Consideration of on farm provisions for raw milk production

A report prepared for the New Zealand Food Safety Authority by

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1 Introduction

Background and aims

Pasteurisation of milk is a key component in control of milk-borne pathogens that threaten public health (Holsinger et al 1997). It was originally developed for the control of infection due to brucellosis and tuberculosis from infected cattle, but also controls a wide range of other human pathogens. However, consumption of raw milk or its products is common or traditional in many countries despite public health risks. Current New Zealand food safety regulations do not permit significant sales of unpasteurised milk or its products.

Before permitting supply of products made from unpasteurised milk in New Zealand, it is necessary to investigate potential hazards to public health and recommend control strategies to mitigate them. Nationwide control programmes have successfully eliminated or greatly reduced the risk of historic pathogens such as brucellosis or tuberculosis entering human milk supply. But product from cows, sheep or goats still cannot be guaranteed free from other pathogens, even when produced under hygienic conditions, because of faecal contamination or direct excretion into the milk (Rampling 1996).

This report aims to identify known or potential milk-borne pathogens in raw milk in New Zealand, from published literature. Additionally potential risk factors for bacteria in milk and on-farm control measures to reduce risk will be reviewed and recommendations given to minimise these risks.

Methods

Published data on milk borne pathogens specific to New Zealand are sparse or non-existent, and much extrapolation has been made from international data in developing this report. There are two main differences between the production systems in New Zealand and those countries from where data regarding raw milk pathogens are available. In the latter, dairy cows are commonly contained in feedlots or housed, which increases the risk of poor udder and teat hygiene, and may increase the prevalence of certain pathogens in raw milk. Secondly, cows in overseas dairies routinely have teats disinfected and/or foremilk checked prior to milking, which, if effective, would tend to decrease the prevalence of some human pathogens in raw milk. Hence, overseas data may either overestimate or underestimate the prevalence of pathogens in raw milk in New Zealand. However, in many cases overseas and local data provide sufficient information to identify the hazards as either known or likely to be present and to inform control methods. Where important gaps in knowledge cannot be filled from local or international data, these are reported.

A literature search was undertaken using Medline and ISI Web of Science to identify human pathogens that can be isolated from raw milk using the following search terms: (public health OR zoonos*) AND (raw OR bulk tank) milk AND bacter*. Publications were considered for review if they were published in English, and data were collected from Australasia, Europe or North America, because their farming systems and pathogens are most similar to those in New Zealand.

Scope

This report does not provide formal risk analyses of human disease following consumption of raw milk products. Where these analyses are available and relevant, they are noted. Hence identified risks are not quantified. Similarly, direct consumption of bulk tank milk is specifically excluded from this report, but it is assumed that further processing (e.g. production of cheeses) would have limited effect in reducing the number of bacteria in milk.

This report deals with milk-borne pathogens known to be of public health significance. It does not address pathogens not known to be endemic in New Zealand e.g. *Coxiella burnetti* (cause of Q-fever in humans) or anthrax; or animal pathogens known to be present in New Zealand but of unproven human significance e.g. *Mycobacterium avium* subsp. *paratuberculosis* (cause of Johne's disease in ruminants and suggested to be associated with Crohn's disease in humans) or caprine arthritis encephalitis virus in goats. Neither is this report exhaustive in its coverage of human pathogens with the potential to contaminate raw milk, covering only those organisms commonly found in the literature. It does not, for example specifically discuss *Enterococcus* spp., *Toxoplasma gondii*, *Cyrptosporidia parvum*, or *Aeromonas hydrophila,* which were rarely or never mentioned in the literature as milk-borne human pathogens. Nevertheless, control of these pathogens would likely be achieved by methods detailed for the other more common pathogens. This report deals principally with dairy cattle and their milk production systems, but information specific to dairy goat or sheep production systems will be noted.

This report does not specifically cover the risk of transmission of antimicrobial-resistant milk-borne pathogens from animals to humans. Monitoring schemes for antimicrobial resistance in animals are in place internationally (Tollefson et al 1998; Aarestrup 2004) and New Zealand authorities have published a report addressing the situation (New Zealand Food Safety Authority 2003), noting that pasteurisation of milk negated any risk of transmission of antimicrobial-resistant pathogens from dairy cows to humans. Hence, this risk should again be assessed when raw milk products are considered for sale in New Zealand.

The main objective of this report is to integrate information from New Zealand and international literature with the authors' knowledge of on-farm milk production and quality systems, in order to provide guidance to regulatory authorities of hazards and

control of milk-borne pathogens of public health concern in New Zealand. A second objective is to review and comment on the appropriateness of currently proposed, but not yet publicly available, additional criteria for the production of milk intended for processing into dairy products made from unpasteurised milk (New Zealand Food Safety Authority 2007a). This is presented in section 4 of this report.

Abbreviations

Bulk tank milk (BTM)

Bulk tank milk somatic cell count (BTMSCC)

Colony-forming unit (cfu)

2 Human pathogens known or likely to contaminate raw milk in New Zealand

2.1 Bacillus cereus

Characteristics

B. cereus is a large Gram-positive rod bacterium, which is facultatively anaerobic and endospore-forming. It grows within a temperature range of 10 - 48°C with an optimum of 28 – 35 °C. Spores are formed under conditions favourable for growth, and are resistant to pasteurisation. It is a saprophyte, widely-distributed in air, soil and water, and is a rare cause of mastitis in cattle (Quinn et al 1999). Toxin-producing *B. licheniformis* and *B. pumilus* have also been isolated from milk from mastitic cows in Finland and have been described as hazards to public health (Nieminen et al 2007).

Public health concerns

B. cereus causes two distinct forms of food poisoning; diarrhoea caused by heat-labile enterotoxin and usually associated with foods that were insufficiently cooked or contaminated after cooking, and an emetic syndrome caused by a very heat-stabile enterotoxin and usually associated with cooked rice (Quinn et al 1999).

Presence in raw milk

B. cereus spores in raw milk have been reported as the main source of contamination of milk products (Lin et al 1998).

Risk factors for contamination of raw milk

Spores are present in high concentrations in deep sawdust bedding of housed animals (Magnusson et al 2007b) and in the soil of grazed areas (Christiansson et al 1999). The spore content of milk in Swedish cows was strongly associated with degree of soil contamination of teats, dirtiness of the cow access lane and its spore concentration (Christiansson et al 1999). The concentration of spores in the air at milking, in feed, faeces and milking equipment were too low to be important sources of raw milk contamination. Foremilk had a much higher spore concentration

than mid or late-stream milk. Feed and faeces were not a source of milk contamination in that report (Christiansson et al 1999), but high spore levels in feed were a source for faecal contamination of milk in another Swedish study (Magnusson et al 2007a).

Public health control methods

Because of the ubiquitous nature of this organism, general hygiene measures related to feeding, milking and milk storage areas are required to reduce contamination of cow teats or the bulk milk tank directly.

Pre-milking teat cleaning methods reduced spore count following experimental challenge. The most effective methods for reducing milk spore content (96% reduction) were use of a moist washable towel, with or without soap, followed by drying with a dry paper towel, for a total time of 20 s per cow (Magnusson et al 2006). Cleaning of teats prior to milking with an individual wet paper towel also halved the concentration of spores in milk (Christiansson et al (1999).

