered during the febrile phase of FMD. Further, FMDV may persist in the bones and lymph nodes of infected animals. Realistically though, the only way FMDV in meat is likely to enter livestock in an importing country is if infected tissues are fed to pigs. In examining this risk, two factors (apart from those discussed above) need to be taken into account. These are:

- the concentration (titre) of FMDV likely to be present in the meat
- the dose of FMDV required to infect pigs by the oral route.

FMDV may be present in the edible tissues of living animals from the time of onset of viraemia until an immune response to the infection has developed (14, 48). Viraemia usually begins about one day before, or coincides with the first appearance of vesicular lesions, and (in cattle at least) lasts for three to five days. The virus titres will be at their greatest from the time of onset of viraemia until an immune response has developed.

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<tr>
<td>Rift Valley fever</td>
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<tr>
<td>Paste des petits ruminants and rinderpest</td>
<td>A</td>
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<tr>
<td>Sheep pox and goat pox</td>
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<tr>
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<td>B</td>
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<tr>
<td>Augeray's disease</td>
<td>B</td>
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<tr>
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<tr>
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<tr>
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<td>B</td>
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<tr>
<td>Maedi-Visna</td>
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<tr>
<td>Mycoplasmosis</td>
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<tr>
<td>Paratuberculosis</td>
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<td>0 fever</td>
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<tr>
<td>Rabies</td>
<td>B</td>
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<tr>
<td>Salmonellosis (Salmonella abortus ovis)</td>
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<tr>
<td>Scaple and bovine spongiform encephalopathy</td>
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<tr>
<td>Tuberculosis (Mycobacterium bovis)</td>
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### Table I

**Diseases of sheep and goats which could, theoretically, be carried in carcasses, meat, offals or meat products**

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However, recent studies have suggested that higher core temperatures or longer cooking times may be necessary to ensure complete inactivation of FMDV (27, 32, 38).
- \(10^{8.2}\) ID\(_{50}\)/g in retropharyngeal lymph nodes
- \(10^{6.0}\) ID\(_{50}\)/ml in blood
- \(10^{3.6}\) ID\(_{50}\)/g in liver.

These peaks were recorded on the second day after inoculation. By the fourth day the titres in blood and liver had dropped to \(10^{3.5}\) ID\(_{50}\)/g or less. The concentration in bone marrow declined to \(10^{1.6}\) ID\(_{50}\)/g by the sixth day after inoculation. Data for sheep and goats have not been documented as thoroughly, but peak titres of \(10^{5.0}\) ID\(_{50}\)/g or less have been reported for bone marrow and blood respectively (42) and Gomes et al. (21) reported titres of \(10^{3.0}\) to \(10^{3.7}\) ID\(_{50}\)/g in kidneys and \(10^{1.8}\) to \(10^{4.9}\) ID\(_{50}\)/g in various lymph nodes.

A relatively high dose of FMDV is required to infect by the oral route. The minimum dose required to infect pigs by ingestion has been reported as \(10^{5.0}\) ID\(_{50}\) (42). To receive such a dose a pig would need only to consume around a gram of blood from an animal at the peak of viraemia. However, the pig would need to consume 100 g of bone marrow containing \(10^{4.0}\) ID\(_{50}\)/g or 1 kg of liver containing \(10^{3.0}\) ID\(_{50}\)/g. For tissues containing \(10^{1.0}\) ID\(_{50}\)/g or less, the amount to be eaten would need to be greater than the daily intake (42). Nevertheless, caution is needed before dismissing the risks posed by such tissues. It may be that there are circumstances where an animal could be infected by doses smaller than those suggested above, perhaps through virus being inhaled into the nostrils rather than ingested. Given the serious effects which would result from an introduction of FMDV, precautions should take into account the unusually susceptible host, unusually invasive or pathogenic strains of the virus and environmental conditions unusually favourable to virus survival.

