# RISK PROFILE:
# *MYCOBACTERIUM BOVIS*
# IN RED MEAT

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by

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## SUMMARY

The purpose of a Risk Profile is to provide contextual and background information relevant to a food/hazard combination so that risk managers can make decisions and, if necessary, take further action. Risk Profiles include elements of a qualitative risk assessment, as well as providing information relevant to risk management. Risk profiling may result in a range of activities e.g. immediate risk management action, a decision to conduct a quantitative risk assessment, or a programme to gather more data, ranking of a particular food safety issue.

Tuberculosis is most commonly caused by *Mycobacterium tuberculosis*, but a proportion of human cases are caused by *Mycobacterium bovis*. The notified incidence of tuberculosis in New Zealand in 2005 was 9.3 per 100,000 population. The proportion of total tuberculosis cases caused by *M. bovis* in New Zealand (about 2-3%) is similar to other developed countries. The significance of *M. bovis* as a cause of tuberculosis has decreased since the widespread introduction of milk pasteurisation.

While transmission of tuberculosis to humans through consumption of *M. bovis* infected meat is possible no cases of this have been confirmed in New Zealand or overseas.

At slaughter all cattle and deer are subject to an examination for evidence of tuberculosis infection. Action is taken to remove infected tissues from the food chain; further, if there is evidence of haematogenous spread of *M. bovis* the whole carcase is condemned. This risk is further reduced by the fact that primary infection site tissues (head, thorax, alimentary tract) do not commonly enter the fresh meat trade. The dose response relationship for ingestion of *M. bovis* is unclear, but this route of exposure appears to be of lower risk than infection via inhalation.

De la Rua-Domenech (2006) identifies several factors that mitigate against *M. bovis* transmission via meat:

- Lesions in skeletal muscle are rare and observed only in animals with advanced infection. Such carcases are likely to be condemned following post-mortem inspection;
- *M. bovis* is slow growing and will not replicate outside the living host;
- *M. bovis* is relatively heat sensitive and any residual contamination in muscle meat should be destroyed by cooking; and
- Ingestion is a far less efficient route of infection than inhalation.

Data from the UK published by the ACMSF indicates that only a small proportion (<5%) of animals with tuberculosis infection are culture positive for the organism in edible tissues. Considered alongside the measures taken to eliminate infected animals from the food supply, this indicates that the risk of transmission of *M. bovis* in meat to New Zealanders must be considered to be negligible.

Active risk management for *M. bovis* in meat in New Zealand includes:

- Cattle and deer herd monitoring and active measures to eradicate Tb from all breakdown herds;
- Ante-mortem and post-mortem examination for slaughtered cattle and deer; and,

- Vector control measures (especially possum control), which markedly reduces the incidence of *M. bovis* infection in cattle and deer.

The first two of these measures represent best practice, in the opinion of the European Scientific Panel on Biological Hazards (2003). The third measure is directed at a *M. bovis* reservoir problem specific to New Zealand.

The data gaps identified in this Risk Profile are the:

- Level (if any) of *M. bovis* in the meat of infected animals.
- Importance of bacteraemic episodes in the progression of the disease, with the associated risk of generalised spread of the organism within the infected animal;
- Dose response relationship for *M. bovis* infection in humans via the gastrointestinal route.

# 1 INTRODUCTION

The purpose of a Risk Profile is to provide contextual and background information relevant to a food/hazard combination so that risk managers can make decisions and, if necessary, take further action. The place of a risk profile in the risk management process is described in "Food Administration in New Zealand: A Risk Management Framework for Food Safety" (Ministry of Health/Ministry of Agriculture and Forestry, 2000). Figure 1 outlines the risk management process.

**Figure 1: Risk Management Framework**

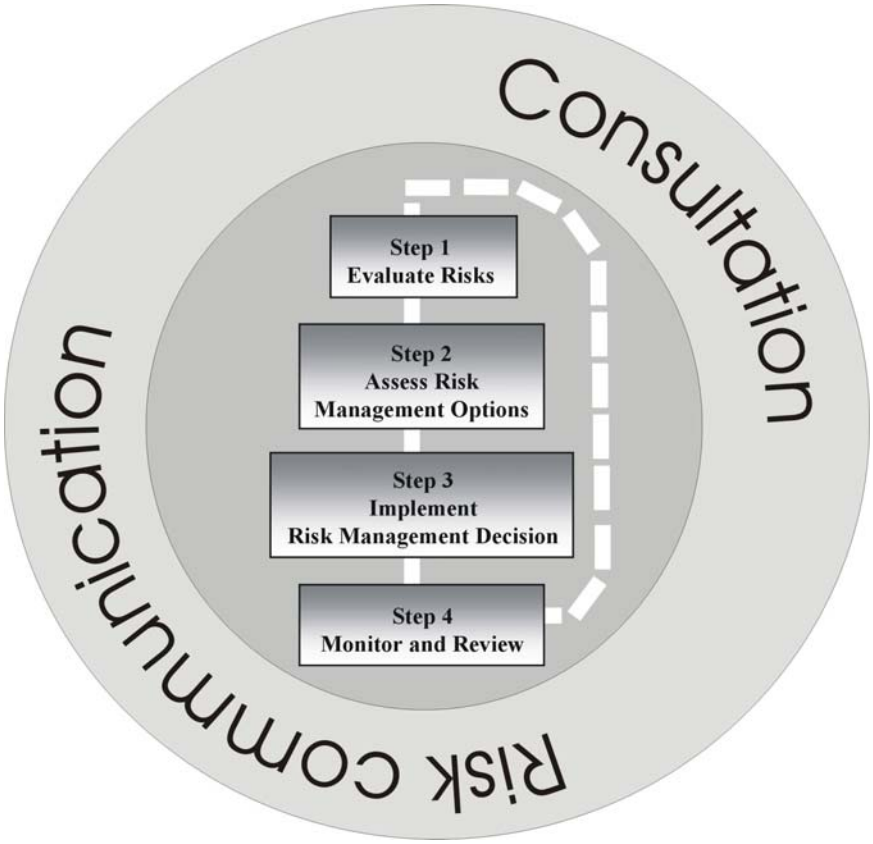


Figure reproduced from "Food Administration in New Zealand. A risk management framework for food safety" (Ministry of Health/Ministry of Agriculture and Forestry, 2000).

In more detail, the four step process is:

*1. Risk evaluation*

- identification of the food safety issue
- **establishment of a risk profile**
- ranking of the food safety issue for risk management
- establishment of risk assessment policy
- commissioning of a risk assessment
- consideration of the results of risk assessment

*2. Risk management option assessment*

- identification of available risk management options
- selection of preferred risk management option
- final risk management decision

*3. Implementation of the risk management decision*

*4. Monitoring and review.*

The Risk Profile informs the overall process, and provides an input into ranking the food safety issue for risk management. Risk Profiles include elements of a qualitative risk assessment. However, in most cases a full exposure estimate will not be possible, due to data gaps, particularly regarding the level of hazard in individual foods. Consequently the risk characterisation part of a risk assessment will usually rely on surveillance data. The Risk Profiles also provide information relevant to risk management. Based on a Risk Profile, decisions are made regarding whether to conduct a quantitative risk assessment, or take action, in the form of gathering more data, or immediate risk management activity.

The hazard *Mycobacterium bovis* was chosen as a topic for a Risk Profile because, although it is likely to have minimal public health significance, demonstration of the safety of New Zealand produced food with respect to this pathogen may have trade implications.

The sections in this Risk Profile are organised as much as possible as they would be for a conventional qualitative risk assessment, as defined by Codex (1999).

*Hazard identification, including:*

- A description of the organism.
- A description of the food group.

*Hazard characterisation, including:*

- A description of the adverse health effects caused by the organism.
- Dose-response information for the organism in humans, where available.

*Exposure assessment, including:*

- Data on the consumption of the food group by New Zealanders.
- Data on the occurrence of the hazard in the New Zealand food supply.
- Qualitative estimate of exposure to the organism (if possible).
- Overseas data relevant to dietary exposure to the organism.

*Risk characterisation:*

- Information on the number of cases of adverse health effects resulting from exposure to the organism with particular reference to the food (based on surveillance data)
- Qualitative estimate of risk, including categorisation of the level of risk associated with the organism in the food (categories are described in Appendix 1).

*Risk management information:*

- A description of the food industry sector, and relevant food safety controls.
- Information about risk management options.

*Conclusions and recommendations for further action*

## 2 HAZARD IDENTIFICATION: THE ORGANISM

The following information is taken from data sheets prepared by ESR under a contract for the Ministry of Health. The data sheets are intended for use by regional public health units.

### 2.1 *Mycobacterium bovis*

*M. bovis* one of the "*M. tuberculosis* complex" (MTBC), a group of genetically similar organisms which infect humans and animals, including four named 'species' (*M. tuberculosis, M. bovis, M. africanum* and *M. microti*) and several variants whose taxonomy is still under debate (de la Rua-Domenech, 2006). *M. tuberculosis* is the major human pathogen. Cases of *M. tuberculosis* infections in cattle have been reported. These were thought to be of human origin. However the disease is not progressive and the lesions are usually small and self-limiting (O'Reilly and Daborn, 1995). *M. bovis* commonly infects cattle and other animals and so infection could potentially be spread to humans via contaminated meat.

Note that in the following text the term "D" is used. In microbiological terms "D" refers to a 90% (or decimal or 1 log cycle) reduction in the number of organisms.

#### 2.1.1 Growth and survival

**Growth**

The organism is very slow growing, and so given the short shelf life of foods that it has been associated with, e.g. unpasteurised milk and raw meat, growth in foods is unlikely to be significant. The organism is a microaerophile.

**Survival**

Temperature: Survival is better under cool conditions, e.g. survived in cow faeces for five months in winter and two months in summer (O'Reilly and Daborn, 1995). A New Zealand study employing *M. bovis* absorbed on cotton ribbons demonstrated shortest survival times on pasture, forest floor or in brushtail possum dens in summer, and longest survival times in spring and winter (Jackson *et al*., 1995).

Water Activity: Survives dry conditions well.

#### 2.1.2 Inactivation (CCPs and Hurdles)

Temperature: Inactivated by normal pasteurisation. Further details given in section 3.2.

Radiation: Inactivated by sunlight.

#### 2.1.3 Sources

Human: Humans are a possible source or amplifier host of the organism (especially in the developing world), but human-to-human infection occurs only rarely. Most reports of human-to-human transmission are largely anecdotal, although van Soolingen *et al*. (1994) identified

the same strain type in three members of one family and another person in the same apartment building. None of the cases had frequent contact with domesticated or other animals. Coinfection with *M. bovis* and HIV increases the likelihood of tuberculosis development and a nosocomial outbreak amongst HIV patients has been reported (Bouvet *et al*., 1993). Humans are not regarded as a reservoir of *M. bovis*.

Animal: Many domestic and wild animals have been found to be infected with *M. bovis*. Some are reservoirs of infection (e.g. cattle and possums in New Zealand, Eurasian badgers in the UK, Cape buffalo in South Africa), but others may assume this role given certain environmental/management conditions. For example, in the wild, deer are spill-over hosts (infection occurs due to the presence of reservoir or maintenance hosts in their ecosystem), but when farmed (i.e. a high stocking rate) they can maintain infection independently (see de la Rua-Domenech, 2006 for a fuller discussion).

Food: Meat and milk derived from infected animals may contain the organism. Following infection there is a strong cell-mediated response, which leads to the development of granulomas or "tubercles". These vary in size but may be detectable post-mortem in food animals.

Environment: Can persist and remain infective in the environment for long periods, e.g. 178 days in sterile faeces. Survival is linked to the degree of exposure to sunlight (Menzies and Neill, 2000).

Transmission Routes: Can be by respiratory aerosols between animals and humans. However, prior to the widespread adoption of pasteurisation, the major *M. bovis* pathway from cattle to humans in Europe, USA, Canada, Australia, and New Zealand was via infected milk. This is still reported infrequently in countries that allow the sale or processing of unpasteurised milk. While transmission by meat derived from infected animals is theoretically possible, no cases have been documented and the risk is believed to be small (Francis, 1973; Scientific Panel on Biological Hazards, 2003).