2.2 Brucella spp.

Brucella abortus is not present in New Zealand. *Brucella ovis* is endemic in the New Zealand sheep population but not known to affect man. There is no evidence of locally-acquired cases of Brucellosis in humans since declaration of freedom in cattle in New Zealand in 1998 (Anonymous 2007).

Other *Brucella* spp. with zoonotic potential are not present in New Zealand (e.g. *Br. melitensis, Br. canis, Br. suis*) and hence are not considered further.

2.3 Campylobacter spp.

Characteristics

Campylobacter jejuni is a microaerophilic, Gram negative, motile, curved rod bacterium that multiplies between 37 and 43°C (Quinn et al 1999). Human pathogenic strains produce adhesion molecules, a cytotoxin and a heat-labile toxin. A range of wild and domesticated animals (up to 70% of ruminants and pigs) and birds (up to 100% of poultry) are symptomless carriers. It is associated with outbreaks of abortion in sheep. Some strains of *C. coli* may also cause enteritis, and are commonly recovered from the intestines of pigs. Both *Campylobacter* spp. only transiently infect humans. Natural bodies of water are thought to be an important reservoir of infection for livestock.

Public health concerns

Campylobacteriosis is the most commonly reported notifiable disease in New Zealand (Anonymous 2007) , associated with incorrectly handled and cooked poultry, and other meats. Consumption of raw milk is not given as a risk factor on disease notification forms in New Zealand, but *C. jejuni* is commonly recorded in international literature as a milk-borne pathogen for humans. Raw milk contaminated by infected cattle is reported as a risk factor for human infection in

the United Kingdom (Fenwick 1996; Gillespie et al 2003) and in New Zealand (Hill 1994).

Presence in raw milk
No New Zealand data are available on the prevalence of *C. jejuni*, but it is reported internationally in surveys of bulk tank milk (BTM). *Campylobacter* spp. were isolated from 2% of samples in the UK (de Louvois and Rampling 1998), 2% of Pennsylvania state farms (Jayarao et al 2006), 9.2% of BTM samples from South Dakota/Minnesota dairies (Jayarao and Henning 2001), and 17% of German samples (Ormeci and Ozdemir 2007).

Risk factors for contamination of raw milk
Contamination of raw milk occurs mainly through faecal contamination of teats either directly, or via bedding or pasture, and thereby into teat cup liners and milk lines during the milking process.

Public health control methods
Improving milking and farm hygiene are the main measures for control of raw milk contamination. Access to natural water supplies should also be restricted to limit transmission to livestock from wild animals.

2.4 Escherichia coli

Characteristics
E. coli is a Gram negative, facultative anaerobic rod. The bacterium is widely distributed in the environment, in soil, water, on plants, and is a commensal in the intestines of humans and animals. *E. coli* can survive in faecal particles, dust and water for weeks or months (Quinn et al 1999). Enterotoxigenic strains form both heat stabile and labile toxins. Several virulence factors are associated with different strains of *E. coli* which cause disease in humans and animals, including verotoxin and shiga-toxins, known as VTEC and STEC, respectively.

Public health concerns
E. coli is the cause of "travellers' diarrhoea", a worldwide illness of short duration which may be either food or water-borne. Outbreaks of more severe disease in humans (including haemolytic uraemic syndrome) are associated with VTEC and STEC and *E. coli* type O157 infection. In 2006, 87 cases of VTEC/STEC infection were notified in New Zealand, some of which resulted from consumption of unpasteurised milk or milk products (majority O157:H7 serotype) (Anonymous 2007). Of particular concern is the low infective dose of O157:H7 (less than 100 organisms) and high prevalence in some raw foods (Riemann and Cliver 1998).

Presence in raw milk
E. coli is commonly reported as a contaminant of raw milk. In a New Zealand survey, 4 out of 7 farms and 4 out of 20 samples of bulk tank milk had >1000 cfu/ml (Howard 2006). Overseas surveys of pathogens in raw milk have found 2.4% of samples from BTM on Pennsylvania state farms positive for STEC (Jayarao et al 2006), 3.8 % of

samples from BTM on South Dakota/Minnesota dairy farms positive for STEC (Jayarao and Henning 2001), and 0.7% of Belgian raw milk products positive for O:157 (De Reu et al 2004).

Risk factors for contamination of raw milk

E. coli may contaminate raw milk directly as a result of both clinical and subclinical mastitis in dairy cows and sheep, especially in early lactation and in housed or intensively-fed animals. However, *E. coli* mastitis occurs in only 5% of clinical cases in pasture-grazed herds in NZ (McDougall 1998) but may be more than 3 to 4 times that percentage in confined herds (Olde Riekerink et al 2008). More commonly however, indirect contamination occurs through faecal contamination of teats due to poor hygiene practices at milking and generally poor farm hygiene.

Public health control methods

The main control methods require hygiene in the holding yards and milking parlour (and housing area if applicable), and during the milking process (including pre-milking teat cleaning and disinfection). In studies of cattle housed in free-stall barns these approaches reduced both contamination of teats and the risk of *E. coli* mastitis (Schukken et al 1991). Observational studies in New Zealand have found that heifers with poor teat and udder hygiene are at higher risk of intramammary infection. However, contamination of udders and teats with *E. coli* in NZ pasture-grazing conditions may not be as severe as in overseas systems, but there is no data for comparison.

2.5 Leptospira spp.

Characteristics

Leptospira spp. are aerobic coiled, motile, Gram negative bacteria (Quinn et al 1999). *Leptospira borgpetersenii* serovar *Hardjo* type *Hardjobovis* is present in New Zealand, with dairy cows as its natural (or reservoir) host and with zoonotic potential via raw milk. Infection in cows produces no or minimal clinical signs, but results in prolonged urinary shedding. No current data are available on the prevalence of *Leptospira hardjo* infection in the New Zealand dairy herd. Other serovars may cause transient and acute clinical disease in cattle, including *Leptospira interrogans* serovars *Pomona* causing abortion in cows and *Copenhageni* causing anaemia and jaundice in calves. However, animals affected by these 2 serovars would be diagnosed by farmers as sick and hence should be excluded from milking. They are therefore not considered a significant hazard for contamination of raw milk. *Leptopsira* spp. are also prevalent in sheep in New Zealand (Dorjee et al 2005). No data are available for goats, although they are known to be at risk of infection (Radostits et al 1984).

Public health concerns

Serovar *Hardjo* is the most common cause of human *Leptospira* infection reported in New Zealand. In 2006, 88 cases of human leptospirosis were reported, of which 41% were Hardjo (Anonymous 2007). Infection in humans is most commonly attributed to

contact of mucous membranes of mouth and eyes or damaged skin with urine from animals that are persistent urinary-shedders. Infection of humans by ingestion of contaminated raw milk or its products has not been described, but is presumably possible.

Presence in raw milk

Leptospira spp. contamination of raw milk has not been reported in the literature.

Risk factors for contamination of raw milk

The main risk pathway for contamination of raw milk may be by urine splashes onto teat ends prior to milking, permitting bacteria to enter the milk line. Another possible risk pathway is via contamination of teat ends from discharge from the reproductive tract from cows aborting as a result of *L. pomona* infection.

Public health control methods

Vaccination programmes for dairy herds have been widely adopted since 1979 (Cranefield 2000). Currently, 6 vaccines available in New Zealand have registered claims for prevention of urinary shedding in dairy cattle (Table 1).