Importation of boneless chilled or frozen beef from countries in which FMD is present may be permitted safely, provided certain conditions are met (37). The most important of these conditions are that the beef originates from deboned carcasses which, prior to deboning, have been matured at a temperature above 2°C for a minimum of 24 hours and in which the pH value is below 6.0 when tested in the middle of the longissimus dorsi muscles. As the pH of meat of sheep slaughtered while febrile may not fall below 6.0 (21), testing muscle pH would be an essential safeguard if importing sheep meat from a country in which FMD is endemic. However, because FMD can be mild or inapparent in sheep and goats, because these species are not routinely vaccinated (thus are at a greater risk of being viraemic) and because, in general terms, it is considered impractical to debone sheep and goat carcasses prior to export, the recommendations of the International Animal Health Code are not considered applicable to these species.

**Rift Valley fever**

Rift Valley fever (RVF) is a mosquito-borne viral disease of cattle, sheep and goats characterised by necrotic hepatitis and haemorrhages and abortions in pregnant animals. Although mortality rates may be high in newborn animals, infections may also be mild or inapparent. RVF is a zoonosis.

RVF virus (RVFV) is transmitted by a wide range of insect vectors including Aedes, Anopheles and Culex species which may become infected by feeding on viraemic livestock or humans.

**Meat as a vehicle**

The liver is the primary site of replication of RVFV and high titres are achieved in most susceptible animals (13, 16). However, viral infectivity is lost rapidly below pH 6.8 (13).

While humans can become infected through handling contaminated tissues of diseased animals at slaughter (10, 13) and housewives have been infected through handling fresh meat on farms (13), no outbreaks of RVF attributable to meat have been recognised in urban consumers and it is surmised that the pH fall associated with meat maturation inactivates the virus (13).

The animals most likely to be fed on meat scraps (pigs, dogs and cats) are relatively resistant to infection with RVFV (13).

Carcasses of infected animals reaching abattoirs are generally recognised as being unfit for human consumption.

There is little risk that RVF could be spread internationally through trade in sheep and goat meat.

**Peste des petits ruminants and rinderpest**

Rinderpest is an acute, highly contagious viral disease primarily of cattle and secondarily of sheep, goats and all cloven-hoofed animals. Swine may become infected and spread the disease (10, 13). The disease in cattle is characterised by high fever, necrotic stomatitis and gastroenteritis. Mortality in epizootics of rinderpest can be very high: 90% to 100% in previously unexposed populations and up to 30% to 50% in enzootic situations (10, 18).

Peste des petits ruminants (PPR) is a similar acute disease of sheep and goats caused by a virus closely related to, but distinct from, that of rinderpest. Explosive outbreaks of PPR occur, with mortalities reaching 90% (10, 18).

In Africa, sheep and goats are said to play a secondary role in maintaining rinderpest. The situation in India is different, with strains of rinderpest distinguishable from PPR virus having become established in sheep and goats (13).

**Meat as a vehicle**

The transmission of rinderpest is nearly always dependent on close contact between animals. However, under certain circumstances the virus may persist in meat and infect swine fed on scraps of such meat (13). Pigs then spread the virus to...
cattle, sheep, goats and other susceptible ruminants (10, 47). Such indirect spread is, however, unusual (18).

PPR is said not to spread in this way. Close contact between infected and susceptible live animals is required (10), although pigs can be infected subclinically by experimental inoculation.

PPR virus appears to be relatively fragile, having a half-life of two to three hours at temperatures above 37°C. The virus is reported to be stable between pH 5.85 and 9.5 and may be recoverable from lymph nodes for at least eight days at 4°C (13).

The rinderpest virus is not very hardy (18). Virus in infected meat is usually inactivated rapidly due to the drop in pH which accompanies rigor mortis (8,10). Muscle tissue, lymph nodes and spleen held at 5°C will usually be free of virus within two to three days (18). However, meat frozen before rigor mortis has developed may retain infective virus for several months (10). Indeed, even in refrigerated meat the virus may persist for some time. The virus has been recovered from carcasses held at 4°C for 30 days and from quarters aged for 24 hours and then held at 4°C for eight days (8). In salted meat, rinderpest virus may persist for several months (10).