# 3 HAZARD IDENTIFICATION: THE FOOD

In New Zealand the major potential sources of *M. bovis* foodborne contamination are infected cattle and deer. Many other mammals can become infected, including pigs (especially feral pigs) but infection in sheep is rare (MacDiarmid and Thompson, 1997). Birds do not become infected.

Possums act as a reservoir of *M. bovis* infection in New Zealand. It has been suggested that a contributing factor to the rarity of infection in sheep is due to their lack of exploratory behaviour towards possums (Sauter and Morris, 1995a), while cattle and deer, especially dominant individuals, show a high level of exploratory behaviour towards possums (Sauter and Morris, 1995a,b).

## 3.1 The Food Supply in New Zealand

Livestock numbers for New Zealand in 2005 are shown in Table 1.

**Table 1: Livestock numbers for New Zealand in 2005**

| Main Classes of Livestock (millions) at June 2005* | |
|---|---|
| Total sheep | 39.5 |
| Total beef | 4.38 |
| Total dairy | 5.30 |
| Total pigs | 0.37 |
| Total deer | 1.61 |

* From SONZAF 2005 (MAF, 2005)

In 2005 New Zealand produced 652,000 tonnes of beef meat (carcase weight). Over 80% of this production was exported, representing 10% of the world trade in beef.

Approximately 90% of New Zealand's sheep meat production is exported. The majority is frozen, but chilled meat exports now represent 12% of the total. Total production for 2005 was approximately 438,000 tonnes of lamb and 105,000 tonnes of mutton.

New Zealand venison production for 2002/2003 was 29,000 tonnes and was predicted to increase. Approximately 80% of production is exported to Europe (http://www.maf.govt.nz/mafnet/rural-nz/overview/nzoverview010.htm).

New Zealand has a relatively small pig industry, which focuses on the domestic market. Since 1995 pigmeat production has been relatively static averaging 49,000 tonnes per year (50,845 tonnes carcase weight in the 2005 season). Imports of pork account for approximately 38% of total consumption (31,862 tonnes in 2005; New Zealand Pork Industry Board, 2005).

### 3.1.1 Imported food

New Zealand imports relatively small amounts of beef and sheep meat, according to data from Statistics New Zealand. For the year to September 2005 approximately 8,100 tonnes of

beef carcases, cuts and products were imported, mainly from Australia (the balance was New Zealand product re-imported). For the same period, 3,600 tonnes of sheep meat (all types) was imported, mainly from Australia with smaller amounts of re-imported New Zealand product.

Larger amounts of pigmeat are imported (see above). For the year to September 2005 New Zealand imported pork and pork products mainly from Australia (42%), followed by Canada (30%) and the USA (18%).

### 3.2 Relevant Characteristics of the Food: Red Meat and Meat Products

All fresh red meats have water activities ($a_w$) of >0.99 which provides an excellent environment for microbial growth. Most of the extrinsic factors (salt and sugar addition, drying and smoking) applied to extend shelf life and safeguard against food poisoning act by lowering the $a_w$ (Lawrie, 1998). The flesh of stock animals prior to slaughter has a pH of about 7.1. The pH falls post-slaughter to reach a minimum of 5.4-5.8 within 24 hours of slaughter.

Research carried out by MIRINZ on microbial growth at sub-freezing temperatures clearly indicates that meat or meat products stored at product temperatures below -8°C will not support any microbial growth (Winger, 1984).

While growth of *M. bovis* is unlikely in meat products after processing, it appears likely to survive. In work with a contaminated ox quarter, survival was noted up to 270 days when the meat was stored at $-5^oC$. Similarly survival for 126 days in smoked sausages has been recorded (Mitserlich and Marth, 1984).

Examination of the destruction of *M. bovis* in meat products showed that no viable cells remained after the test meat products reached 60°C. This was below the temperature needed to control the MAI complex (*M. avium-M. intracellulare*) found in swine, so control measures for that group will also easily control *M. bovis* (Merkal and Whipple, 1980). In meat products the D time at $61^oC$ was one minute, while at $55^oC$ it was approximately 10 minutes. Treatment at $65^oC$ for one minute gave a 5 D kill.

# 4 HAZARD CHARACTERISATION: ADVERSE HEALTH EFFECTS

Tuberculosis is the general name for a group of diseases associated with the presence of *Mycobacterium* spp., of which pulmonary (lung) tuberculosis is the most important. Although it usually affects the lungs it can affect almost any organ, usually spreading via the lymphatic vessels. Various manifestations of the disease are known as scrofula and consumption. The organism is less commonly found in muscle tissue, or in parts of the body with few blood vessels.

Infection is generally acquired by inhalation of aerosols from an infected person or inhalation of contaminated dust, as the organism can survive for long periods in the environment, although sunlight will destroy the bacteria. The importance of inhalation is demonstrated by the fact that over 90% of tuberculosis fatalities are caused by pulmonary tuberculosis. Infections in the lung and throat can be transmitted via aerosols to other people while infections in other parts of the body are usually not transmitted.

Infected people may not develop symptoms as their immune system can usually control the bacterium, sometimes throughout life. However, inactive bacteria can become active again later in life, particularly if the immune system is weakened. Reactivation of *M. bovis* infections acquired prior to widespread milk pasteurisation is a significant contributor to the current incidence of infection with this organism (Cousins and Dawson, 1999).

Ingested *M. bovis* is protected from digestion by the fatty coating of the bacterium. The ileococcal region (junction of small and large intestines) is the main site of infection for ingested organisms, where the bacterium migrates to mucosal glands and establishes an inflammatory process. Bacteria are carried to Peyers patches (part of the lymphatic system) by phagocytes which results in the formation of tubercles (a site of infection characterised by a granular appearance) which can later necrose and release organisms causing further (secondary) sites of infection (Vanderpool and O'Leary, 1988).

Intestinal tuberculosis can occur either through direct ingestion of the organism (primary tuberculous enteritis) or due to the spread of the disease after pulmonary infection (secondary). Bentley and Webster (1967) reviewed a case series of 14 cases of gastrointestinal tuberculosis and found no evidence of tuberculosis elsewhere in the body in 50% of cases. Gastrointestinal tuberculous lesions can be classified into three categories on the basis of clinical and pathological factors:

- Ulcerative. This process is virulent and carries a poor prognosis. It appears to result from a continuous inoculum from the lungs (secondary infection).
- Hypertrophic. This process is the commonest cause of tuberculous ileocaecal tumour and is often the only tuberculous lesion (primary infection). These are often amenable to surgical resection.
- Ulcero-hypertrophic. An intermediate description.

Primary gastrointestinal infections were all hypertrophic or ulcero-hypertrophic, with a high survival rate. The presumed secondary intestinal infections were mainly ulcerative, with a resulting poor patient survival rate (Bentley and Webster, 1967).

Akgun (2005) examined 80 cases with either peritoneal or intestinal tuberculosis. Microbiological analysis was only reported for nine cases, of which five cultured positive for *M. bovis*, three for *M. tuberculosis* and one an atypical form of mycobacterium.

This Risk Profile is concerned with risks of primary intestinal infection, and the symptoms below principally concern this form of the disease. However, it should be noted that oral exposure to *M. bovis* can also cause cervical lymphadenopathy, a tumour-like inflammation of the lymph nodes in the neck also known as scrofula (Grzybowski and Allen, 1995). In some cases the affected nodes may rupture through the skin, resulting in sinus formation and occasionally chronic skin tuberculosis (lupus vulgaris; Grange, 2001). The combination of lymphadenopathy and lupus vulgaris is termed scrofuloderma.

The pattern of tuberculosis infections due to *M. bovis* has changed since the pasteurisation of milk, with a decreasing proportion of tuberculosis cases associated with non-pulmonary sites of infection. At the beginning of last century, it was reported that 91% of cervical lymph node and 28% of meningeal tuberculosis cases in children under five years were due to *M. bovis* (Grange, 1995). By the end of last century genitourinary tuberculosis was reported to be the most common non-pulmonary site of infection caused by *M. bovis* (Grange, 1995).

### 4.1 Symptoms

Incubation: Tuberculosis is characteristically a slowly developing chronic condition. Symptoms may not appear for many months or even years. Cases of the gastrointestinal form can occur after reactivation of infections that must have occurred many years earlier.

Symptoms: Fever, chills, weight loss, abdominal pain, diarrhoea or constipation. Other symptoms depend on the organs infected. Symptoms may last for months or years.

Condition: Intestinal tuberculosis or tuberculous enteritis.

Toxins: Does not produce toxins.

People Affected: Immunosuppressed people are especially at risk of either acute infection or reactivation of an infection acquired in the past. In countries where infection is uncontrolled children are at greater risk of infection.

Long Term Effects: The course of the disease is long term and may result in death.

Treatment: Multiple antibiotic treatment is required to be administered over protracted periods, usually employing combinations of rifampicin, isoniazid and ethambutol (Collins, 2000). This is because the organism may have antibiotic resistance and this will not be apparent for long periods because of the slow growth of the organism. Surgical removal of infected tissues (bone lesions, non-functioning kidneys and intestinal obstructions) is also employed.

## 4.2 *Mycobacterium bovis* and AIDS

Patients with AIDS are susceptible to opportunistic infections, and outbreaks of multi-drug resistant tuberculosis have been reported amongst such patients. While *M. tuberculosis* is the most common agent identified, outbreaks within hospitals involving *M. bovis* have also been reported (Bouvet *et al*., 1993; Samper *et al*., 1997; Gori *et al*., 1998). Although in one of these outbreaks the index case had possibly acquired the infection in Brazil where the prevalence of *M. bovis* in cattle is reported as up to 18% (Bouvet *et al*., 1993), these outbreaks have not been linked with foodborne transmission.

## 4.3 Dose Response

No specific human dose response studies for ingestion of *M. bovis* were located. Results from animal experiments in 1934 and earlier, indicate that infection via the oral route requires thousands or millions more organisms than infection via the inhalation route (O'Reilly and Daborn, 1995). It has been estimated that the human infectious dose, via the respiratory route is of the order of tens of hundreds of organisms, while via the oral/gastrointestinal route it is believed to be of the order of millions of organisms (de la Rua-Domenech, 2006).

## 4.4 Types Causing Disease

Stable genotypes of *M. bovis* have been identified and various typing methods have been used in the field, especially when investigating the epidemiology of new outbreaks in animals. Van Embden *et al*. (1995) have reviewed typing methods. These include Restriction Fragment Length Polymorphism (RFLP) or Restriction Enzyme Analysis (REA) of genomic DNA and techniques that utilise a range of polymorphic genetic markers, including two insertion sequences IS6110 and IS1081, and three small repetitive DNA elements: the major polymorphic tandem repeat (MPTR), the direct repeat (DR) and the polymorphic GC rich repeat (PGRS). Kremer *et al.* (1999) has described further typing techniques based on a repeat GTG sequence and analysis of exact tandem repeat (ETR) loci using Variable Number of Tandem Repeats (VNTR) typing. Kamerbeek *et al*. (1997) developed a technique known as spacer oligonucleotide typing (spoligotyping) for typing of *M. tuberculosis* isolates, that has subsequently been applied to *M. bovis* (Cousins *et al*., 1998).

In New Zealand the DNA typing technique of restriction endonuclease analysis (REA) of *M. bovis* has been developed and is now used routinely. Over a period of 23 years, approximately 2,700 isolates of *M. bovis* from domestic animals and wildlife have been examined by DNA typing. These isolates have been characterised into over 250 different DNA types. (Ryan *et al*., 2006)

In a study of *M.bovis* infection in humans in New Zealand over the period 1995 to 2002, in approximately one third of cases the strain type had been previously identified in domestic or wild animals (Baker *et al*., 2003).

A study in Australia on isolates obtained between 1970 and 1994, using IS6110, PGRS, DR and spoligotyping, showed that most Australian-born patients working in the livestock industry had isolates similar to those isolated from cattle, indicating occupational exposure.

Patients born outside of Australia yielded different types indicating that they had been exposed to the organism prior to entry into Australia (Cousins *et al*., 1999).