Table 1. Vaccines currently licensed for use in dairy cows in New Zealand, which claim to prevent urinary shedding of *Leptospira borgpetersenii* serovar *Hardjo* type *Hardjobovis.*

Vaccine Trade Name	Manufacturer	Licensed for use in
Leptoshield 3	Pfizer Animal Health, Auckland	Cattle [a]
Ultravac 7:1		Cattle
Leptoshield		Cattle, sheep ,goats
Leptavoid 3	Schering-Plough Animal Health Ltd., Wellington	Cattle
Leptavoid 2		Cattle, sheep
Lepto 2-way	Virbac New Zealand Ltd., Auckland	Cattle
Lepto 3-way		Cattle

[a] Can also be used in sheep and goats.

Leptoshield (Pfizer Animal Health, Auckland, New Zealand) is licensed for use in goats and sheep, but has no claim for prevention of urinary shedding in these species. A comprehensive vaccination and risk management control plan, Leptosure ® programme (http://www.leptosure.co.nz/), has been developed by the New Zealand Veterinary Association, Dairy Cattle Branch of the New Zealand Veterinary Association and Livestock Improvement Corporation Inc. This programme provides the current best-practice to prevent infection in both animals and humans. Pre-milking teat cleaning or disinfection would also reduce the risk of contamination of raw milk by leptospires on teat ends.

Diagnosis of infection in animals is carried out using serological techniques on blood samples collected from clinically-affected or in-contact animals. However, vaccination may give false-positive test results, and hence their interpretation is difficult in vaccinated herds (O'Keefe 2002). Routine screening for infected herds is not currently practiced.

2.6 Listeria monocytogenes

Characteristics

Listeria species are motile Gram positive, facultative anaerobic rod bacteria. *Listeria monocytogenes* is widely distributed in the environment and can be isolated from soil, plants, decaying vegetation and silage with pH >5.5 (Quinn et al 1999). However, farm environments containing ruminants maintain a higher prevalence of

Listeria monocytogenes than other natural ecosystems (Nightingale et al 2004). Many subtypes of this bacterium are linked to cases of human disease. The organism can be excreted intermittently in milk and faeces of both clinically- and subclinically-affected ruminants, and is part of the normal intestinal flora of many mammals and birds (Cooper and Walker 1998). It grows in an unusually wide range of temperature (3 to 45°C), pH (5.6 to 9.6) and salinity (up to 10% sodium chloride). It can replicate under a variety of conditions and may survive high temperature including short time pasteurisation. Animals and humans are mainly infected by the oral route. Abortion and neural ("circling") disease are the most common signs of clinical infection in ruminants. The incubation period for listeriosis may vary from 1 to 90 days, depending on the immune status of the host, but is usually 2 to 6 weeks (Cooper and Walker 1998).

Public health concerns

The majority of infections in adult humans are asymptomatic, but clinical disease is more common in neonates, pregnant women, the elderly and immune-compromised. The septicaemic and neural forms of the disease are more common in neonates and the immunocompromised; pregnant women may suffer abortion or premature birth. The mortality rate in clinically-affected humans is high (30%) (Quinn et al 1999). In 2006, 19 cases of listeriosis were reported in New Zealand (Anonymous 2007).

Sporadic cases of human listeriosis in New Zealand have been associated with consumption of contaminated raw or processed milk products (George 1987; Hill 1994). Similarly, isolated cases and outbreaks of human listeriosis have been associated with raw milk products, particularly soft cheeses, in the USA and several European countries (Linnan et al 1988; Goulet et al 1995; Jemmi and Stephan 2006). Listeriosis in humans has not been associated with hard cheese, processed sliced cheese, cottage cheese or yoghurt (Cooper and Walker 1998). Recovery of the organism from implicated foods is difficult because of the often long incubation period meaning foods are no longer available for testing and is technically difficult from soft cheeses (Cooper and Walker 1998).

Presence in raw milk

International surveys show 0 to 45% of raw milk samples are contaminated with *L. monocytogenes* (Jemmi and Stephan 2006), with reported prevalence usually less than 10%. Samples were positive from 2.8% of BTM on Pennsylvania state farms (Jayarao et al 2006), 6.5% of BTM on US dairies (Van Kessel et al 2004) and 6% of raw milk samples from Belgium (De Reu et al 2004).

Risk factors for contamination of raw milk

Contamination of raw milk with *Listeria* is usually due to faecal and environmental contamination (Sanaa et al 1993). *Listeria* is also a rare cause of mastitis in cattle and sheep (Jemmi and Stephan 2006). Environmental contamination on dairy cattle farms in New York state was greater than on dairy farms containing small ruminants (Nightingale et al 2004), although clinical disease is reported to be more common

on the latter. Cattle act as amplifiers of the organism to re-contaminate the environment via their faeces. On the dairy cattle farms, the prevalence of *Listeria* from faecal and soil samples was higher in winter and spring than in other seasons. On small ruminant dairy farms faecal, feed, soil and water samples were more commonly contaminated in winter than the other seasons (Nightingale et al 2004). The same seasonal pattern of raw milk contamination with *Listeria* and association with faecal shedding was found in studies of dairy cattle in Finland (Husu 1990). An investigation of farm management practices found that no access to pasture, feeding poor quality silage and storing silage in a bunker significantly increased the risk of faecal shedding of *Listeria* in cattle; in small ruminant farms the risk was increased with feeding of silage and history of clinical disease (Nightingale et al 2005). The consumption or access to silage of pH >5 by cows was also reported as a risk factor for animal infection by George (1987). Other risk factors associated with contamination of raw milk with *L. monocytogenes* include bucket milking, lack of pre-milking teat disinfection, lack of pre-milking examination for presence of abnormal milk, prolonged use of whole-herd dry cow therapy (Hassan et al 2001); feeding of poor quality silage (pH >4.0), and poor cleanliness in the barn and poor milking hygiene (Sanaa et al 1993).

Quantitative risk assessments of human listeriosis from consumption of soft cheese made from raw milk have been published and provide detailed descriptions of risks and control points (Bemrah et al 1998; Sanaa et al 2004).

Public health control methods

In view of the ubiquitous nature of *Listeria* and lack of animal vaccination or testing programmes to identify carrier animals, good hygiene and infection control procedures are needed. Further, no relationship between presence of *L. monocytogenes* in milk and standard plate count or BTM somatic cell count (BTMSCC) has been found (Van Kessel et al 2004), therefore these indicators of milk quality cannot be used to quantify risk of *L. monocytogenes* contamination.

Pre-milking teat sanitisation and drying is recommended to control *L. monocytogenes* contamination of raw milk, together with a reduction in the mud and dust around the cow yard and bulk milk tank (George 1987; Hassan et al 2001; Jemmi and Stephan 2006). Foremilk stripping also significantly reduced the risk of recovering *L. monocytogenes* from raw milk in New York dairy herds (Hassan et al 2001). Animals that are diagnosed with clinical listeriosis should be isolated and treated, and those that die should be immediately rendered, burned or deep-buried in a pit covered with quicklime. Any survivors should be considered persistent shedders and immediately culled (Cooper and Walker 1998). Wild animals, including birds should be controlled from feed storage, feeding out and milking areas to prevent faecal contamination.