The risk of introduction

There is no evidence to suggest the PPR could be introduced through importation of sheep and goat meat.

Pigs may be infected when fed meat scraps contaminated with rinderpest virus (10, 47) and, because the signs of rinderpest are mild in pigs, the disease could be overlooked for some time, increasing the chances of infection spreading to other livestock (10, 47). Although at least one epidemic of rinderpest has been attributed to the importation of beef (13), the risk from sheep or goat meat must be regarded as minimal.

Sheep pox and goat pox

Sheep pox and goat pox are acutely progressing viral diseases characterised by a rise in body temperature and lesions on those parts of the skin devoid of hair covering. The disease may also affect the mucous membranes of the respiratory and gastrointestinal tracts.

Sheep pox is probably the most economically serious pox disease of livestock. Goat pox tends to be milder.

Meat as a vehicle

The main routes by which sheep pox and goat pox are transmitted are direct contact with infected animals or contaminated materials, and by the respiratory route (10, 16).

Following infection with sheep and goat pox viruses, there is a viraemic phase and so, theoretically, virus could be expected to be present in muscle. It has been reported that another pox virus, orf, may be 'indirectly transmitted by way of carcasses or processed meat' (16). No such claims appear to have been made for sheep pox or goat pox and it may be that any virus present in muscle is inactivated by the pH fall which accompanies maturation. The related vaccinia virus is reported to be labile below pH 7.0 (16).

Putrefaction destroys sheep pox and goat pox viruses (10).

Most strains of sheep pox and goat pox are highly host specific (10, 16) and do not appear to have been reported as affecting pigs, dogs or cats.

It is unlikely that meat would serve to introduce sheep pox or goat pox.

Anthrax

Anthrax is an acute, non-contagious bacterial disease of mammals caused by the spore-forming bacterium Bacillus anthracis. In the most common form, the disease is a septicaemia characterised by a rapidly fatal course.

While all mammals are susceptible to anthrax, the degree of susceptibility varies. Common domesticated animals may be ranked in order of decreasing susceptibility as: sheep, cattle, goats, horses, pigs, dogs and cats (10, 43, 47). The course of the disease is usually rapid in herbivores, but in pigs can be as long as 14 days (10).

Birds are generally more resistant than mammals, but carrion-eating birds may become infected and/or spread anthrax after feeding on infected tissue (1,10,43).

Meat as a vehicle

Most cases of anthrax result from animals ingesting spores present on feed-stuffs but cases may also occur in pigs, dogs and cats following ingestion of meat from animals dying of anthrax.

It is unlikely that meat from animals dying from anthrax would find its way into products intended for human consumption. However, meat meal, blood meal or bone meal intended for stock food could serve as a vehicle for introducing anthrax. A major outbreak of anthrax in the United States of America was attributed to the feeding of contaminated bone meal to swine, from which the disease then spread to other livestock (43).

To ensure bone meal is not contaminated with anthrax spores, it must be heated to 150°C for at least three hours (43).

The risk of introduction

Meat from sheep or goats dying from anthrax would be unlikely to find its way into the commercial operations
producing meat products intended for export. Pigs, dogs and cats, the animals which one would expect to be those infected by contaminated meat, are all relatively resistant to anthrax. However, contaminated meat meal, blood meal or bone meal could serve as vehicles to infect herds of pigs and so appropriate certification as to origin and/or treatment should be required.

**Aujeszky’s disease**

Aujeszky’s disease (AD), or pseudorabies, is a viral disease which may affect all species of domestic livestock and many species of birds, including poultry. In all species except swine AD is rapidly fatal.