A study of Swedish isolates, using RFLP probed for IS6110, showed a distinct type among cases in farmed deer, which was distinct from types involved with cases of disease in humans, camels and cats. A common type was therefore shown to be infecting the deer, but the degree of precision is not detailed enough to determine the clonal status of the human isolates (Szewzyk *et al*., 1995).

Van Soolingen *et al*. (1994) used IS6110, DR and PGRS typing to demonstrate that most human cases of *M. bovis* infection in Argentina were due to transmission from cattle, while human infections in the Netherlands were mainly contracted from animals other than cattle.

# 5 EXPOSURE ASSESSMENT

## 5.1 The Hazard in the New Zealand Food Supply: *Mycobacterium bovis* in Meat

The observed occurrence of *M. bovis* in meat in the New Zealand food supply depends on:

- The prevalence of *M. bovis* infection in cattle and deer slaughtered for food;
- The efficiency of detection of infected cattle and deer during ante and post mortem examination and the subsequent management of these animals; and
- The spread of bacteria from the primary and secondary sites of infection (complexes), which are principally located in the lymph nodes, into skeletal muscle tissue (meat).

A national tuberculosis control programme, of varying intensities, for cattle and deer has operated in New Zealand for over 70 years. Currently this is managed by the Animal Health Board (AHB). Under the Biosecurity Act, the AHB has developed and implemented the national 'Bovine Tuberculosis Pest Management Strategy (PMS)' (see http://www.ahb.org.nz/AHBWebsite ). The main PMS objective is to reduce the period prevalence of infected cattle and deer herds to a maximum of 0.2% by 2013. This is one aspect of the World Animal Health Organization's (OIE) standard for 'country freedom' from bovine tuberculosis.

Operationally there are two key inter-related elements of the control programme; elimination of Tb-infected wildlife (mainly possums) and disease control activities in cattle and deer herds. The latter involves on-going surveillance for infection (periodic testing and abattoir examination), rapid eradication of infection from herds, and movement control (to stop the spread of infection between herds).

The PMS has been very successful. The period prevalence of infected herds has been reduced to 0.65% (2004/2005) and is on-target to meet the PMS objective. The annual number of tuberculous cattle and deer has been reduced from a high of 3,196 to 556 and 777 to 339 respectively (see: http://www.ahb.org.nz/NR/rdonlyres/79CB90CA-EBCE-46F7-BEB0-153E42860FB6/263/Section5AHBAR2005.pdf). The annual animal prevalence is 0.06%, which is less than the other associated criteria in the OIE standard (0.1%) for country freedom.

In animals, as in humans, pre-clinical infection may be recognised by use of the tuberculin test. This test is based on detection of the specific immunological response to infection, and involves intradermal injection of protein antigens derived from *M. bovis* (purified protein derivative PPD) and inspection three days later for evidence of a local inflammatory reaction at the site of injection. Other tests of cellular and humoral immunity may also be used (AHB, 2005). In New Zealand, an animal that has been directed to be slaughtered as a result of positive official tests is termed a 'reactor' (AHB, 2005).

All cattle and deer are subject to ante-mortem and post-mortem examination (http://www.nzfsa.govt.nz/animalproducts/meat/meatman/manual-16/m16.pdf). Live animals exhibiting clinical signs of tuberculosis infection are condemned. For all other animals, immediately after slaughter an extensive range of lymph nodes and other tissues are systematically incised and/or palpated. An 'intensified' version of this examination is conducted on Tb reactors. If Tb-like lesions are identified in non-reactors the intensified

procedure is also conducted. All tissues associated with Tb lesions are condemned; if there is evidence that a bacteraemia has occurred (e.g. lesions in peripheral lymph nodes) then the carcase is condemned.

As noted in Section 5.1.1 around 95% of infected animals have lesions limited to the head, thorax and intestinal lymph nodes, the majority with single lesions. The intensity of the control programme in New Zealand, coupled with the slow progression of tuberculosis in cattle and deer means that nowadays few generalised cases of tuberculosis occur in animals.

### 5.1.1 *Mycobacterium bovis* in meat

Little information on the prevalence of *M. bovis* in meat has been located. It is considered that the flesh or skeletal muscle from infected animals rarely contains *M. bovis* bacteria (Francis, 1973; Food Safety Authority of Ireland, 2003; Scientific Panel on Biological Hazards, 2003). Nevertheless, bacteraemia in animals infected with *M. bovis* does occur and therefore the bacteria may be spread through the body (ACMSF, 2001). Therefore, meat from animals infected with *M. bovis* could theoretically contain the organism.

Infection generally enters via the respiratory or oral route. Lesions at these sites are sometimes called the primary complex and as one might expect these are the most commonly observed. For example, the lesion frequency recorded in 1,110 culture-positive cattle and 446 deer in New Zealand are shown in Table 2 (Dr Terry Ryan, NZFSA, personal communication).

**Table 2: Frequency of occurrence by location of lesions resulting from *M. bovis* infection**

| Site | Cattle (%) | Deer (%) |
|---|---|---|
| Retropharyngeal LN | 31 | 50 |
| Submaxillary LN | 3 | 5 |
| Parotid LN | 3 | 2 |
| Atlantal LN | 2 | 1 |
| Mediastinal LN | 43 | 10 |
| Bronchial LN | 26 | 13 |
| Apical LN | 3 | 3 |
| Lung tissue | 6 | 7 |
| Pleura | | 9 |
| Mesenteric LN | 7 | 32 |
| Liver | 5 | 2 |
| Spleen | 0 | 0 |
| Hepatic LN | 2 | 0.2 |
| Renal LN | 0.1 | 0.2 |
| Lumbar LN | 0 | 0.4 |
| Internal Iliac LN | 0.2 | 0.4 |
| Inguinal LN | 0.1 | 0.4 |
| Ischiatic LN | 0.1 | 0.4 |
| Prescapular LN | 3 | 5 |
| Precrural LN | 0.3 | 0.4 |
| Popliteal LN | 2 | 0.2 |
| Other | 6 | 3 |

LN = lymph node

In cattle, typical lesions were seen associated with thoracic tissues in 61% of infected animals, with tissues of the head in 35% and with tissues of the intestine in 7%. Approximately 94% of infected animals were reported as having typical lesions in one or more of these three areas.

In deer, typical lesions were seen associated with thoracic tissues in 31% of infected animals, with tissues of the head in 54% and with tissues of the intestine in 28%. That is 95% of infected animals were reported as having typical lesions in one or more of these three areas.

It is also of note that with both cattle and deer, 75% of animals had only one lesion, with 90% less than 3 lesions.

During the 2004/2005 financial year 339 of slaughtered deer and 556 slaughtered cattle were reported as having typical tuberculosis lesions. Assuming a 'meat inspection sensitivity' of approximately 70% (Pharo and Livingstone), an estimated 484 infected deer and 794 infected cattle would have been killed.

### 5.2 Food Consumption: Red Meat and Meat Products

The WHO GEMS/Food regional diets (see http://www.who.int/fsf/GEMS/index.htm) list consumption figures for red meat (cattle, pigs and sheep) in the range 15.0-149.3 g/day. The higher figure relates to the European regional diet, which is most applicable to New Zealand. This total is made up of cattle meat 63.3 g/day, pigmeat 75.8 g/day, and sheep meat 10.2 g/day.

Red meat (sheep and beef) consumption has declined since 1985, as shown in Table 3. A major shift in consumption patterns has taken place with gains by the poultry and pork industries.

**Table 3: New Zealand domestic meat consumption per capita 1985-2001 (kg/person/year)**

| Year | Sheep and Lamb | Beef and Veal | Pig meat | Total Red meat | Poultry | Total Meat |
|---|---|---|---|---|---|---|
| 1985 | 27.3 | 36.5 | 14.2 | 78.0 | 15.0 | 93.0 |
| 1995 | 23.2 | 34.6 | 15.7 | 73.5 | 26.2 | 100.1 |
| 1996 | 20.6 | 37.8 | 16.1 | 74.5 | 25.1 | 99.8 |
| 1999 | 14.3 | 31.2 | 17.1 | 62.6 | 26.8 | 89.5 |
| 2001 | 16.6 | 27.1 | 16.5 | 60.2 | 31.0 | 91.2 |

From: http://www.beef.org.nz/statistics/sld002.asp

The meat consumption figures for New Zealand in Table 3 are similar for red meat to estimates made for the Australian population (Baghurst, 1999). The Australian consumption levels for 1996-97 were; beef 40.2 kg/person/year, sheep and lamb 17.5 kg/person/year, pig meat 17.9 kg/person/year, and poultry 10.2 kg/person/year.

An international comparison of meat consumption as calculated for 2003 is given in Table 4. Figures are taken from Food Balance Sheets (http://faostat.fao.org/).

**Table 4: International comparison of meat consumption, 2003 (kg/person/year)**

| Country | Bovine meat | Sheep and goat meat | Pigmeat | Poultry meat |
|---|---|---|---|---|
| Argentina | 54.7 | 1.5 | 5.1 | 19.4 |
| Australia | 45.1 | 14.4 | 21.1 | 35.6 |
| Canada | 34.3 | 1.0 | 27.4 | 36.3 |
| New Zealand | 26.4 | 24.8 | 20.7 | 35.2 |
| UK | 20.9 | 5.9 | 26.0 | 30.0 |
| USA | 41.9 | 0.5 | 30.1 | 50.2 |

Source: http://faostat.fao.org/

The figures given above represent the meat available for consumption in New Zealand. Information on amounts of meat reported to be actually consumed by individuals can be abstracted from the 1997 National Nutrition Survey (NNS) (Russell *et al*., 1999). FSANZ have carried out an analysis of this dataset (ANZFA, 2001), including application of a set of standard recipes, to allow composite foods to be reduced to their component parts. Table 5 gives the estimates for meat consumption derived by FSANZ and compares those levels of consumption to the estimates based on meat available for consumption (Table 3).

**Table 5: Mean estimates of meat consumption (total population over 15 years), 1997 and estimates of meat available for consumption, 1996 (g/person/day)**

| Meat type | Estimated consumption (1997)* | Amount available for consumption (1996)# |
|---|---|---|
| Beef and veal | 87.9 | 103.6 |
| Sheep and Lamb | 13.7 | 56.4 |
| Pig meat | 32.3 | 44.1 |
| Deer meat | 0.9 | |
| Rabbit meat | 0.1 | |
| **Total red meat** | **134.9** | **204.1** |
| Poultry | 35.4 | 68.8 |
| **Total meat** | **170.3** | **272.9** |

* from FSANZ analysis of 1997 National Nutrition Survey data (ANZFA, 2001)
\# from Table 3, recalculated from kg/person/year to g/person/day

The difference between these two estimates of consumption will reflect wastage (meat available for consumption, but not consumed), and under-reporting in the NNS. Through use of standard recipes, the FSANZ analysis of the 1997 NNS data will include all meat consumed, including meat which is consumed as a component of a processed food such as meat pies or luncheon meat (ANZFA, 2001). While the total amount of red meat consumed in New Zealand is quite similar to that in the WHO GEMS/Food European regional diet, the distribution is quite different with significantly more beef and significantly less pigmeat being consumed in New Zealand. This level of consumption is also quite similar to US figures of 147.9 g/day (retail cut equivalent) or 139.1 g/day (trimmed equivalent). Beef consumption is similar in the US, with proportionally more pigmeat and less sheep meat being consumed (EPA, 1997).

The analysis of the 1997 NNS data concluded that 78% of the population consumed red meat (cattle, sheep or pig meat) during any 24-hour period. The mean daily consumption, for consumers only, was 172.5 g/day. The median daily consumption, for consumers only, was 124.1 g/day. The 97.5$^{th}$ percentile daily consumption, for consumers only, was 616 g/day.

Table 6 represents an analysis of dietary records from the 1997 National Nutrition Survey and shows a breakdown of total red meat and red meat product consumption on the basis of number of servings and on the basis of consumption weight.