Preparation of silage should avoid contact with soil, animal or bird faeces to reduce *Listeria* contamination. When a silage stack is opened, the pH should be checked

and monitored, as material with pH >4.0 to 5.0, poor digestibility and high ash content (suggesting soil contamination) is more likely to have high levels of *Listeria.* Silage with obvious mould and that from the edges of the stack are also more likely to have high levels of the organism, and should not be fed to stock (Cooper and Walker 1998). Feeding of silage or other fermented feeds should follow milking, and feed stacks should be covered to prevent windborne contamination. Control efforts should be emphasised in the winter and spring periods when the risk of raw milk contamination with *Listeria* is greatest.

Monitoring of raw milk for presence of *Listeria* is also an important control measure. Raw BTM collected for processing without pasteurisation for Camembert and Brie cheese, in France, undergoes testing 2 to 3 times per month for *Listeria* and must be *Listeria*-free for 3 consecutive tests before it is accepted. In addition, each tanker load is tested, with trace-back to farms when positive samples are found (Sanaa et al 2004) with auditing of hygienic practices and testing of individual milk samples with high somatic cell counts (>300,000 cells/ml).

2.7 Salmonella species

Characteristics

Salmonella spp. are Gram negative, facultative anaerobic rod bacteria. The natural reservoir of infection is the intestinal tract of animals (most of which are subclinical intermittent excretors of the organism), although the organism can survive for several months in the environment in moist soil, water, faecal particles and animal feed (Quinn et al 1999). They have an optimum growth temperature of 37°C, can grow at 43°C, but are killed at 60°C within 10 min. Transmission between animals is by the faecal-oral route.

Public health concerns

The development of clinical disease in humans depends on the species and strain of organism, infective dose and host immunological factors. Species such as *S. typhimurium* and *S. enteriditis* usually cause gastroenteritis, but others may be more invasive and cause septicaemia and more serious disease.

A total of 1335 cases of enteric salmonellosis were reported for all serotypes in New Zealand in 2006 (Anonymous 2007). The most common *Salmonella* species causing food-poisoning in humans in New Zealand are *S. typhimurium* and *S. enteritidis*, with consumption of food from commercial premises and contact with farm animals the most common risk factors. Internationally, ingestion of contaminated egg and meat products is especially risky, but milk products are also implicated as cause of sporadic cases and outbreaks of disease (De Buyser et al 2001), some of which have been associated with eating cheeses made from unpasteurised milk (Altekruse et al 1998).

Approximately 15% of cattle and sheep in New Zealand were reported to be infected with *Salmonella* spp. at slaughter, and carrier animals may shed large

numbers of organisms in faeces and milk (Ekperigin and Nagaraja 1998). Antibiotic-resistant *S. typhimurium* have been isolated in the USA and UK from raw milk and were reported to be transmitted from cattle and sheep to humans (Ekperigin and Nagaraja 1998).

Presence in raw milk

Surveys from Belgium and various states in the USA report between 0 and 10% of BTM samples are positive for pathogenic *Salmonella* spp. (Jayarao and Henning 2001; De Reu et al 2004; Van Kessel et al 2004; Jayarao et al 2006).

Risk factors for contamination of raw milk

The prevalence of *Salmonella* spp. infection within herds varies. No associated risk factors for infection were identified in one study in New York dairy herds (Hassan et al 2000), but other authors suggest that stress conditions may cause clinical disease (Forshell and Wierup 2006). In the experience of this report's authors, clinical disease in New Zealand dairy cows is most common immediately prior to and following calving.

Mastitis associated with *Salmonella* spp. is uncommon but documented (Van Kessel et al 2004) and therefore is a possible source of milk contamination. However, the most likely route of contamination of raw milk is by faecal contamination of teat ends prior to milking.

Public health control methods

A commercial vaccine (Salvexin+B, Schering-Plough Animal Health, Wellington) is licensed in New Zealand for prevention of clinical disease due to *S. typhimurium, S. bovis-morbificans*, *S. hindmarsh* and *S. brandenburg* in cattle and sheep. Current usage nationally is likely low. For example, only 9 of 589 (1.5%) dairy herds serviced by one dairy practice (Animal Health Centre) used the vaccine in 2007/08. No claims are made for the prevention of shedding by carrier animals and no efficacy data are apparently available. A whole herd vaccination programme may be expected to reduce the risk of *Salmonella* spp. contaminating raw milk, by reducing contamination of the environment by the vast numbers of bacteria shed by clinical cases.

Other non-specific control methods for *Salmonella* spp. should be based on prevention of cows with gastroenteritis being milked and improving hygiene in all stages of milk harvesting.

No relationship exists between presence of *Salmonella* spp. in milk and standard plate count or BTMSCC (Van Kessel et al 2004) and hence these routine milk quality measures cannot be used to assess the risk of BTM contamination with *Salmonella* spp.

2.8 Staphylococcus aureus

Characteristics

S. aureus is a Gram positive, salt-tolerant facultative anaerobic bacterium. The organism colonises the nasal cavity, skin and mucous membranes and can transiently infect the intestinal tract. The majority of strains causing food-poisoning are of human origin and produce heat stable enterotoxins. It is estimated 20-50% of the human population are carriers of *S. aureus* on hands or in the nasal cavity, and 15% of these are food-poisoning strains. Non-septic lesions on the skin of humans can harbour high numbers, and septic lesions can release very large numbers of the organism (Quinn et al 1999). In ruminants in New Zealand and elsewhere, *S. aureus* is a cause of subclinical, chronic, peracute and acute mastitis. It mainly acts as a contagious pathogen, and spreads between teats on a cow and between cows during the milking process via milk left in the liners or on the hands of milking staff (Neave et al 1966).

Public health concerns

Occasionally a strain of *S. aureus* from cows is implicated in outbreaks of food poisoning, following consumption of raw milk or a raw milk product (Leclerc et al 2002). A further public health concern is the potential for spread of antibiotic resistant *S. aureus* from cattle to human populations via milk (Juhasz-Kaszanyitzky et al 2007), as *S. aureus* from cattle and the environment are known to contaminate raw milk and its products (Jorgensen et al 2005).

Presence in raw milk

A New Zealand survey reported 17% of raw milk samples from BTM had >500 cfu/ml of *S. aureus* (Howard 2006); and 31% of BTM samples from Pennsylvania state herds were positive for the organism (Jayarao et al 2004).

Risk factors for contamination of raw milk

Poor management of mastitis in general, but particularly contagious mastitis increases the risk of contamination of raw milk with *S. aureus*. In dairy farms from Pennsylvania, the risk of isolation of *S. aureus* was significantly associated with elevated BTMSCC. Low BTMSCC and bacterial counts were associated with the use of dip cups instead of teat sprays for teat disinfection, use of both pre- and post-milking teat disinfection, use of automatic cup removers and use of sand as bedding material (Jayarao et al 2004).

Milk can also be contaminated by human carriers (Quinn et al 1999) and consideration should be given to the hygiene of milking staff.

Public health control methods

Two sources of contamination with *S. aureus* need to be considered in the context of this report; the staff milking the cows and the cows themselves. Use of new disposable rubber gloves by milking staff at each milking and attention to good personal hygiene should limit the spread of organisms from workers' hands to the cow teats, and thence directly into the raw milk or indirectly after causing new intramammary infections. Principles for the control of infectious intramammary pathogens in the milking herd are described in the "5 Point Plan" based on work by

Neave et al (1966). This has been updated in New Zealand to also cover mastitis pathogens from the environment, and is found in the Seasonal Approach to Mastitis Management (SAMM) Plan (National Mastitis Advisory Committee 2006). Best-practice mastitis management involves maintaining good machine function, early detection and treatment of clinical disease, good milking practice, correct selection of cows for non-lactating or dry-cow antibiotic therapy, and culling of cows with recurrent or chronic mastitis.