**Meat as a vehicle**

Cases of AD in dogs, cats, farmed mink and ferrets, and wild rats have been attributed to the consumption of meat from AD-infected swine. Outbreaks in pigs have been attributed to the ingestion of meat from the carcasses of AD-infected rats (10, 28, 40). While it is possible that pigs can be infected via pork scraps in swill (10), the lack of prominence given to this possibility by most writers suggests that it is not very likely (10, 18, 28, 40, 47). As AD is rapidly fatal in sheep and goats it is unlikely that infected animals would be processed for meat. In addition, the pH changes associated with normal meat maturation serve to reduce the levels of any virus which may be present. Freezing also serves to inactivate the virus (17).

Should infected meat be imported, and should it be fed uncooked to animals, Aujeszky’s disease could become established only if the meat were fed to swine. Although dogs and cats could become infected, they are dead-end hosts which die without excreting virus.

**Brucellosis**

Brucellosis is a chronic infection caused by bacteria of the genus *Brucella*. The species which primarily affects sheep and goats is *B. melitensis*, although these animals may occasionally be infected by *B. abortus*. Sheep may also be infected with *B. ovis*.

*B. melitensis* and *B. abortus* may infect pigs and dogs. Cats are resistant to infection with brucellae (1).

**Meat as a vehicle**

When animals first become infected with one of the *Brucella* species a bacteraemia is present. Subsequently, the organisms localise in certain tissues such as lymph nodes, liver and bone marrow (1).

Human cases of brucellosis have occurred as a result of people eating raw bone marrow or raw meat of animals infected with *B. suis* (1). Pigs may become infected by eating the carcasses of hares infected with *B. suis* (10). Dogs may be infected by eating reindeer meat from animals infected with *B. suis* (47). It is apparent, therefore, that under certain circumstances meat may serve as a vehicle for brucellae.

Brucellae are resistant to freezing so could, theoretically, survive for prolonged periods in frozen meat. Experimentally, *B. abortus* has been shown to survive in a (guinea-pig) carcass for up to 44 days when kept under cold conditions (47). *B. abortus* survived more than 15 days in refrigerated experimentally contaminated beef (34).

Brucellae are resistant to pickling and smoke curing, so there is a possibility that some meat products could serve as vehicles for the disease (1, 34). *B. abortus* has been shown to survive in meat and salted meat for 65 days at 0°C-20°C (47). In sausage, *B. abortus* has been reported as surviving up to 175 days (34).

Brucellae are quite sensitive to heat and are destroyed by cooking or pasteurisation (10, 34, 47).

**The risk of introduction**

Sheep or goat meat products could possibly carry brucellae. However, to establish infection, the infected meat would need to be fed to either dogs or pigs. While it is possible that these animals could become infected, the risk of their passing infection on to other animals is not great. Pigs can be infected with *B. abortus*, but are dead-end hosts and do not transmit the disease to other animals (1). Dogs can be infected with *B. abortus* or *B. melitensis*, but transmission of infection to other animals is rare (1).

It is unlikely that sheep or goat meat or meat products could introduce brucellosis.

**Echinococcosis/hydatidosis**

Echinococcosis (hydatidosis) is a parasitic infestation involving dogs (and some species of wild canids) as primary hosts of the tapeworms *Echinococcus granulosus* or *E. multilocularis*, and sheep, goats and other herbivores as the secondary hosts of the cystic larval stages of the same tapeworms.

Tapeworm eggs are produced by mature adults in the intestine of the primary host, usually the dog, and are ingested by the herbivorous secondary host. Larvae migrate in the body of the secondary host before forming the hydatid cyst. The life-cycle is completed when the carnivorous primary host ingests the cystic stage in the tissues of the secondary host.

Echinococcosis is a serious zoonosis. Humans may become infested by the cystic stages following ingestion of eggs passed in the faeces of infested dogs.