**Table 6: Types of red meat and meat products consumed, by servings and by weight**

| Meat type | Percentage of total red meat consumed (by servings) | Percentage of total red meat consumed (by weight) |
|---|---|---|
| **Beef (including veal)** | | |
| Corned beef | 6.3 | 5.0 |
| Beef offals | 0.6 | 0.5 |
| Beef mince and beef mince recipes (patties, hamburgers, etc) | 14.7 | 24.1 |
| Beef cuts (steak, roast, schnitzel, etc) | 20.2 | 26.2 |
| **Sheep meat (Lamb, hogget and mutton)** | | |
| Hogget/mutton cuts | 4.1 | 3.6 |
| Lamb cuts | 6.0 | 5.2 |
| Lamb mince and lamb mince recipes | 0.1 | 0.1 |
| Lamb offals | 0.6 | 0.6 |
| **Pigmeat (including ham and bacon)** | | |
| Pigmeat cuts | 6.8 | 8.3 |
| Pigmeat mince | 0.1 | 0.1 |
| Pig offals | 0.2 | 0.1 |
| Bacon | 7.3 | 2.9 |
| Ham | 11.5 | 4.3 |
| **Mixed meat products** | | |
| Sausages, saveloys, frankfurters and hotdogs | 13.6 | 15.1 |
| Salami | 1.6 | 0.5 |
| Luncheon meat | 4.1 | 1.7 |
| **Other meats** | | |
| Venison | 0.4 | 0.5 |

## 5.3 Qualitative Estimate of Exposure

### 5.3.1 Number of servings and serving sizes

Red meat and red meat products are commonly consumed products with 78% of respondents in the 1997 National Nutrition Survey reporting consumption of beef, sheep or pigmeat in any 24-hour period. This category of food represents one of the most commonly consumed in New Zealand. Only categories such as dairy products, cereal grains (bread, breakfast cereals, etc.) and water are consumed by a greater percentage of the population on any given day. The greatest contributors to total servings are beef cuts, beef mince and beef mince products, sausages (including saveloys, frankfurters and hotdogs) and ham.

Serving sizes will vary considerably within the red meat and meat products group from hundreds of grams for a meal of meat cuts to a few grams for ready-to-eat meats consumed as a component of a sandwich. According to the FSANZ analysis of the National Nutrition Survey data the average daily consumption of red meat by consumers (only those reporting consumption of red meat) is similar to average daily consumption for consumers of common fruits and vegetables at a mean level of 172.5 g/day (median 124.1 g/day, 97.5$^{th}$ percentile 616 g/day).

### 5.3.2 Frequency of contamination

Unknown, but generally expected to be very low (Francis, 1973; Food Safety Authority of Ireland, 2003; Scientific Panel on Biological Hazards, 2003).

### 5.3.3 Predicted contamination level at retail

Not known for New Zealand. Given the assumption made in the point above, the levels present are also likely to be very low.

### 5.3.4 Growth rate during storage and most likely storage time

The organism is very slow growing and is unlikely to increase significantly in numbers during the storage of raw meats. Other products with very long shelf lives, like salamis, should be of such a composition that growth will not occur.

### 5.3.5 Heat treatment

Heat treatment of raw meat is likely to be sufficient to inactivate the organism.

### 5.3.6 Exposure summary

While a large amount of meat is eaten, the numbers of *M. bovis* cells being ingested by consumers in New Zealand are likely to be very low.

## 5.4 Overseas Context

The results of a UK study by the Advisory Committee on the Microbiological Safety of Food (ACMSF), to investigate whether *M. bovis* is present in the edible tissues of salvaged

carcases from cattle that have reacted positively to the tuberculin test, were published in 2003 (http://www.foodstandards.gov.uk/multimedia/pdfs/acm652.pdf). The study found that, of 110 tuberculin test positive animals with no visible lesions (NVL), 19 (17%) were culture positive for *M. bovis*. However, most of these were culture positive from inedible offal; only five animals (4.5%) with NVL yielded viable *M. bovis* from carcase or edible offal lymph glands. In addition, one of 25 animals (4%) with a single visible lesion and one of 18 animals (5.5%) with two or more visible lesions yielded viable *M. bovis* from carcase or edible offal lymph glands.

These findings and the EFSA report (Scientific Panel on Biological Hazards, 2003) were considered by the UK Food Standards Agency (http://www.food.gov.uk/aboutus/ourboard/boardmeetoccasionalpapers/tbinmeat0204). The UK FSA concurred with the Scientific Panel on Biological Hazards conclusion that the risks to public health through the consumption of meat from Tb reactor animals are very low.

The distribution of lesions in cattle reported for New Zealand is similar to that reported by Phillips *et al*. (2003) for cattle in the United Kingdom in the 1990s and Corner *et al*. (1990) from inspection of Australian cattle.

Some data are available from Argentina. Ten from 719 (1.4%) cattle were condemned because they displayed tuberculosis lesions, but testing of 178 samples from the remaining 709 cattle not condemned found five (2.8%) of these samples to be contaminated by *M. bovis* (De Kantor *et al.*, 1987). The paper speculates that the apparent low sensitivity of meat inspection could be due to the high rate of tuberculosis transmission in the area concerned resulting in a relatively high proportion of small incipient lesions in cattle.

In the USA a campaign of eradication resulted in the reduction of Federally-inspected animal carcases condemned or sterilised at slaughter on account of tuberculosis from 0.53% to 0.02% during the period 1917 to 1941 (Wight *et al.*, 1942).

Some estimates of exposure have been produced for cervid (deer) production in the United States (VanTiem, 1997). References indicating a 65-75% efficiency rate for the detection of tuberculous carcases at slaughter were provided. Since the prevalence of tuberculosis in cervids was estimated at 0.002% then for every million carcases processed six would contain undetected tuberculous lesions. Given that the organism tends to be associated with lymph tissue in the head, thorax and abdomen, the chances of organisms being included with a cut of meat are low and further act to reduce exposure. Normal cooking of meat again reduced exposure. It was concluded that transmission of tuberculosis via cervid meat was no greater than for other meat derived from ruminant animals, although absolute values could not be assigned, as the necessary data do not exist.

# 6 RISK CHARACTERISATION

*M. tuberculosis* is the most common cause of human tuberculosis and, with very few exceptions, is the result of direct person-to-person spread. The proportion of cases caused by *M. bovis* is significant in developing countries where animal tuberculosis is widely distributed, there is close contact between animals and their owners (e.g. penned overnight in close proximity), control measures are not consistently applied and pasteurisation is rarely practiced. In industrialised countries the proportion of cases caused by *M. bovis* is much lower, due to animal tuberculosis control and elimination programmes, together with milk pasteurisation (Cosivi *et al*., 1998).

## 6.1 Adverse Health Effects in New Zealand

### 6.1.1 Incidence

Tuberculosis is a notifiable disease in New Zealand. The incidence of tuberculosis in New Zealand has been stable for the last ten years, at approximately 10 per 100,000 population (350-450 cases per annum). In 2005 the number of notified cases was 348 (9.3 per 100,000) of which 19 (5.5%) were reactivated infections (ESR, 2006).

An analysis of the incidence of human tuberculosis caused by *M. bovis* using data from Wellington Hospital from 1983 to 1990 found that an average of 7.2% of cases of tuberculosis were caused by *M. bovis* (Brett and Humble, 1991). The most common organ affected was the lung (pulmonary tuberculosis) which suggests that the disease was not caused by consumption of contaminated meat or milk. Instead it was suggested that the primary source may be exposure to domestic or wild animals. The risks are higher in those areas where there is a wildlife reservoir of *M. bovis*, especially the possum.

Only 50 – 75% of the notified cases of tuberculosis are able to be confirmed by the identification of an isolated organism; for the remaining cases the causative *Mycobacterium* species is unknown. *M. tuberculosis* is distinguished from *M. bovis* on the basis of biochemical tests and antibiotic and drug susceptibility. Information on the relative proportions of *M. tuberculosis* to *M. bovis* isolates obtained from recent cases in New Zealand are given in Table 7.

**Table 7: Identity of *Mycobacterium* isolates from tuberculosis notifications and laboratory sources in New Zealand**

| Year | Number of isolates identified | | | Reference |
|---|---|---|---|---|
| | Total | *Mycobacterium tuberculosis* | *Mycobacterium bovis* (percentage of total) | |
| 1997 | 200 | 194 | 6 (3.0%) | ESR, 1998 |
| 1998 | 256 | 248 | 8 (3.1%) | Perks *et al*., 1999 |
| 1999 | 302 | 297 | 5 (1.7%) | Kieft *et al.*, 2000 |
| 2000 | 250 | 242 | 8 (3.2%) | Lopez *et al*., 2001 |
| 2001 | 289 | 283 | 6 (2.1%) | Sneyd *et al*., 2002 |
| 2002 | 268 | 264 | 4 (1.5%) | Sneyd and Baker, 2003 |
| 2003 | 322 | 316 | 6 (1.9%) | ESR, 2004 |
| 2004 | 288 | 283 | 5 (1.7%) | ESR, 2005a |

The percentage of tuberculosis cases from which *M. bovis* was identified appears to have decreased in New Zealand from an average of 7.2% in 1983-1990 (Brett and Humble, 1991) to an average less than 2% in 2002-2004 (Table 7).

The details of notified cases of infection with *M. bovis* from 1995 to 2005 were reviewed for this document. For only three cases (one each in 1998, 1999 and 2002) was a food noted as a risk factor; in all three cases this was unpasteurised milk. In none of these cases was the infection conclusively linked to the milk, and one was a dairy farm worker who could have acquired the infection via exposure to animals. This is supported by the fact that the site of the infection was pulmonary. One other case (an older adult) reported consuming unpasteurised milk as a child. There were no cases for which meat consumption was reported as a risk factor.

Fifty percent of cases were reported as having pulmonary infections, a further 6% had both pulmonary and extrapulmonary infections, while the site of infection was unknown in 15% of cases. There was no consistent pattern in the site of extrapulmonary infections, although four instances of infection of the cervical lymph node were reported. Infection at this site was more common prior to milk pasteurisation (Grange, 1995) and, given the age of the cases (55-80), these cases may represent reactivation of old infections.

Significant risk factors included; farm or meatworks contact (9% of cases), other animal contact (research, veterinary clinic; 4%), occupational exposure (lab technician; 2%), overseas travel or residence (Pacific islands, South Africa, Iraq; 15%).

(Data obtained from various articles in the New Zealand Public Health Report, Elizabeth Sneyd and Charlotte Kieft, ESR Kenepuru Science Centre, personal communication).

### 6.1.2 Clinical consequences of tuberculosis disease

Hospitalisation and fatality rates for notified cases of tuberculosis (from both *M. tuberculosis* and *M. bovis* infection) in New Zealand are given in Table 8. These outcomes are not always reported for each case, so percentages are expressed in terms of the number of cases for which outcomes are known.

**Table 8: Outcome data for tuberculosis in New Zealand**

| Year | Hospitalised cases | Fatalities | Reference |
|---|---|---|---|
| 1997 | 229/293 (78.2%) | 15/330 (4.5%) | ESR, 1998 |
| 1998 | 251/340 (73.8%) | 8/368 (2.2%) | Perks *et al.*, 1999 |
| 1999 | 273/408 (66.9%) | 14/456 (3.1%) | Kieft *et al.*, 2000 |
| 2000 | 199/314 (63.4%) | 8/353 (2.3%) | Lopez *et al.*, 2001 |
| 2001 | 213/334 (63.8%) | 2/381 (0.5%) | Sneyd *et al.*, 2002 |
| 2002 | 193/348 (55.5%) | 6/384 (1.6%) | Sneyd and Baker, 2003 |
| 2003 | 206/361 (57.1%) | 5/358 (1.4%) | ESR, 2004 |
| 2004 | 203/322 (63.0%) | 5/323 (1.5%) | ESR, 2005b |
| 2005 | 175/302 (57.9%) | 4/348 (1.1%) | ESR, 2006 |

### 6.1.3 Case control studies, risk assessments and other investigations

An analysis carried out by MAF in New Zealand concluded that the importation of *M. bovis* into New Zealand in sheep or goat meat is remote (MacDiarmid and Thompson, 1997).