2.9 Serratia marcescens

Characteristics
S. marcescens is a Gram negative rod-shaped bacterium. Its natural habitat is in the environment, including soil and plants, but especially water (Hogan et al 1999).

Public health concerns
S. marcescens is described as an uncommon infection of neonates (Fleisch et al 2002).

Presence in raw milk
S. marcescens has not been reported in surveys of pathogenic bacteria in raw milk. It is an uncommon cause of mastitis in dairy cattle in New Zealand (S McDougall *pers. comm*.), although more common in confined management systems used in Europe and North America (Hogan et al 1999).

Risk factors for contamination of raw milk
Mastitis in dairy cattle due to *S. marcescens* is associated with poor quality water, and poor environmental and milking hygiene. Outbreaks of *Serratia* mastitis have been associated with contaminated chlorhexidine teat disinfectants and cow bedding (Hogan et al 1999).

Public health control methods
Specific control methods for *Serratia* are to ensure freedom of contamination of water supplies with the organism, including exclusion of access to natural waterways. It is also important to ensure high quality water is used in formulating teat disinfectants and that original and ready-to-use teat spray containers are closed and free from risk of contamination. Other general control methods are those relating to improving hygiene of the environment and milking process.

2.10 Human pathogenic *Streptococcus spp.*

Characteristics
Streptococcus spp. are Gram positive, facultative anaerobic bacteria. Most live as commensal organisms in the upper respiratory and lower urogenital tract, and do not survive for long periods in the environment (Quinn et al 1999). The *Streptococcal spp.* that are potential pathogens of humans and that might enter raw milk are *S. Pyogenes*, *S. agalactiae* and *S. equi* subsp. *zooepidemicus*. The natural reservoir of *S. pyogenes* is the human upper respiratory tract, and it is a rare cause of mastitis in

cattle. *S. agalactiae* is a natural inhabitant of the human maternal vagina, and a relatively common cause of mastitis in dairy cows. *S. equi* subsp. *zooepidemicus* causes metritis and mastitis in cattle (Quinn et al 1999).

Public health concerns
S. pyogenes commonly causes upper respiratory and other infections in humans; *S. agalactiae* causes neonatal septicaemia in humans (Quinn et al 1999), and *S. equi* subsp. *zooepidemicus* was associated with an outbreak of bacteraemia/arthritis following consumption of inadequately pasteurised cheese (Bordes-Benitez et al 2006).

Presence in raw milk
The presence of human pathogenic *Streptococcus spp.* in raw milk has not been reported, but one New Zealand study of 7 herds reported 49% of BTM samples had >1000 cfu/ml of esculin positive *Streptococcus spp.* (although these were not differentiated) (Howard 2006). These are likely to be *S. uberis*, which is not a human pathogen.

Risk factors for contamination of raw milk
The main source of contamination is from cases of mastitis, so risk factors are those associated with poor mastitis detection and prevention.

Public health control methods
Control methods are those related to contagious mastitis prevention, and are the same as those given previously for *S. aureus*.

2.11 Yersinia spp.

Characteristics
Yersinia spp. are Gram negative, facultative anaerobic rod bacteria. The natural reservoir of infection is latent infections in the intestinal tract of wild and domestic animals (Quinn et al 1999).

Public health concerns
Yersinia enterocolitica and *Y. pseudotuberculosis* may contaminate raw milk and pose a public health risk. *Y. enterocolitica* produces a heat-stable enterotoxin that is associated with food-poisoning strains in humans and mesenteric lymphadenitis ("pseudo-appendicitis"); *Y. pseudotuberculosis* causes mesenteric lymphadenitis, in addition to ilitis and septicaemia. Clinical disease in humans from both species of *Yersinia* are mainly observed in children and young adults. In New Zealand, 487 cases of yersiniosis were notified in 2006 (Anonymous 2007).

Presence in raw milk
Surveys of BTM in US states found 1.2% (Jayarao et al 2006) and 6.1% (Jayarao and Henning 2001) of samples positive for *Y. enterocolitica.* Irish and French studies reported prevalence's of contamination of 39% and 36%, respectively (Rea et al 1992; Desmasures et al 1997).

Risk factors for contamination of raw milk

Rare cases of mastitis have been associated with *Y. pseudotuberculosis* in Israel *(*Shwimmer *et al 2007)*. More commonly, risk factors for contamination of raw milk are likely to be those associated with poor hygiene at milking and faecal contamination of the teat ends prior to milking cup attachment.

Public health control methods

No vaccines for prevention of yersiniosis are currently available for cattle or small ruminants; neither are there any routinely available test methods for subclinical infections. Control of this pathogen relies on effective hygiene management of the farm, especially milking practice.

3 Control of contamination of raw milk with human pathogens in New Zealand

Several regulations and codes of practice have been developed to control bacterial contamination of raw milk. These include regulatory requirements, processor requirements of their suppliers, and best-practice guidelines published by internationally-recognised specialist groups or organisations. In preparing this section of the report, the following references were particularly reviewed: "Guide to good dairy farming practice" (International Dairy Federation and Food and Agriculture Organization of the United Nations 2004) , "A practical guided for milk producers to the Food Hygiene (England) Regulations" (Dairy Hygiene Inspectorate 2006) and the "Code of hygienic practice for milk and milk products" (Codex Alimentarius Food Standards 2004).

When milk is intended for manufacture of raw milk products, maintenance of hygienic conditions for production are one of the most important public health control measures (Codex Alimentarius Food Standards 2004). Good milking hygiene is essential to obtain milk with a sufficiently low microbial load to enable manufacture of raw milk products that are safe and suitable for human consumption.

New Zealand milk harvesters are currently required to operate under an approved Risk Management Plan (RMP) to ensure high quality raw milk is supplied The RMP is evaluated against the regulatory standards (New Zealand Food Safety Authority 2006a). For example, Fonterra has an approved RMP for the harvesting of milk and this is detailed to suppliers via the "On Farm Procedures Booklet" (Fonterra 2007b) as part of their "Best on-Farm Practice System".

Management practices present in New Zealand differ from other dairy production systems in a number of ways including:

- management of dairy cattle on pasture (rather than in barns),
- grazing of cattle on pasture onto which faecal effluent has been applied
- limited (but increasing) use of supplementary feed,
- limited pre milk harvest diagnostics (e.g. stripping of milk from the glands before application of the cluster and variable levels of assessment of cow health)
- limited use of teat/udder cleaning before application of the milking clusters

These management/production systems differences are likely to result in different prevalence's of the pathogens and levels of exposure in New Zealand produced milk relative to the more intense, housed dairy production systems. For example, *E. coli* is a relatively common (19% of all clinical cases) clinical mastitis pathogen of housed dairy cattle (Bradley et al 2007) whereas in New Zealand it is relatively

uncommon (1% of all clinical cases; McDougall et al 2007). Data on the prevalence and concentration of food borne pathogens in bulk tank milk in New Zealand are not available (see above). But given the management systems employed in New Zealand, these may differ from overseas data. Hence specific risk factors for these pathogens in bulk tank milk may also differ. Moreover, any recommendations about minimising risk of specific pathogens derived from the international literature need to be assessed under New Zealand management systems.