**Meat as a vehicle**

The life-cycle of *Echinococcus* is dependent on meat serving as a vehicle by which the cystic larval stage (protoscolices) are
transmitted to the carnivorous primary host. Most hydatid cysts are found in offal and are only rarely located in muscle tissue.

The protoscolices in hydatid cysts may remain viable in carcasses for at least 3 weeks (45). However, freezing to −18°C or −20°C for at least 48 hours kills most of them (1, 49).

Cooking meat adequately destroys the viability of Echinococcus protoscolices, and manufacturing processes (mincing, drying, heating, smoking) are likely to destroy the cysts, thus ensuring that products do not serve as vehicles for hydatids.

The importation of live animals constitutes a greater risk than the importation of meat products. Because hydatid cysts are rare in muscle tissue, the only real possibility of the disease being introduced in meat products would be in chilled offals.

Leptospirosis

Leptospirosis is a contagious, acute to chronic, often inapparent infection of animals and humans caused by more than 180 serovars of Leptospira interrogans.

Meat as a vehicle

Leptospires are fragile organisms which are destroyed rapidly by heating, drying or extremes of pH (10). However, it is possible that infection may occasionally be spread to carnivores in slaughter scraps from the urinary system (10). It has been demonstrated that leptospires in naturally infected pig kidneys may survive for at least 30 days (22). In refrigerated samples of liver from infected calves L. grippotyphosa may survive for approximately 24 hours (34). L. pomona and L. icterohaemorrhagiae may survive in refrigerated samples of muscle from laboratory animals for three to ten days (34). On account of the short survival time of leptospires in most tissues, kidneys are the only meat products which might serve to introduce new leptospiral serovars.

Kidneys infected with leptospires could introduce leptospirosis in one of two ways. Firstly, humans handling infected kidneys could become infected via skin abrasions while handling the organs (7). Such infections are unlikely to result in leptospirosis being transmitted to other humans or animals and so are unlikely to lead to the establishment of new serovars in the importing country.

The second means by which infection could occur would be if infected kidneys were fed raw to pigs, dogs or cats, or were scavenged by rodents. The establishment of new serovars outside the index case would depend on that case being able to transmit the new serovar to the required maintenance host. If this did not occur, the particular serovar would die out.

Maedi-Visna

Maedi is a slowly progressive interstitial pneumonia of sheep, and visna is a slowly progressive leukoencephalomyelitis. Both syndromes are caused by the same retrovirus. It is unusual for more than a small proportion of infected animals to develop clinical signs.

Maedi-Visna is not highly contagious and prolonged contact appears necessary for transmission of infection. The virus is cell-associated, in monocytes, and is spread mainly through infective droplets during close contact and through colostrum (10, 13, 16).

The virus is host specific and carnivores do not become infected. It is highly unlikely that meat could serve as a vehicle for the transmission of Maedi-Visna.

Mycoplasmosis

Contagious agalactia is a severe mastitic and arthritic condition of sheep and goats caused by Mycoplasma agalactiae. Contagious caprine pleuropneumonia is a highly contagious, frequently fatal pneumonic condition of goats caused by infection with Mycoplasma species F38 biotype (23, 37).

Meat as a vehicle

M. agalactiae is shed in milk, urine, nasal and lacrimal secretions. Contagious caprine pleuropneumonia spreads via the respiratory route and, possibly, also through urine, milk and genital secretions (10). Mycoplasma species do not grow below pH 6 (34). The authors have found no reference to M. agalactiae or F38 biotype in meat, but an avian Mycoplasma (M. gallisepticum) has been shown to survive for a few hours to a few days in chicken muscle held at 20°C-37°C (34).

M. agalactiae and Mycoplasma species F38 biotype are host-specific and will not infect pigs, dogs or cats. The risk of introduction through imports of meat is negligible.