One New Zealand study has examined cases of infection with *M. bovis* in detail (Pooley, 1996). Sixty-four cases were identified from the notification database as having *M. bovis* infection during the period January 1985 to July 1995. Following contact with the cases, four were found not to have the disease and were excluded. Thirty-four cases could not be contacted, and eight cases had died in the intervening period. This left eighteen cases, of which eleven agreed to be interviewed for the study.

Analysis of the notification data was possible for 27 of the cases. This revealed that extra-pulmonary tuberculosis affected nine cases, but none of these reported isolation of the organism from gastrointestinal lesions.

Interviews with the eleven cases showed that all but one had lived or stayed on a farm. Six cases were in occupations that involved possible contact with diseased animals or farming in regions where bovine tuberculosis was known to exist at the time. Meat from a wild source (pork, venison, beef, goat, rabbit and possum) was more likely to have been consumed by males, and two cases had eaten raw meat, particularly mince and steak.

The interview data suggested that five of the eleven cases were likely to have been infected by consuming unpasteurised milk, and they had also lived on a farm. All these cases were older than 35 years. Of the other cases over 35 years of age, their occupations (slaughterhouse workers) and exposures (raw milk) while overseas were considered likely causes of infection. Cases younger than 35 years of age were more likely to have been infected by airborne transmission.

In 2002 an Animal Health Board study was carried out to determine the possible sources of human infection with *M. bovis* over the 1998 to 2002 period was conducted (Baker *et al*., 2003). Combined epidemiological and laboratory investigations of cases were used, including surveillance data collected on notified cases. The study also obtained *M. bovis* isolates from New Zealand's three tuberculosis reference laboratories. AgResearch carried out DNA typing on these isolates using restriction endonuclease analysis (REA).

Notification records for the years 1995-2002 were reviewed and it was concluded that *M. bovis* infection remains an uncommon cause of tuberculosis in New Zealand accounting for only about 3% of cases over the 1995 to 2002 period. The average incidence of 6.8 cases a year (0.18 per 100 000) is similar to the incidence observed in the previous 10-year period.

The 34 cases occurring over the period 1998 to 2002 were reviewed in detail. Most cases (80%) were over 30 years of age, with a median age of 57 years. Compared with people infected with *M. tuberculosis,* people infected with *M. bovis* were significantly more likely to be male, over 60 years of age, European or Maori, and to have been born inside New Zealand rather than migrated here. They were more likely to be living in the South Island at the time of diagnosis. *M. bovis* infection was no more likely to be associated with extra-pulmonary sites than was *M. tuberculosis* infection.

Typable isolates were obtained for 18 of the 34 cases. The infecting organisms had 14 different REA patterns. Of these, six isolates were classified as "foreign" strains as their REA pattern has not been seen previously in a New Zealand animal isolate. One isolate was the strain used for making bovine PPD. The remaining 11 isolates had REA patterns that were the same as, or very similar to, one that has been seen previously in wild or domestic animals in New Zealand. These animals included possums, ferrets and stoats, deer, cattle, pigs and cats. No animal reservoir appeared to dominate. Four of these cases reported animal contact that could potentially have given rise to infection. Four cases were New Zealand born and reported no risk factors for infection. Two cases had insufficient information to evaluate fully, one of whom was born overseas. One case with no other risk factors reported contact with another human case of *M. bovis* infection. These data do not implicate any particular animal reservoir or mode of transmission. They do, however, suggest a small number of cases with unexplained sources of infection.

This small study suggests that *M. bovis* infection is not increasing despite the large reservoir of animal infection in this country. Apart from two well-documented instances (contact with an infected possum, and a laboratory accident), the modes of infection in these human cases have not been established.

## 6.2 Adverse Health Effects Overseas

### 6.2.1 Incidence

A review of the incidence of human tuberculosis caused by *M. bovis* in industrialised countries showed that the proportion of total tuberculosis cases attributable to *M. bovis* was approximately 7% or less, with a high proportion (31 – 73%) being pulmonary tuberculosis (Cosivi *et al*., 1998). This suggests predominantly airborne transmission unrelated to food. Grange (1995) summarised data from Germany, United Kingdom, Denmark, France, Poland, Hungary, Switzerland, Czechoslovakia and Turkey prior to 1965. *M. bovis* infection accounted for 1.1 (Poland) to 10.5% (Germany) of total tuberculosis cases and accounted for a higher proportion of non-pulmonary cases (12.1-90.0%) than pulmonary (0.2-5.9%) cases. Kleeberg (1984) reviewed data from a wider range of countries, mainly from dates prior to 1960. Several general observations can be made from the reviewed information presented:

- *M. bovis* infection represented a higher proportion of total tuberculosis cases in children than in adults.
- *M. bovis* infections represented a higher proportion of non-pulmonary cases than pulmonary.
- The contribution of *M. bovis* infection to total tuberculosis cases appears to have decreased during the latter half of last century.

In France an incidence of 0.07/100,000 cases of tuberculosis caused by *M. bovis* has been recorded (Boulahbal *et al.*, 1999). *M. bovis* was the causative agent in only 0.5% (38 of 7075) of tuberculosis cases examined. Of the 38 cases, three could be attributed to the consumption of unpasteurised milk. Meat consumption was not identified as a cause.

In England and Wales 1.2% (117 of 9687) of tuberculosis cases examined by the PHLS Communicable Disease Surveillance Centre between 1986 and 1991 were caused by *M. bovis*. When supplementary data were included, information for 228 cases was available. Of these, 122 (53%) were from patients aged over 60 years and were attributed to the

reactivation of infection acquired prior to the institution of control measures. Around 22% of the particular body sites infected suggested that the organism could have been ingested (Hardie and Watson, 1992). Cases were attributed to either 1) reactivation of old infections or 2) cases brought into the UK by immigrants.

Between 1993 and 1999 annual reported case numbers of tuberculosis caused by infection with *M. bovis* in the UK ranged between 30 and 50. Around 75% of patients were aged 50 years or over, suggesting reactivation of infections acquired earlier. As there has been an increasing incidence of herd "breakdown" (presumably infection) in cattle, enhanced surveillance of *M. bovis* in humans was instituted in 1998 with the aim of investigating risk factors for transmission of the bacterium to humans. From January 2001 this surveillance has been expanded to solicit further information via a questionnaire (PHLS, 2001).

Case numbers in the UK have continued to decrease and in the period 2000-2003 were in the range 17 to 34 (de la Rua-Domenech, 2006). This represents less than 0.5% of all new tuberculosis notifications.

In the UK, the Department of the Environment, food and rural affairs (DEFRA) has stated "There are no recorded instances of humans catching bovine TB from meat" (www.defra.gov.uk/animalh/tb/point1.shtml).

A stable incidence of 0.56 cases/100,000 has been reported for Ireland over the period 1983-1992 (Cotter *et al.*, 1996). Fifty-three percent of *M.bovis* cases involved pulmonary infection. No rural-urban difference could be detected in rates and it was concluded that the initial infection was likely to have occurred in childhood through the consumption of unpasteurised milk.

Cousins and Dawson (1999) reviewed the information available on *M. bovis* infections in Australia from 1970 to 1994. The mean number of cases per year was 9.4, representing approximately 1% of Australian cases of tuberculosis during this period. Data were available for 150 patients. A high proportion (71.6%) of patients suffered pulmonary disease. Only one case suffered from infection at the gastrointestinal site, two in the meninges and five in the lymph nodes; sites typical for gastrointestinal infection. Males were more than twice as likely to be infected by the organism, perhaps reflecting occupational exposure. It was considered that most cases of extra-intestinal infection result from reactivation of chronic infections, some of which would have been acquired by the consumption of milk before pasteurisation became commonplace. Many of the patients in the study had a history of working in the livestock industry, including abattoirs.

There is some evidence that different ethnic groups have different susceptibilities to tuberculosis. It has been reported that African American US servicemen are more likely to die from tuberculosis if they contract it, but have the same probability of contracting it as their Caucasian counterparts. Jewish people appear to be the most resistant (O'Reilly and Daborn, 1995).

### 6.2.2 Contributions to outbreaks and incidents

No information on this could be located. This may be because foodborne incidents of bovine tuberculosis are very rare, or that such data are not kept. Given the severity of the disease, the former of these options is the most likely.

A documented instance of a cat contracting tuberculosis from eating infected meat has been reported (Isaac *et al.*, 1983), but the link between food and disease was only established in lieu of any other plausible source of infection.

### 6.2.3 Case control studies

Outbreaks leading to investigations into risk factors have occurred. However, those identified occurred in unusual settings and did not involve ingestion of the organism. For example Bouvet *et al.* (1993) reported the results of a case control study of an outbreak of multidrug resistant *M. bovis* occurring in an AIDS ward. The main risk factor was the length of time of exposure to the index case.

Besser *et al*. (2001) conducted a case-control study to examine potential source of *M. bovis* tuberculosis infection in children in San Diego. Cases were more likely to have received BCG vaccine (OR = 44), been born overseas (OR = 4.3) and to have consumed raw milk or cheese (OR = 3.76) and the high prevalence of bovine tuberculosis in Mexican cattle was discussed. A multiagency investigation in New York city identified 35 cases of human *M. bovis* infection. Fresh cheese from Mexico was identified as the likely source of infection (Winters *et al*., 2005).

### 6.2.4 Risk assessments and other activity overseas

#### *6.2.4.1 Australia*

Although not a risk assessment as would be recognised today, an assessment has been made in Australia on the health impact of eating the flesh of infected cattle (Francis, 1973). In general, and with reference to some very early work, it was concluded that the number of tubercle bacilli that might be on the surface of meat would be low and the number needed to be consumed to cause disease is high and so the risk would consequently be low. Given that good slaughter hygiene would minimise contamination the risk would be reduced further in practice.

#### *6.2.4.2 United Kingdom*

A 2001 paper by the UK Advisory Committee on the Microbiological Safety of Food reported on the health risk to consumers of meat from cattle with evidence of *M. bovis* infection (ACMSF, 2001). The Committee noted that there were no reports of clinical cases of tuberculosis associated with the consumption of meat and there was no evidence of an increase in the number of cases of human *M. bovis* infection in the UK, nor was there a correlation between increases in human tuberculosis and areas of the country where *M. bovis* infection of cattle had increased. Overall the risk, if any, from meat was considered to be very low.

#### *6.2.4.3 Ireland*

The Food Safety Authority of Ireland published a report in July 2003 (Food Safety Authority of Ireland, 2003) which considered the potential for transmission of zoonotic tuberculosis through the food chain. Although the scientific information available did not permit a formal risk assessment, it was the opinion of the Microbiology Subcommittee that, given existing safeguards and the nature and distribution of tuberculous lesions and of the infecting organism in infected animals, the probability of *M. bovis* entering the food chain in meat in significant numbers was very low. In contrast, there was some concern about the continuing consumption of unpasteurised milk and derived products.

#### *6.2.4.4 Europe*

The Scientific Panel on Biological Hazards have expressed an opinion on the risks to human health due to tuberculosis in bovine animals (Scientific Panel on Biological Hazards, 2003). Account was taken of the characteristics of the organism, on farm control measures and procedures in place to remove affected material from the food chain. It was concluded that in light of these measures the risks associated with consumption of meat were "considerably low". It was also concluded that "there is no evidence to suggest that additional restrictions on the use of beef from tuberculin reactor cattle and from carcases with or without localized lesions of tuberculosis will contribute to the prevention of tuberculosis due to *M. bovis* under these circumstances. Meat plant surveillance for tuberculosis in slaughter cattle augments *ante-mortem* monitoring of the tuberculosis status of national herds. This combination represents best practice".

### 6.2.5 Secondary transmission

Person-to-person spread could occur, most probably by the inhalation route. However, the likelihood of this occurring is not great with Grange (2001) describing it as an "exceptional event".

## 6.3 Qualitative Estimate of Risk

There is no evidence for transmission of *M. bovis* in meat to humans in New Zealand.

## 6.4 Risk Categorisation

The rationale for categorisation of food/hazard combinations is presented in Appendix 1.