Management of the risk of milk borne pathogens includes management of the risks of intramammary infection (i.e. mastitis control measures) as well as management of pathogens that are not specific mastitis pathogens but may enter the bulk tank milk via faecal contamination of the udder or indirectly via dust entering the bulk tank. Management strategies that aim to reduce the risk of intramammary infection (such as milking only 'clean dry' teats) may also reduce the risk of food borne pathogens entering the bulk tank milk via contaminated teat skin.

However, other pathogens have specific risk pathways that are not controlled by 'standard' mastitis management approaches. For example, L*eptospira* spp. may enter the bulk tank milk via urine entering the milking clusters independent of faecal contamination of the teat skin. Hence pathogen specific management strategies are required for such pathogens.

Control of contamination of raw milk with human pathogens may be conveniently divided into three stages: pre-harvest (pre-milking), harvest, and post-harvest stages. This is schematically shown in Figure 1. Each stage and details of control measure are discussed below, including current requirements, additional recommended controls, and the opinions of the authors of this report on how effectively existing controls are implemented.

Figure 1. Diagram of options for on-farm control of contamination of raw milk with human pathogens in New Zealand

3.1 Pre-harvest control

Exclusion of milk for supply from diseased cows

Currently milk for processing is only to be harvested from healthy animals (Code of Practice for the Design and Operation of Farm Dairies Version 5. Ministry of Agriculture and Forestry, 2007b).This meets the requirements of the Animal Products

(Dairy Processing Specifications) Notice 2006 (New Zealand Food Safety Authority 2006b) and DPC 2 (New Zealand Food Safety Authority 2006a). These require the identification, isolation and withholding of milk from supply of animals with clinical diseases communicable to humans, animals suffering severe weight loss, severe injury or fever, and specifically mention salmonellosis and leptospirosis. DPC 2 also specifically requires the withholding of milk for supply from mammary glands of cows that are inflamed or injured until healed or the clinical signs have resolved. It also requires adequate record-keeping by the farm dairy operator and monitoring of the farm and animal health by a veterinarian.

Vaccination programmes

Eighty to ninety percent of dairy farmers already undertake vaccination of their herd and replacements against leptospirosis (Cranefield 2000). Vaccination is not compulsory, but highly recommended by all veterinary practices, although there may be differences between practices in the level of veterinary supervision. No national data are available on the use of vaccination against salmonellosis, but it is not routinely used in dairy herds, in the opinion of the authors of this report.

The authors of this report recommend that management programmes including vaccination against leptospirosis (using the Leptosure ® programme) and salmonellosis, supervised by a registered veterinarian, should be a condition of supply of milk for processing into raw-milk products. These programmes should cover all replacement stock, milking cows and service bulls. Correct use of these vaccines combined with other risk management procedures e.g. isolation and vaccination of bought-in animals, reduction of exposure of animals and feed to wild animal vectors, should eliminate the risk of leptospirosis, and greatly reduce the risk of clinical salmonellosis in herds.

Farm hygiene control

Provision for general farm hygiene is already covered under DPC 2 (New Zealand Food Safety Authority 2006a) and suppliers undergo inspection annually to monitor their performance in this area (Code of Practice for the Design and Operation of Farm Dairies Version 5. Ministry of Agriculture and Forestry, 2007b). Animals should be kept clean by maintaining hygiene of their environment. This includes ensuring that where animals are housed for lying down, there is sufficient area for each cow and the bedding material is kept clean and dry. Concrete races, holding and feeding areas should be free of accumulations of dung and slurry, and paddocks, tracks and gateways should be well maintained and free of accumulations of mud, dung and slurry (Dairy Hygiene Inspectorate 2006).

Irrigation of farm dairy effluent onto pastures presents a risk for infection of grazing cattle or contamination of udders and teats. A review of the environmental effects of application of farm effluents in New Zealand suggested that following irrigation, human pathogens including *Salmonella, Campylobacter jejuni* and *Yersinia enterocolitica* can exist on soil and pasture at elevated concentrations for between

10 and 70 days, depending on temperature, moisture and sunlight levels (Wang et al 2004). Sufficient farm area needs to be available for effluent irrigation, to allow a minimum paddock "withholding period", thus allowing pathogen numbers on grazed areas to naturally reduce. A minimum of 14 days is recommended by the authors of this report based on what is practical on-farm, and on published data.

Farmers who wish to supply milk for processing into raw milk products will require extra training for maintaining high farm hygiene standards, and extra monitoring compared with the current minimum annual inspection. Monitoring tools, including an assessment of farm and animal hygiene, need to be expanded for harvesters of milk intended for processing into raw milk products.

Dietary management

Standards for quality of feed for dairy stock is covered under NZCP1: Code of Practice for the Design and Operation of Farm Dairies Version 5 (New Zealand Food Safety Authority 2007b). This requires that producers must not offer cows any feed that will contaminate milk with residues, contaminants or taints. Processors may also require producers to cease feeding any material to cows that may contaminate milk with toxins, residues or any other harmful substance, including feed grown on land where human waste has been applied (Code of Practice for the Design and Operation of Farm Dairies Version 5. Ministry of Agriculture and Forestry, 2007b).

The authors of this report recommend that where fermented feeds (including silages) are offered to stock supplying milk for production of raw milk products, they should be of an acceptable quality. A feed testing regimen must be implemented to test pH (as an indicator of safety) prior to opening, and during the use, of stacks or bales of these feeds (Cooper and Walker 1998). Feed with pH >5.0 should not be fed to animals supplying milk for raw milk products. The authors also recommend that fermented feeds are not offered immediately pre-milking to reduce spore or bacterial contamination of teat ends.

Mastitis management

Dry cow therapy is an important part in control of all, but particularly infectious pathogens associated with mastitis, such as *S. aureus* and *Strep. agalactiae.* Guidelines for use of dry cow therapy are given in the SAMM Plan booklet (National Mastitis Advisory Committee 2006), The authors of this report recommend that dairy farm operators supplying milk for raw-milk products must have in place a programme or procedures for the management of mastitis (e.g. SAMM Plan).

3.2 Harvest control

Examination of foremilk prior to milking

This practice, commonly known as "foremilk stripping", is used to quickly identify cows with clinical mastitis, or other abnormalities e.g. blood in the milk, to prevent such milk entering the bulk tank and human food supply. It is either a recommended or compulsory practice for many overseas producers (International Dairy Federation

and Food and Agriculture Organization of the United Nations 2004; Dairy Hygiene Inspectorate 2006). Cows with clinical mastitis shed vast numbers of bacteria in the milk from affected glands, and hence pose a serious risk for contamination of BTM if not identified prior to milking. Lack of foremilk examination was associated with increased odds of isolation of *L. monocytogenes* from in-line milk filters from New York state dairy herds (Hassan et al 2001). Removal of milk from the streak canal before cup attachment may also serve the purpose of flushing out many potential human pathogens present there, but not in the gland cistern (Hassan et al 2001). Foremilk stripping may be included as part of the pre-milking teat disinfection routine (see below). However, foremilk stripping is currently an uncommon practice in New Zealand, especially following the initial period of colostrum production (the first four days of lactation).