Paratuberculosis

Paratuberculosis, or Johne's disease, is a chronic, mostly fatal infection of cattle, sheep, goats and deer caused by Mycobacterium paratuberculosis. The principal signs of the disease are a progressive diarrhoea in cattle and wasting in all species. Pigs can be infected experimentally with M. paratuberculosis and should thus be regarded as potential shedders of the organism (10, 47).

Meat as a vehicle

Lesions of paratuberculosis are found in the intestines, regional lymph nodes and liver. They may occasionally occur in the spleen, uterus, udder and male reproductive organs (47). Theoretically, infected tissues, such as liver or lymph nodes, could find their way into the diet of swine which could then pass infection on to other livestock.

M. paratuberculosis is readily destroyed by 'moderate heat' (47). Little other relevant information has been documented.
The risk that new strains of *M. paratuberculosis* could be introduced in meat is very low indeed. The organism is not usually present in edible tissue and the animals likely to be fed scraps (i.e. swine) are relatively resistant to infection.

**Q fever**

Q fever is a rickettsial infection caused by *Coxiella burnetii*. The infection in animals is usually inapparent, but clinical disease involving fever, conjunctivitis, arthritis, mastitis, abortions and reproductive disorders is seen occasionally. Cattle, sheep and goats are the species most likely to show clinical signs of Q fever. The disease is a zoonosis.

The agent, *C. burnetii*, is maintained in a wildlife reservoir involving especially rodents and birds. Infection is transmitted by ticks to domestic animals, particularly sheep and cattle (10).

**Meat as a vehicle**

During the bacteraemic phase of the disease, *C. burnetii* is carried to all organ systems. In some cattle the agent may persist for months in liver, kidney, muscles, lymph nodes, etc. (10).

While slaughterhouse workers are particularly at risk from Q fever, their exposure is usually via aerosols, not meat per se. Nonetheless, infection may occur through skin abrasions while handling infected organs (1, 6, 44).

Humans may, occasionally, become infected by eating infected foodstuffs but this route of infection is uncommon (10). The authors have found no reference to meat serving as a vehicle for Q fever and suspect that this is because it is only milk which serves as a vehicle for oral infection.

In contaminated meat stored under refrigeration, the organism may survive up to 30 days (34). Heat treatments which have been shown to inactivate the organism in moist environments are:
- 62.8°C for 30 minutes
- 65°C for 15 minutes
- 71.7°C for 15 seconds
- 75°C for 8 seconds
- 100°C for 7 seconds (6, 10).

The risk that *C. burnetii* could be introduced into an importing country through sheep and goat meat products is small.

**Rabies**

Rabies is an almost invariably fatal viral encephalitis which may affect all warm-blooded animals although infection in birds is uncommon. Rabies is characterised by a unique mode of transmission and a long and variable incubation period. The disease is an important zoonosis.

**Meat as a vehicle**

Although rabies virus has never been isolated from meat (16), a low titre could be expected because the virus spreads centrifugally along nerves late in infection and has been found in a number of tissues outside the nervous system, such as respiratory, gastrointestinal and urogenital tracts (47). Laboratory animals have been infected with rabies by mouth (1), and oral infection through ingestion of contaminated milk from an infected dam has been claimed for a lamb and a human baby (13). The possibility of meat serving as a vehicle for rabies cannot be excluded (10) but, if it does occur, must be rare (47).

Rabies virus is fragile and heat labile (47) and would be inactivated by cooking (13, 16).

The probability that rabies could be introduced in meat or meat products must be considered remote.

**Salmonella abortus ovis infection**

Salmonellosis is a bacterial infection of many wild and domestic animals as well as humans. It is caused by the numerous species (serotypes and serovars) of the genus *Salmonella*. All *Salmonella* species are pathogenic, with their virulence varying considerably between species. As a zoonosis, salmonellosis is seldom acquired directly; it is usually a food-borne infection (10).

*Salmonella abortus ovis* is a relatively uncommon cause of abortion in ewes. The reservoir of infection is said to be the carrier sheep and organisms are excreted in the faeces and vaginal mucus. Ingestion is probably the main route of infection. *S. abortus ovis* is highly adapted to the sheep and is found only in that species.