The proportion of severe outcomes (hospitalisation, long term sequelae, and death) resulting from *M. bovis* infection in New Zealand should be considered as high. The course of the disease has a long term (months or years) and a mortality rate of 3.1% has been reported for tuberculosis in New Zealand. It would seem reasonable to assign *M.bovis* to the highest severity category (>5% of cases resulting in severe outcomes, see Appendix 1).

The average proportion of tuberculosis cases caused by *M. bovis* in New Zealand from 1983 to 1990 of 7.2% was relatively high compared to other developed countries (Cosivi *et al*., 1998). More recent data show proportions of approximately 3% that is comparable with the proportion of cases in other developed countries.

In 2005 the incidence of tuberculosis in New Zealand, based on notifications, was 9.3/100,000 (see section 6.1.1). Testing of isolates identified *M.bovis* in 2% or fewer of tuberculosis cases, giving a *M.bovis*-related tuberculosis rate of 0.3/100,000 of population. Brett and Humble (1991) reported that the most commonly affected organ for *M.bovis* infections was the lung, suggesting aerogenic, rather than dietary, transmission. There is no evidence for the transmission of *M. bovis* in meat and so this food hazard combination is assigned to the lowest incidence category.

## 6.5 Summary

| Food/hazard combination | Severity | Incidence | Trade importance | Other considerations |
|---|---|---|---|---|
| *Mycobacterium bovis* in meat | 1 (>5% serious outcomes) | 4 (<1 per 100,000) | High (control essential) | |

# 7 RISK MANAGEMENT INFORMATION

## 7.1 Animal Products Act

The Animal Products Act 1999 reformed the New Zealand law that regulates the production and processing of animal material and animal products to:

- Manage associated risks; and
- Facilitate overseas market access.

The Animal Products Act requires all animal products traded and used to be "fit for intended purpose". This means they must meet New Zealand animal product standards. The New Zealand animal product standards are contained in Part 1 of the Animal Product Regulations 2000.

The Animal Products Act (except for Part 2) and the transitional Act commenced on 1 November 1999. Part 2 of the Animal Products Act commenced on 20 November 2000. Part 2 provides the requirements for risk management programmes.

The risk management system potentially applies anywhere in the value chain from production, through processing to the market. The risk management system comprises the following main types of controls:

- Risk management programmes;
- Regulated control schemes; and
- Controls relating to the export of animal material and animal products.

All animal product primary processing businesses, except those exempt under the Act or under the Animal Products (Exemptions and Inclusions) Order 2000, must have a risk management programme. The transition time to the Animal Products Act (previously to 1 November 2002), has been extended during a phase-in period from July 2003 to July 2006.

A risk management programme is a documented programme to identify and manage biological, chemical and physical hazards. The programme is to be based on the principles of Hazard Analysis and Critical Control Point (HACCP): identifying the hazards, the systems of control, and demonstrating that the controls are effective. Risk management programmes are to be designed by individual businesses for the animal materials used, the processes performed and the product range produced.

## 7.2 Control of Bovine Tuberculosis in New Zealand

*M. bovis*, the causative agent of bovine tuberculosis, is a notifiable organism under the Biosecurity (National Bovine Tuberculosis Pest Management Strategy) Order 1998 (Livingstone, 2002).

A bovine tuberculosis national pest management strategy (NPMS) for both cattle and deer operates under the Biosecurity Act and is administered by the Animal Health Board (O'Neil and Pharo, 1995; Livingstone, 1996). A tuberculosis control programme was introduced for cattle in 1945, which caused substantial declines in tuberculosis incidence until the 1970s.

Further progress was hampered until the importance of possums as a reservoir of infection was recognised. A voluntary eradication scheme for deer was introduced in 1985 and this became compulsory in 1990. The Animal Health Board NPMS has a primary objective of reducing New Zealand's Tb period prevalence to fewer than 0.2% infected herds by 2013 (AHB, 2005). Three progress objectives were also defined in the 2004 amendment of the NPMS:

- To prevent the establishment of vector populations (principally ferrets and possums) infected with Tb in areas that are Tb-vector free from 1 July 2004.
- To increase the area deemed to be Tb-free to at least 226,000 square kilometres by 30 June 2006. (As at 30 June 2004, the area was 201,750 square kilometres).
- To reduce the mean annual number of infected vector-related breakdowns in herds located in Tb-vector risk areas to no more than 12 breakdowns to every 1000 uninfected herds (AHB, 2005).

The control of bovine tuberculosis infection in New Zealand is measured by the number of infected herds. This may be measured by the **period** prevalence of infected herds (the number of infected herds at the beginning of the previous 12 month period plus any additional herds identified during the period as a percentage of the total herds) or **point** prevalence (the number of infected herds within an area of interest at a particular time as a percentage of the total herds within the area).

Recent data on period and point prevalence of tuberculosis in animals in New Zealand come from the Surveillance publication (http://www.biosecurity.govt.nz/publications/surveillance/index.htm) and are summarised in Table 9. These data indicate the continuation of a downward trend in prevalence seen in both cattle and deer herds since 1992/1993.

**Table 9: Point and period prevalence for tuberculosis in cattle and deer herds in 2001 to 2005**

| Year | Point prevalence* | | Period prevalence* | |
|---|---|---|---|---|
| | Cattle herds | Deer herds | Cattle herds | Deer herds |
| 2001 | 414 (0.62%) | 92 (1.67%) | 1.23% | 2.51% |
| 2002 | 364 (0.5%) | 79 (1.5%) | 0.99% | 2.35% |
| 2003 | 275 (0.4%) | 67 (1.3%) | 0.82% | 2.19% |
| 2004 | 235 (0.3%) | 73 (1.4%) | 0.69% | 1.84% |
| 2005 | 185 (0.26%)# | 50 (0.96)# | 0.57%§ | 1.71%§ |

* As at 30 June of the relevant year
# From Animal Health Board annual report (http://www.ahb.org.nz/NR/rdonlyres/79CB90CA-EBCE-46F7-BEB0-153E42860FB6/263/Section5AHBAR2005.pdf)
§ From Terry Ryan, NZFSA.

A country or area is considered to be free of tuberculosis when 99.8% of the herds in the area have been officially free for 3 years. New Zealand is approaching this level, and is ahead of other countries such as Spain and Ireland. Given the extensive tuberculosis control programme for both cattle and deer, intensive meat inspection procedures which ensure that infected meat is not exported, and the mandatory pasteurisation of milk in New Zealand

(apart from very small quantities sold directly from farms), it has been considered that this issue would not cause any trade problems (O'Neil and Pharo, 1995).

The control programme involves both repeated testing of live animals (with slaughter of infected stock) and examination of all carcases in licensed slaughter premises for lesions. Controls are in place for the movement of stock between uninfected areas, and regions where infection is endemic (Ryan and Livingstone, 2000).

An important component of the programme is the control of wild animal vectors of tuberculosis, especially possums. Tuberculous possums and occasionally other feral and wild animals have been identified in 18 discrete areas of New Zealand is association with persistent infection in cattle and deer herds. These Vector Risk Areas cover approximately 34% of New Zealand's land area. The remainder is classified as Vector Free.

### 7.3 UK Advisory Committee on the Microbiological Safety of Food (ACMSF): Report on *Mycobacterium bovis*

In December 2001 this Advisory Committee to the UK Food Standards Agency considered a report on *M. bovis* (ACMSF, 2001). The herd incidence of bovine tuberculosis has been rising in Great Britain. In 1996, 1.3% of all tests in cattle herd not subjected to restrictions resulted in a confirmed tuberculosis incident, while in 2001 the figure had risen to just under 3%. Nevertheless, the risk from *M. bovis* in meat was considered to be very slight given the existing control measures which include:

- Regular testing of all cattle using the single comparative intradermal tuberculin test (a slightly different test to that used in New Zealand);
- If a reactor or an inconclusive reactor is discovered then movement restrictions are placed on the farm, reactor cattle are slaughtered, and inconclusive reactors are retested;
- Slaughtered animals are subject to post mortem meat inspection, and if lesions are detected a sample is taken for culture;
- In the absence of visible lesions a pooled sample of targeted lymph nodes is collected for laboratory culture;
- If bovine tuberculosis is not found at post mortem or in the laboratory further herd tests are done to ensure there is no other evidence of infection.

Carcases, or parts of carcases, from reactor animals can be salvaged for food use depending on the nature and extent of any infection.

Untested cattle are also visually inspected for lesions, and in the year 2000 an additional 177 commercially slaughtered cattle were identified as infected, and 93% of these were confirmed by bacterial culture.

The Committee made a number of recommendations to further manage the risk of transmission of *M. bovis* in meat, including:

- Amending the rules for salvaging carcases from infected animals to be in line with slightly more restrictive EU rules;
- Slaughtering any reactors, inconclusive reactors and contacts, at the end of the day prior to full cleansing and disinfection of the line;

- Requiring meat from cattle with localised disease (or possibly all reactor cattle) to be heat treated;
- Holding carcases of reactor cattle with no visible lesions in cold storage pending receipt of bacteriological results.

A key question that the Committee was unable to answer was whether *M. bovis* is present in the edible tissues of salvaged carcases from cattle which have reacted to the tuberculin test, or show evidence of *M. bovis* infection at post mortem inspection. A study of this issue was commissioned by the FSA (see section 5.4), which indicated that about 4-5% of tuberculin test positive/NVL animals, animals with a single visible lesion and animals with two or more visible lesions cultured positive for *M. bovis* in the carcase or edible offal lymph glands (http://www.foodstandards.gov.uk/multimedia/pdfs/acm652.pdf).

### 7.4 World Organisation for Animal Health (OIE)

To qualify as officially free from bovine tuberculosis a country is required to satisfy a number of requirements set out in the *Terrestrial Animal Health Code* of the World Organisation for Animal Health (OIE) (see: http://www.oie.int/). A current requirement of this international standard is that 99.8% of the herds in the geographical area under consideration have been officially free from bovine tuberculosis for at least the past three years demonstrated by periodic testing of all cattle.

Two new articles were introduced in the 2005 edition of the Code. First, for fresh meat and meat products of cattle, importing countries should require 'the presentation of an international veterinary certificate attesting that the entire consignment of meat comes from animals which have been subject to ante-mortem and post-mortem inspections as described in the Codex Alimentarius Code of Practice for Meat Hygiene'. Second, for milk and milk products it has either been derived from animals in a herd free from bovine tuberculosis; or was subject to pasteurization or a combination of control measures with equivalent performance as described in the Codex Alimentarius Code of Practice for Milk and Milk Products'.

### 7.5 Economic Costs

The absence of evidence for human cases of infection with *M. bovis* caused by transmission in meat means that the cost to New Zealand in public health terms will be negligible. However, the cost of tuberculosis disease control in animals is substantial. The Animal Health Board Annual Report for 2005 states that it spent approximately $79 million in that year, principally on vector and disease control.

A cost-benefit analysis of *M. bovis* eradication in the United States showed an actual cost of $US 538 million between 1917 and 1992, with current costs of between $US 3.5 and 4 million per annum (Nelson, 1999). However, by reducing the number of cattle lost from 100,000 to less than thirty per annum, the programme saves approximately $US 150 million in replacement costs per annum. Further costs savings are realised through reduced levels of milk and meat production losses and decontamination procedures.

# 8 CONCLUSIONS

## 8.1 Description of Risks to New Zealand Consumers

### 8.1.1 Risks associated with meat

Approximately 2-3% of all notified cases of tuberculosis in New Zealand are caused by infection with *M. bovis* (see Section 6.1), equating to a current incidence of tuberculosis caused by this organism of approximately 0.18 per 100,000. However there is no evidence that these infections are caused by transmission in meat. Given that *M. bovis* infection is not more associated with extra-pulmonary sites of infection than *M. tuberculosis* (Baker *et al*., 2003) this suggests that inhalation (rather than diet) is the most common route of exposure.

At slaughter all cattle and deer are subject to an examination for evidence of tuberculosis infection. Action is taken to remove infected tissues from the food chain; further, if there is evidence of haematogenous spread of *M. bovis* the whole carcase is condemned. This risk is further reduced by the fact that primary infection site tissues (head, thorax, alimentary tract) do not commonly enter the fresh meat trade. The dose response relationship for ingestion of *M. bovis* is unclear, but this route of exposure appears to be of lower risk than infection via inhalation.