The authors of this report recommend that foremilk stripping of all glands prior to cup attachment at each milking be considered as a requirement of all producers supplying milk for raw-milk products.

Pre-milking teat disinfection

This is a key component for control of environmental, faecal- and urine-associated human pathogens on teats. Faeces, bedding and soil matter from teats, udders and tails are important sources of milk contamination (Anonymous 2006). Effective pre-milking teat disinfection both reduces new intramammary infections (Pankey et al 1987; Oliver et al 1993; Oliver et al 1994) and improves the microbiological quality of raw milk (Pankey 1989; Rasmussen et al 1991; Hassan et al 2001). Summarising a number of studies, it was concluded that antiseptic teat dipping with manual drying was most effective in reducing bacterial counts on teat skin, compared with wet towel washing and manual drying, or dry towel preparation alone (Pankey 1989). Effective pre-milking teat disinfection is regarded as essential for the production of high quality milk.

Drying teats after washing and before cup attachment is important for the reduction of bacterial contamination of collected milk (Galton et al 1982; Galton et al 1984). Further, only teats, rather than the udder and teats, should be routinely cleaned either by water or an effective disinfectant, followed by drying with single-use paper towels, which additionally removes disinfectant residue (Galton et al 1984). However, the benefits of pre-milking teat disinfection on raw milk contamination may depend on the season and feeding system used, as results from the UK reported no benefit in pasture-grazed cows in summer, compared with confined animals in winter (McKinnon et al 1990).

Only two products are currently licensed in New Zealand for use as a pre-milking dip or spray. The first is an iodine-glycerol solution (Spray & Dip RTU, DeLaval Ltd., Hamilton, New Zealand, ARB#9355). The manufacturer recommends that any excess organic matter from the teats be firstly removed using a moist paper towel, all quarters before-stripped, then dipped or sprayed with the product allowing 15 to 30

seconds contact time, then all teats be dried thoroughly using a single-service paper towel before attaching teat cups. The second is a 500g/L sodium dichloroisocyanurate product (Mastitab, Bayer New Zealand, ARB# A008269). No peer-reviewed data regarding the effectiveness of pre-milking teat disinfection are available from New Zealand. Anecdotal reports from New Zealand dairy farmers indicates that pre-milking teat disinfection is used, but washing and/or drying of teats before milking is not practised due to time constraints.

The authors of this report recommend that effective pre-milking teat disinfection be a condition for supply of milk for processing into raw milk products.

Milking hygiene

Hygiene of staff and equipment at milking is an important control point for reducing contamination of raw milk from faecal-and urine-associated pathogens (Anonymous 2006), and from human-associated pathogens.

Requirements for the design, construction and maintenance of the milking area to maintain hygienic practices are covered under DPC 2 (New Zealand Food Safety Authority 2006a). Annual milking machine function tests are also recommended as part of the "Best on-Farm Practice System". Regulators in the UK require that the hands of milking staff, contact surfaces and milking equipment be kept clean at all times (Dairy Hygiene Inspectorate 2006).

The hands and forearms of milking staff should be cleaned before milking starts and kept clean during milking and milk handling. Exposed skin wounds should be hygienically covered. Best milking practice includes use of gloves by milking staff, especially during the search for and treatment of cows with clinical mastitis (Brightling et al 2000).

Milking management

Milking management covers all aspects of milking cows quickly and effectively while assuring the health of the cows and quality of the milk (International Dairy Federation and Food and Agriculture Organization of the United Nations 2004). Good milking management includes consistent milking techniques such as avoiding excessive air ingress at cup attachment, minimising over-milking, gentle removal of cups and care to avoid cups sucking up faecal or other material.

Managing cow milking order and housing of known infected or high risk cows separately from uninfected cows may reduce the BTMSCC and bacterial contamination. Herds that milked uninfected cows before cows with subclinical and clinical mastitis were less likely to have *Listeria* spp. isolated from the bulk tank milk (Vilar et al 2007).

Post-milking teat disinfection

This is a key component of both the 5-Point Plan and the SAMM Plan to control contagious mastitis pathogens (already discussed under sections 2.8 and 2.10 for *S. aureus* and *Strep. agalactiae)*. This practice is common on most New Zealand dairy

farms, especially in the winter and spring lactation periods, but is discontinued in many herds in summer and autumn (McDougall 1999). Other common problems with teat disinfection are failure to mix the product according to label recommendations or to measure amounts accurately; the addition of inappropriate emollients; use of poor quality water; incorrect or prolonged storage of teat disinfectants, and most commonly, inadequate coverage of teat skin (Brightling et al 2000). Teat disinfectant coverage can be assessed using a 'paper towel' technique, and adequate volume (10 ml for dipping, 20 ml for spraying per cow per milking) estimated from volumes used.

Effective teat disinfection following every milking should be a condition for supply of milk for processing into raw milk products.

Farm dairy water quality
Maintaining water supplies of high quality is important for ensuring good milk plant hygiene, for use in pre-milking teat cleaning and for preparation of teat disinfectants. It is also important for the control of *Serratia marcescens*.

Suppliers are required to meet standards set out by their own processors (Fonterra 2007a) which meet those in NZFSA Approved Criteria: DPC2: Animal Products (Dairy)(New Zealand Food Safety Authority 2006a). These standards include the absence of *E. coli* in a 100 ml sample and regular monitoring of water quality.

3.3 Post-harvest control

Milking plant hygiene
This is an important step for control of multiplication of all pathogens in milk transport and storage areas of the plant. Milk must be protected from contamination during transfer and storage. Bulk milk tanks should be cleaned and disinfected after each milk collection and kept in good condition. A potential source of bacterial contamination of raw milk is failure to adequately clean and disinfect milking equipment and bulk milk tanks (Anonymous 2006).

The cleaning of the milking plant is covered by DPC 2 (New Zealand Food Safety Authority 2006a).

Milk filtering and cooling
Milk must be adequately filtered to meet requirements for removal of sediment and foreign matter as stated in DPC 2 (New Zealand Food Safety Authority 2006a). Adequate chilling of raw milk is also required as a key component for quality of milk for processing, as well as control of multiplication of human pathogens in BTM. Time since milk harvesting and temperature standards are also set out in DPC 2 (New Zealand Food Safety Authority 2006a) and processors may reject milk from collection if these standards have not been met (Fonterra 2007a). These standards include pre-cooling of milk to 18°C and cooling of the milk in the vat to 7°C within 3 hours of collection.

Bulk tank hygiene security

Suppliers are required to secure the BTM silo from contamination by foreign matter and vermin (Fonterra 2007a). Requirements for the design, construction and maintenance of the milk receiving area to achieve this are covered under DPC 2 (New Zealand Food Safety Authority 2006a). These requirements minimise the risk of introduction of environmental and faecal or urinary-associated pathogens.

3.4 Monitoring of raw milk hygiene

A range of milk quality assessment measures are already undertaken by processors to meet the requirements of DPC2 (New Zealand Food Safety Authority 2006a). The tests undertaken and their frequency vary between processors and at different risk periods of the season, and cover a range of quality measures.