**Meat as a vehicle**

While almost any foodstuffs, whether of vegetable or animal origin, may serve as a vehicle for those salmonellae which are not highly adapted to a particular host, *S. abortus ovis* is not a food-borne pathogen.

Salmonellae are sensitive to heat and will not survive temperatures above 70°C (50). *S. abortus ovis* would not, therefore, be expected to survive processing should meat-and-bone meal be made from infected sheep.

It is highly improbable that *S. abortus ovis* would be introduced in meat or meat products.

**Scrapie and bovine spongiform encephalopathy**

Scrapie is a transmissible, progressive and invariably fatal neurological disease of sheep, usually between two and a half and four and a half years of age. Scrapie also occasionally occurs in goats which have been in contact with infected sheep.
Scrapie is caused by a small infectious agent (termed a prion by most researchers), which has many of the biological properties of a virus. For example, it is filterable and exhibits strain variation and mutation. It differs from conventional virus in that:

- it is highly resistant to many disinfection procedures, such as heating, ultraviolet and ionizing radiation, and prolonged exposure to formalin
- it does not induce humoral or cellular immunity in an infected animal.

Bovine spongiform encephalopathy (BSE) is a related progressive, fatal neurological disease of cattle, first described in British cattle in 1986. BSE is believed by many researchers to have originated from feeding cattle concentrates containing meat-and-bone meal prepared from scrapie-infected sheep offal (5, 25).

**Meat as a vehicle**

The possibility that rations containing meat-and-bone meal could serve as a vehicle for the spread of scrapie was considered by Icelandic regulators as long ago as 1976 when the feeding of such rations to sheep was prohibited in Iceland (P.A. Palsson & S. Sigurdarson, personal communication, 1995). However, the potential for meat-and-bone meal to spread diseases of this sort was not more widely appreciated until the BSE epidemic in Britain in the 1980s. While the origin of the BSE epidemic may have been the transmission of scrapie to cattle through meat-and-bone meal, such transmission was at an extremely low level and recycling of infection from cattle to cattle, through the use of contaminated feedstuffs, was the major factor responsible for the large scale of the epidemic (26).

Subsequently BSE has been found to have infected several species of captive antelopes, domestic cats and great cats (5). BSE has also been transmitted by experimental oral dosing to sheep and goats (19).

The agents of scrapie and BSE are extraordinarily resistant to procedures which normally inactivate pathogens (10, 24, 46). The only method considered to be effective at present is heat treatment at 133°C at 3 bar for 20 minutes (46).

Meat could introduce scrapie or BSE into livestock populations of an importing country only through the practice of feeding rations containing meat-and-bone meal made from scrapie- and/or BSE-infected animals. For this reason, the feeding of ruminant-derived meat-and-bone meal to ruminants is unwise.

**Tuberculosis**

Tuberculosis is a chronic, infectious disease caused by Mycobacterium bovis, M. tuberculosis or M. avium. Cattle are the principal hosts of M. bovis, but goats, swine, deer, humans, dogs, horses and cats may also become infected with this organism. Birds do not become infected (10, 47). Infection is rare in sheep (3, 15) and uncommon in goats (2, 41).

* M. avium affects mainly birds. Cattle, swine and deer may be infected with *M. avium* when exposure is sufficiently great, and infection, although rare, has been reported in sheep, goats, horses and cats (10, 47).

* M. tuberculosis is primarily a pathogen of humans.

**Meat as a vehicle**

Meat is an unlikely vehicle for tuberculosis. However, ‘alimentary transmission via the intake of raw meat of tuberculosis-infected animals and its unheated products is... possible’ (10). Swine may contract tuberculosis after being fed improperly cooked or raw offal from tuberculous cattle or poultry (28). *M. bovis* has been shown to survive up to 126 days in experimentally contaminated smoked sausages (34). However, the doses required to infect by mouth are very high (20). For example, as few as five bacilli may infect calves by the respiratory route, but oral infection requires several million bacilli.