De la Rua-Domenech (2006) identifies several factors that mitigate against *M. bovis* transmission via meat:

- Lesions in skeletal muscle are rare and observed only in animals with advanced infection. Such carcases are likely to be condemned following post-mortem inspection;
- *M. bovis* is slow growing and will not replicate outside the living host;
- *M. bovis* is relatively heat sensitive and any residual contamination in muscle meat should be destroyed by cooking; and
- Ingestion is a far less efficient route of infection than inhalation.

Data from the UK published by the ACMSF indicates that only a small proportion (<5%) of animals with tuberculosis infection are culture positive for the organism in edible tissues. Considered alongside the measures taken to eliminate infected animals from the food supply, this indicates that the risk of transmission of *M. bovis* in meat to New Zealanders must be considered to be negligible.

### 8.1.2 Risks associated with other foods

Unpasteurised milk used to be a common vehicle for transmission of *M. bovis*. However, since the introduction of mandatory pasteurisation, milk has largely ceased to be a vehicle. Since 1995, two cases of *M. bovis* infection in New Zealand have reported consuming unpasteurised milk, but in neither case was this vehicle confirmed.

### 8.1.3 Quantitative risk assessment

A quantitative risk assessment would have value in more clearly defining the public health risk and providing a context from which to assess the value of any future changes to the

control strategies for *M. bovis* in animals. An important part of any such assessment would be the exposure assessment, and this is currently hampered by a shortage of data

## 8.2 Commentary on Risk Management Options

Active risk management for *M. bovis* in meat in New Zealand includes:

- Cattle and deer herd monitoring and active measures to eradicate Tb from all breakdown herds;
- Ante-mortem and post-mortem examination for slaughtered cattle and deer; and,
- Vector control measures (especially possum control), which markedly reduces the incidence of *M. bovis* infection in cattle and deer.

The first two of these measures represent best practice, in the opinion of the European Scientific Panel on Biological Hazards (2003). The third measure is directed at a *M. bovis* reservoir problem specific to New Zealand.

## 8.3 Data Gaps

The data gaps identified in this Risk Profile are the:

- Level (if any) of *M. bovis* in the meat of infected animals.
- Importance of bacteraemic episodes in the progression of the disease, with the associated risk of generalised spread of the organism within the infected animal;
- Dose response relationship for *M. bovis* infection in humans via the gastrointestinal route.

## 9 REFERENCES


ACMSF. (2001) Advisory Committee on the Microbiological Safety of Food (ACMSF): Report on *Mycobacterium bovis*. Paper FSA 01/08/03.

AHB (Animal Health Board). (2005) National Bovine Tuberculosis Pest Management Strategy. National Operational Plan: 1 July 2005 – 30 June 2013. http://www.ahb.org.nz/NR/rdonlyres/ACED1B11-F535-4C89-848A-7E4CD635949E/241/NTOPv1.pdf

Akgun Y. (2005) Intestinal and peritoneal tuberculosis: changing trends over 10 years and review of 80 patients. Canadian Journal of Surgery; 48(2): 131-136.

ANZFA. (2001). Raw Commodity Consumption Figures. Canberra: ANZFA.

Baghurst K. (1999) Red meat consumption in Australia: intakes, contributions to nutrient intake and associated dietary patterns. European Journal of Cancer Prevention; 8: 185-191.

Baker M, Lopez L, de Lisle G, Collins D, Cannon M. (2003) Tuberculosis in humans caused by *Mycobacterium bovis*: A combined epidemiological and microbiological analysis of cases from 1998 to 2002. ESR Client Report FW0381. Porirua: ESR.

Bentley G, Webster JHH. (1967) Gastro-intestinal tuberculosis. A 10-year review. British Journal of Surgery; 54(2): 90-96.

Besser RE, Pakiz B, Schulte JM, Alvarado S, Zell ER, Kenyon TA, Onorato IM. (2001) Risk factors for positive Mantoux tuberculin skin tests in children in San Diego, California: Evidence for boosting and possible foodborne transmission. Pediatrics; 108: 305-310.

Boulahbal RJ, Boulahbal F, Trytram D, Truffot-Pernot C, de Benoist VA, Jarlier V, Grosset J. (1999) A national survey of human *Mycobacterium bovis* infection in France. Network of Microbiology Laboratories in France. International Journal of Tuberculosis and Lung Disease; 3: 711-714.

Bouvet E, Casalino E, Mendoza-Sassi G, Lariven S, Vallée E, Pernet M, Gottot S, Vachon F. (1993) A nosocomial outbreak of multidrug resistant *Mycobacterium bovis* among HIV-infected patients. A case-control study. AIDS; 7: 1453-1460.

Brett JL, Humble MW. (1991) Incidence of human tuberculosis caused by *Mycobacterium bovis*. New Zealand Medical Journal; 104: 13-14.

Codex. (1999) Draft principles and guidelines for the conduct of microbiological risk assessment. Report of the thirty first session of the Codex committee on food hygiene. ALINORM 99/13A. Rome: Codex Alimentarius Commission.

Corner LA, Melville L, McCubbin K, Small KJ, McCormick BS, Wood PR, Rothel JS. (1990) Efficiency of inspection procedures for the detection of tuberculous lesions in cattle. Australian Veterinary Journal; 67(11): 389-392.

Cosivi O, Grange JM, Daborn CJ, Raviglione MC, Fujikura T, Cousins D, Robinson RA, Huchzermeyer HFAK, de Kanto I, Meslin F-X. (1998) Zoonotic tuberculosis due to *Mycobacterium bovis* in developing countries. Emerging Infectious Diseases; 4 (1): available from http://www.cdc.gov/ncidod/eid/vol4no1/cosivi.htm

Cotter TP, O'Shaughnessy E, Sheehan S, Cryan B, Bredin CP. (1996) Human *Mycobacterium bovis* infection in the south-west of Ireland 1983-1992: a comparison with *M. tuberculosis*. Irish Medical Journal; 89: 62-63.

Cousins DV, Williams S, Liebana E, Aranaz A, Bunschoten A, van Embden J, Ellis T. (1998) Evaluation of Four DNA Typing Techniques in Epidemiological Investigations of Bovine Tuberculosis. Journal of Clinical Microbiology; 36(1): 168-178.

Cousins DV, Dawson DJ. (1999) Tuberculosis due to *Mycobacterium bovis* in the Australian population: cases recorded during 1970-1994. International Journal of Tuberculosis and Lung Disease; 3: 715-721.

Cousins DV, Williams SN, Dawson DJ. (1999) Tuberculosis due to *Mycobacterium bovis* in the Australian population: DNA typing of isolates, 1970-1994. International Journal of Tuberculosis and Lung Disease; 3: 722-731.

De Kantor IN, Nader A, Bernardellia A, Giron DO, Man E. (1987) Tuberculosis infection in cattle not detected by slaughterhouse inspection. Journal of Veterinary Medicine-Series B; 34: 202-205.

De la Rua-Domenech R. (2006) Human *Mycobacterium bovis* infection in the United Kingdom: Incidence, risks, control measures and review of the zoonotic aspects of bovine tuberculosis. Tuberculosis; 86: 77-109.

EPA (US Environmental Protection Agency). (1997) Exposure Factors Handbook. Volumes I, II and III. http://cfpub.epa.gov/ncea/cfm/exposfac.cfm?ActType=default

ESR. (1998) Annual surveillance summary 1997. Porirua: ESR.

ESR. (2004) Notifiable and other diseases in New Zealand: Annual Report 2003. Client Report FW0426. Kenepuru: ESR.

ESR. (2005a) Antituberculosis drug resistance in New Zealand, 2004. http://www.surv.esr.cri.nz/PDF_surveillance/Antimicrobial/TB_2004.pdf

ESR. (2005b) Notifiable and other diseases in New Zealand: Annual Report 2004. Client Report FW0532. Kenepuru: ESR.

ESR. (2006) Notifiable and other diseases in New Zealand: Annual Report 2005. Client Report FW0621. Kenepuru: ESR.

Food Safety Authority of Ireland. (2003) Zoonotic tuberculosis and food safety. Final Report FSAI Scientific Committee, July 2003.

Francis J. (1973) Very small public health risk from flesh of tuberculous cattle. Australian Veterinary Journal; 49: 496-497.

Gori A, Marchetti G, Catozzi L, Nigro C, Ferrario G, Rossi MC, Degli Esposti A, Orani A, Franzetti. (1998) Molecular epidemiology characterisation of a multi-drug resistant *Mycobacterium bovis* outbreak amongst HIV positive patients. AIDS; 12: 445-446.

Grange JM. (1995) Human aspects of *Mycobacterium bovis* infection. In: Thoen CO, Steele JH (Eds). Mycobacterium bovis infection in animals and humans. Ames: Iowa State Press; pp29-46.

Grange JM. (2001) *Mycobacterium bovis* infection in human beings. Tuberculosis; 81: 71-77.

Grzybowski S, Allen EA. (1995) History and importance of scrofula. Lancet; 346 (8988): 1472-1474.

Hardie RM, Watson JM. (1992) *Mycobacterium bovis* in England and Wales*:* past, present and future. Epidemiology and Infection; 109*:* 23-33.

Isaac J, Whitehead J, Adams JW, Barton MD, Coloe P. (1983) An outbreak of *Mycobacterium bovis* infection in cats in an animal house. Australian Veterinary Journal; 60: 243-245.

Kamerbeek J, Schouls L, Kolk A, van Agterveld M, van Soolingen D, Kuijper S, Bunschoten A, Molhuizen H, Shaw R Goyal M, van Embden J. (1997) Simultaneous detection and strain differentiation of Mycobacterium tuberculosis for diagnosis and epidemiology. Journal of Clinical Microbiology; 35(4): 907-914.

Kleeberg HH. (1984) Human tuberculosis of bovine origin in relation to public health. Revue Scientifique et technique de l'Office International des Epizooties; 3(1): 11-32.

Kremer K, van Soolingen D, Frothingham R, Haas WH, Hermans PWH, Martin C, Palittapongarnpim P, Plikaytis BB, Riley LW, Yakrus MA, Musser JM, van Embden JDA. (1999) Comparison of methods based on different molecular epidemiological markers for typing of *Mycobacterium tuberculosis* complex strains: Interlaboratory study of discriminatory power and reproducibility. Journal of Clinical Microbiology: 37(8): 2607-2618.

Jackson R, de Lisle GW, Morris RS. (1995) A study of the environmental survival of *Mycobacterium bovis* on a farm in New Zealand. New Zealand Veterinary Journal; 43(7): 346-352.

Kieft C, Perks M, Baker M, Galloway Y, Sutherland H. (2000) Annual Surveillance Summary 1999. ESR Client Report FW0059. Porirua: ESR.

Lake RJ, Baker MG, Garrett N, Scott WG, Scott HM. (2000) Estimated number of cases of foodborne infectious disease in New Zealand. New Zealand Medical Journal; 113: 278-281.

Lawrie RA. (1998) The spoilage of meat by infecting organisms. In: Lawrie's meat science. 6th Edition. Cambridge: Woodhead Publishing Limited.

Livingstone PG. (1996) National pest management strategy for bovine tuberculosis. Surveillance; 23 (1): 10-11.

Livingstone P. (2002) Reports from national pest management strategies: bovine tuberculosis. Surveillance; 29: 20-21.

Livingstone P. (2003) Reports from national pest management strategies: bovine tuberculosis. Surveillance; 30: 23-24.

Lopez L, Baker M, Perks M. (2001) Annual surveillance summary 2000. ESR Client Report FW0156. Porirua: ESR

MacDiarmid SC, Thompson EJ. (1997) The potential risks to animal health from imported sheep and goat meat. Revue Scientifique et Technique de l'Office International des Epizooties 16(1): 45-56. See also: http://www.maf.govt.nz/biosecurity/pests-diseases/animals/risk/sheep-goat-meat/index.htm

MAF. (2005) SONZAF 2005. Situation and outlook for New Zealand agriculture and forestry.
http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/2005/index.htm

MAF Biosecurity Authority. (2000) Animal Health Surveillance Report – 1999. Surveillance; 27 (1): 22-23.