Tubercle bacilli are not usually found in the muscle of infected animals. Although tuberculous animals may have bacteremic episodes, these occur infrequently and involve small numbers of bacilli only. Even in animals dying from miliary tuberculosis, the dose of bacilli present in muscle tissue is only 100–200 per gram (20).

... The danger to [humans] from tubercle bacilli in or on flesh is very slight indeed if animals are in reasonably good health at the time of slaughter and good hygienic procedures are observed – this is still generally true even when cattle have quite severe lesions of tuberculosis’ (20).

* M. bovis, *M. avium* and *M. tuberculosis* are destroyed readily by normal cooking and temperatures greater than 60°C for 10 minutes have been shown to destroy *M. bovis* in sausage (33). The United States Department of Agriculture regulations consider that meat from tuberculous carcasses may be rendered safe for human consumption by cooking at 76.7°C for 30 minutes (28).

The probability of *M. bovis* being introduced through importation of sheep or goat meat is remote.

**Conclusion**

The results of study conducted for this paper show that although it is theoretically possible for sheep and goat meat to serve as a vehicle for a number of pathogens, in reality there are relatively few for which specific safeguards need be applied.
Historically, because dramatic outbreaks of foot and mouth disease and the swine fevers have been attributed to trade in meat, quarantine services have adopted conservative policies to regulate meat imports. Often the mere presence of a particular disease in the exporting country has been sufficient to prevent trade.

However, a qualitative assessment of the animal health risks posed by the importation of sheep and goat meat suggests that, with the possible exception of foot and mouth disease, there is little risk of disease transmission through meat produced from animals which have passed veterinary ante-mortem and post-mortem inspection and which has been permitted to mature to its ultimate pH.

Additional safeguards may be required when foot and mouth disease is present in the exporting country. The need for these safeguards, and an assessment of their likely effectiveness, may be determined by the process of quantitative risk analysis.

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Risques potentiels pour la santé animale liés à l'importation de viande de mouton et de chèvre

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Résumé
Devant les épidémies de fièvre aphteuse et de peste porcine, attribuées au commerce international de la viande, les pouvoirs publics ont eu tendance à prendre des mesures de plus en plus contraignantes lors d'importation de viande. Cependant, ces importations n'entraînent l'apparition d'une maladie, dans le pays importateur, que sous certaines conditions bien définies. Une évaluation qualitative des risques que présente la viande de mouton et de chèvre a permis d'aboutir à la conclusion qu'à l'exception, peut-être, de la fièvre aphteuse, il n'existe qu'une faible probabilité de propagation des maladies des Listes A et B de l'Office international des épidémiologies résultant du commerce de la viande, pour autant que celle-ci ait subi une maturation correcte et provienne d'animaux ayant été examinés par les Services vétérinaires avant et après l'abattage.

Mots-clés

Riesgos zoosanitarios potenciales asociados a la importación de carne ovina y caprina

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Resumen
Alarmadas por los brotes de fiebre aftosa y pestes porcinas atribuidos a los intercambios internacionales de carne, las autoridades reguladoras han tendido a adoptar políticas de suma prudencia en materia de importación de carne. Sin embargo, la introducción de una enfermedad a resultas de la importación de carne depende de una serie de circunstancias precisas.
Una evaluación cualitativa de los riesgos asociados a la carne ovina y caprina conduce a la conclusión de que, con la posible excepción de la fiebre aftosa, son remotas las probabilidades de que alguna enfermedad de las Listas A y B de la Oficina Internacional de Epizootias se propague a resultas del comercio de carne, siempre y cuando ésta haya madurado adecuadamente y provenga de animales sometidos a las debidas inspecciones veterinarias ante y postmortem.

Palabras clave

References