Merkal RS, Whipple DL. (1980) Inactivation of *Mycobacterium bovis* in meat products. Applied and Environmental Microbiology; 40: 282-284.

Menzies FD, Neill SD. (2000) Cattle-to-cattle transmission of bovine tuberculosis. The Veterinary Journal; 160: 92-105.

Ministry of Health/Ministry of Agriculture and Forestry. (2000) Food Administration in New Zealand: A Risk Management Framework for Food Safety. Wellington: Joint Ministry of Health and Ministry of Agriculture and Forestry Food Harmonisation Project.

Mitserlich E, Marth EH. (1984) Microbial Survival in the Environment. Berlin: Springer-Verlag.

Nelson AM. (1999) The cost of disease eradication: Smallpox and bovine tuberculosis. Annals of the New York Academy of Sciences; 894: 83-91.

New Zealand Pork Industry Board. (2005) 2005 Annual Report. http://www.pork.co.nz/nzpork/annual_report/2005_annual_report.pdf

O'Neil BD, Pharo HJ. (1995) The control of bovine tuberculosis in New Zealand. New Zealand Veterinary Journal; 43: 249-255.

O'Reilly LM, Daborn CJ. (1995) The epidemiology of *Mycobacterium bovis* infections in animals and man: a review. Tubercle and Lung Disease; 76 Supplement 1: 1-46.

Perks M, Galloway Y, Baker M. (1999) Annual Surveillance Summary 1998. Institute of Environmental Science and Research. Porirua: ESR.

Pharo H, Livingstone P. (1997) Tests to diagnose tuberculosis in cattle and deer in New Zealand. Surveillance; 24: 12-14.

Phillips CJC, Foster CRW, Morris PA, Teverson R. (2003) The transmission of *Mycobacterium bovis* infection in cattle. Research in Veterinary Science; 74(1): 1-15.

PHLS. (2001) Enhanced surveillance of *Mycobacterium bovis* disease in humans in England and Wales from January 2001. CDR Weekly; 11(1): 2-3.

Pooley RB. (1996) *Mycobacterium bovis*: An old disease in a new era? A review of the epidemiology and public health importance of human *Mycobacterium bovis* infection in New Zealand. A dissertation submitted for the degree of Master of Public Health. Christchurch: University of Otago, New Zealand.

Russell DG, Parnell WR, Wilson NC *et al*. (1999) NZ Food: NZ People. Key results of the 1997 National Nutrition Survey. Wellington: Ministry of Health.

Ryan T, Livingstone P. (2000) Risk analysis: Movement of cattle from tuberculosis infected herds. Surveillance; 27 (1): 8-10.

Ryan TJ, Livingstone PG, Ramsey DSL, de Lisle GW, Nugent G, Collins DM, Buddle BM. (2006) Advances in understanding disease epidemiology and implications for control and eradication of tuberculosis in livestock: The experience from New Zealand. Veterinary Microbiology; 112: 211-219.

Samper S, Martin C, Pinedo A, Rivero A, Blazquez J, Baquero F, van Soolingen D, van Embden J. (1997) Transmission between HIV-infected patients of multidrug-resistant tuberculosis caused by *Mycobacterium bovis*. AIDS; 11: 1237-1242.

Sauter CM, Morris RS. (1995a) Behavioural studies on the potential for direct transmission of tuberculosis from feral ferrets (*Mustelo furo*) and possums (*Trichosurus vulpecula*) to farmed livestock. New Zealand Veterinary Journal; 43(7): 294-300.

Sauter CM, Morris RS. (1995b) Dominance hierarchies in cattle and red deer (*Cervus elaphus*): their possible relationship to the transmission of bovine tuberculosis. New Zealand Veterinary Journal; 43(7): 301-305.

Scientific Panel on Biological Hazards. (2003) Opinion of the Scientific Panel on Biological Hazards on a request from the Commission related on "Tuberculosis in Bovine Animals: Risks for human health and control strategies". EFSA Journal; 13: 1-53. Accessed at: http://www.efsa.eu.int/science/biohaz/biohaz_opinions/230/opinion_biohaz_03_en1.pdf

Selwyn P, Hathaway S. (1990) A study of the prevalence and economic significance of diseases and defects of slaughtered farmed deer. New Zealand Veterinary Journal; 38: 94-97.

Sneyd E, Lopez L, Eglinton M, McDowell R, Margolin T. (2002) Annual surveillance summary 2001. Client Report FW0156. Kenepuru: ESR.

Sneyd E, Baker M. (2003) Infectious diseases in New Zealand: 2002 annual surveillance summary. Client Report FW0332. Kenepuru: ESR.

Szewzyk R, Svenson SB, Hoffner SE, Bölske G, Wahlström H, Englund L, Engvall A, Källenius G. (1995) Molecular epidemiological studies of *Mycobacterium bovis* infections in humans and animals in Sweden. Journal of Clinical Microbiology; 33: 3183-3185.

Van Embden JDA, Schouls LM, van Soolingen D. (1995) Molecular techniques: Application in epidemiologic studies. In: Thoen CO, Steele JH (Eds). Mycobacterium bovis infection in animals and humans. Ames: Iowa State Press; pp15-25.

Van Sooligen D, de Haas PEW, Haagsma J, Eger T, Hermans PWM, Ritacco V, Alito A, van Embden JDA. (1994) Use of various genetic markers in differentiation of *Mycobacterium bovis* strains from animals and humans and for studying epidemiology of bovine tuberculosis. Journal of Clinical Microbiology; 32(10): 2425-2433.

Vanderpool DM, O'Leary JP. (1988) Primary tuberculosis enteritis. Surgery, Gynaecology and Obstetrics; 167: 167-173.

VanTiem JS. (1997) The public health risks of cervid production in the United States of America. Revue Scientifique et Technique;16, 564-570.

Wight AE, Lash E, O'Rear HM, Crawford AB. (1942) Tuberculosis and its eradication. In: Keeping Livestock Healthy Yearbook of Agriculture 1942. Washington DC: United States Department of Agriculture: 237-249.

Winger RJ. (1984) Storage life and eating-related quality of New Zealand frozen lamb: A compendium of irrepressible longevity. In: Zeuthen P, Cheftel JC, Eriksson C, Jul M, Leniger H, Linko P, Varela G, Vos G (Eds). Thermal Processing and Quality of Foods. London: Elsevier Applied Science Publishers. pp. 541-552.

Winters A, Driver C, Macaraig M, Clark C, Munsiff SS, Pichardo C, Driscoll J, Salfinger M, Kreiswirth B, Jereb J, LoBue P, Lynch M. (2005) Human tuberculosis caused by *Mycobacterium bovis* – New York city, 2001-2004. MMWR; 54(24): 605-608.

## APPENDIX 1: CATEGORIES FOR RISK PROFILES

The assignment of a category for a food/hazard combination uses two criteria: incidence and severity.

*1. Incidence*

The incidence is an estimate of the proportion of the foodborne disease rate due to an individual hazard, that is transmitted by a single food or food group. The overall rate of foodborne disease caused by individual hazards can be derived from information in the published estimate of foodborne disease (Lake *et al*., 2000). This estimate has been updated to reflect more recent notifications rates for the 12 months to June 2001, but still using 1996 census figures (3,681,546 population). Rates include estimates for unreported cases who do not present to a GP.

| **Disease/organism** | **Food rate (/100,000 population) Calculated for 12 months to June 2001** | **Food rate (/100,000 population) Calculated for 12 months to December 1998** |
|---|---|---|
| Campylobacteriosis | 1320 | 2047 |
| Listeriosis | 0.4 | 0.4 |
| VTEC/STEC | 1.9 | 1.4 |
| Salmonellosis | 176 | 230 |
| Yersiniosis | 38 | 62 |
| Shigellosis | 7 | 7 |
| NLV* | 478 | 478 |
| Toxins* | 414 | 414 |
| Typhoid* | 0.3 | 0.3 |
| Hepatitis A* | 0.4 | 0.4 |

* not recalculated.

These are **total** foodborne rates, so it is probably safe to assume that in most cases the rates associated with a particular food are likely to be an order of magnitude lower. For instance, a category of ">1000" would only be assigned if it was decided that all campylobacteriosis was due to a single food/food type. The following categories are proposed for the rates attributable to a single hazard/food (or food group) combination:

| **Category** | **Rate range** | **Comments/examples** |
|---|---|---|
| 1 | >100 | Significant contributor to foodborne campylobacteriosis<br>Major contributor to foodborne NLV |
| 2 | 10-100 | Major contributor to foodborne salmonellosis<br>Significant contributor to foodborne NLV |
| 3 | 1-10 | Major contributor to foodborne yersiniosis, shigellosis |
| 4 | <1 | Major contributor to foodborne listeriosis |

A further category, of "no evidence for foodborne disease in New Zealand" is desirable, but it was considered more appropriate to make this separate from the others. Also separate is another category, of "no information to determine level of foodborne disease in New Zealand".

The estimation of the proportion of the total foodborne disease rate contributed by a single food or food group will require information from a variety of sources including:

- exposure estimates
- results from epidemiological studies (case control risk factors)
- overseas estimates

For illnesses where the rate is <1 per 100,000 the ability to assign a proportion is unlikely to be sensible. For such illnesses it may be more useful to consider a Risk Profile across the range of all high risk foods, rather than individual foods or food groups.

*2. Severity*

Severity is related to the probability of severe outcomes from infection with the hazard.

The outcomes of infectious intestinal disease are defined in the estimate of the incidence (Lake *et al.*, 2000) as:

- death
- hospitalised and long term illness (GBS, reactive arthritis, HUS)
- hospitalised and recover
- visit a GP but not hospitalised
- do not visit a GP

The first three categories of cases were classed as severe outcomes. Some hospitalisations will result from dehydration etc. caused by gastrointestinal disease. However, for infections with *Listeria* and STEC hospitalisation will result from more severe illness, even if recovery is achieved. The proportion of severe outcomes resulting from infection with the hazards can be estimated from the proportion of cases hospitalised and recover, hospitalised and long term illness, and deaths (Lake *et al.*, 2000).

| **Disease/organism** | **Percentage of outcomes involving death or long term illness from foodborne cases** |
|---|---|
| Campylobacteriosis | 0.3 |
| Listeriosis | 60.0 |
| VTEC/STEC | 10.4 |
| Salmonellosis | 1.0 |
| Yersiniosis | 0.4 |
| Shigellosis | 2.7 |
| NLV | Assumed to be <0.5% |
| Hepatitis A | 15.4 |
| Typhoid | 83.3 |
| Toxins | Assumed to be <0.5% |

Categories for the probability of severe outcomes are suggested as follows:

| Severity Category | Percentage of cases that experience severe outcomes | Examples |
|---|---|---|
| 1 | >5% | listeriosis, STEC, hepatitis A, typhoid |
| 2 | 0.5 – 5% | salmonellosis, shigellosis |
| 3 | <0.5% | campylobacteriosis, yersiniosis, NLV, toxins |

There are a number of hazards for which the incidence of foodborne disease is uncertain. These have been assigned to the above severity categories as follows:

**Severity category 1:**

Bacteria

*Clostridium botulinum*

Protozoa

*Toxoplasma*

**Severity category 3:**

Bacteria

*Aeromonas/Plesiomonas*
*Arcobacter*
*E. coli* (pathogenic, other than STEC)
*Pseudomonas*
*Streptococcus*
*Vibrio parahaemolyticus*

Viruses

Others (e.g. rotavirus)

Protozoa

*Giardia*
*Cryptosporidium*
*Cyclospora*
Others (e.g. *Entamoeba*)

**Proposed Category Matrix**

| Incidence | >100 | 10-100 | 1-10 | <1 |
|---|---|---|---|---|
| **Severity 1** | | | | |
| **Severity 2** | | | | |
| **Severity 3** | | | | |

Alternatives:

No evidence for foodborne disease in New Zealand

No information to determine level of foodborne disease in New Zealand