However, current processor testing regimens for raw milk have been designed with the expectation of further processing (pasteurisation). The tests used and their frequency may not be adequate to ensure the quality of raw milk when pasteurisation does not occur. Further, existing tests may not be sufficiently sensitive, or specific, to detect human pathogens contaminating raw milk and new bacteriological tests may need to be introduced to monitor these hazards. For example, as described in section 2.6 on *Listeria monocytogenes*, individual suppliers of raw milk for soft cheese manufacture in France undergo defined high frequency testing for this and other pathogens, as a condition of supply.

The scope of this report does not include specifying the testing regimens required to monitor these hazards. Insufficient data from New Zealand have been published regarding the prevalence and concentration of pathogens in raw milk New Zealand on which to base such regimens. Conducting statistically-based surveys to generate such data is an essential first step in formulating new testing regimens.

Current programmes to train farm staff in the hygienic harvesting and storage of milk, and on-farm auditing of these practices and facilities may not be sufficient if this milk was to be used for the production of raw milk products to safeguard public health. The authors of this report recommend that a new monitoring programme for raw milk and its products would be an essential part of any change to make raw milk products available to the New Zealand public.

4 Conclusions

Raw milk products are consumed by the public in many countries, especially in Europe. Significant public health risks are inherent in this practice, as consumption of products from milk which has not been pasteurised results in risk of exposure to a wide range of disease-causing bacteria. However, these risks are managed in such countries and the practice continues and is accepted by the public.

In New Zealand there is currently no published information available regarding the range of pathogens present in raw milk, or the prevalence or degree of contamination. However, it is likely that a real health risk would exist if raw milk products were available to the public from milk produced under current management systems. New on-farm management procedures and monitoring regimens are required to mitigate these risks. These procedures will need to be designed to take account of New Zealand management systems and environments, which differ from those experienced overseas (see Section 3).

Additional management procedures are recommended for consideration by the authors of this report that are not commonly used in New Zealand dairies. These include pre-milking examination of foremilk and pre-milking teat disinfection. These practices will increase milking time for most producers and require additional skill and experience by milking staff to be successfully implemented. However, together these are probably the most important new requirements for the control of contamination of raw milk by human pathogens. It is anticipated that further compliance costs would be faced by these producers, and by processors, in the areas of auditing of farm management and facilities, and additional testing of raw milk and its products.

5 Recommendations

Specific recommendations that should be implemented for herds producing milk for manufacture into raw milk products include:

1. Implementation of more stringent on-farm disease management protocols including (but not limited to) mandatory involvement in the Leptosure leptospirosis management plan and development of a salmonellosis risk management plan including the use of the already registered salmonella vaccine. A herd level disease risk management plan should be developed in conjunction with the herd veterinarian.

2. Development, validation and implementation of a semi-quantative farm and animal hygiene scoring system that would be undertaken at least six monthly on all farms supplying raw milk.

3. Testing and documentation of ensiled feeds to ensure that the pH is <5.

4. Monitoring and documentation of ensure full implementation of a mastitis management plan, as found for example in the "SAMM" plan.

5. Pre-milking stripping and teat disinfection, using approved products, at each milking.

6. Wearing of new, clean latex gloves by all milking personnel at all milkings.

7. Removal from supply, management as a separate physical group and milking after those animals producing milk for supply, of all animals with grossly evident clinical disease (even if not being treated) and any animal being treated with an animal remedy.

Other recommendations that require further work before implementation include:

1. Assessment of prevalence and quantification of bulk tank contamination with potential food borne pathogens.

2. Based on 1, development of suitable bulk tank milk monitoring process that results in identification of herds producing milk containing significant numbers of food borne pathogens, a reporting process that ensures supply is suspended and that action is undertaken on-farm and that re-supply is contingent on some further number of tests.

Data needs to be collected in New Zealand on raw milk microbiology and effectiveness of proposed changes to control pathogen contamination of raw milk. Initial survey data would provide a baseline against which to measure changes over time, and essential prevalence data on which to base scientific sampling schemes. This would also build capability to undertake the microbiology needed in the future for monitoring raw milk contamination to assure safety of those products.

References

Aarestrup FM. Monitoring of antimicrobial resistance among food animals: Principles and limitations. *Journal of Veterinary Medicine. Series B* 51, 380-88, 2004

Altekruse SF, Timbo BB, Mowbray JC, Bean NH, Potter ME. Cheese-associated outbreaks of human illness in the United States, 1973 to 1992: Sanitary manufacturing practices protect consumers. *Journal of Food Protection* 61, 1405-07, 1998

Anonymous. A practical guide for milk producers to the Food Hygiene (England) Regulations 2006, Food Hygiene Regulations (Wales) 2006 incorporating EC Regulations 852/853/854- 2004. In. (Dairy Hygiene Inspectorate, Food Standards Agency) 2006

Anonymous. Notifiable and other diseases in New Zealand Annual Report 2006. Population and Environmental Health Group, Institute of Environmental Science and Research Limited, 2007

Bemrah N, Sanaa M, Cassin MH, Griffiths MW, Cerf O. Quantitative risk assessment of human listeriosis from consumption of soft cheese made from raw milk. *Preventive Veterinary Medicine* 37, 129-45, 1998

Bordes-Benitez A, Sanchez-Onoro M, Suarez-Bordon P, Garcia-Rojas AJ, Saez-Nieto JA, Gonzalez-Garcia A, Alamo-Antunez I, Sanchez-Maroto A, Bolanos-Rivero M. Outbreak of Streptococcus equi subsp zooepidemicus infections on the island of Gran Canaria associated with the consumption of inadequately pasteurized cheese. *European Journal of Clinical Microbiology and Infectious Diseases* 25, 242-46, 2006

Bradley AJ, Leach KA, Breen JE, Green LE, Green MJ. Survey of the incidence and aetiology of mastitis on dairy farms in England and Wales. *Veterinary Record* 160, 253-8, 2007

Brightling P, Mein GA, Hope AF, Malmo J, Ryan DP. Countdown Downunder: Technotes for Mastitis Control. Dairy Research and Development Corporation, Melbourne, Australia, 2000

Christiansson A, Bertilsson J, Svensson B. Bacillus cereus spores in raw milk: Factors affecting the contamination of milk during the grazing period. *Journal of Dairy Science* 82, 305-14, 1999

Codex Alimentarius Food Standards. Code of hygienic practice for milk and milk products. FAO/WHO, 2004

Cooper J, Walker RD. Listeriosis. *Veterinary Clinics of North America Food Animal Practice* 14, 113-25, 1998

Cranefield SW. The future of veterinarians in the management of leptospirosis. In: Vetscript. Pp 3-4. 2000

Dairy Hygiene Inspectorate FSA. A practical guide for milk producers to the Food Hygiene (England) Regulations 2006, Food Hygiene Regulations (Wales) 2006 incorporating EC Regulations 852/853/854- 2004. In. 2006

De Buyser ML, Dufour B, Maire M, Lafarge V. Implication of milk and milk products in food-borne diseases in France and in different industrialised countries. *International Journal of Food Microbiology* 67, 1-17, 2001

de Louvois J, Rampling A. One fifth of samples of unpasteurised milk are contaminated with bacteria. *British Medical Journal* 316, 625, 1998

De Reu K, Grijspeerdt K, Herman L. A Belgian survey of hygiene indicator bacteria and pathogenic bacteria in raw milk and direct marketing of raw milk farm products. *Journal of Food Safety* 24, 17-36, 2004

Desmasures N, Bazin F, Gueguen M. Microbiological composition of raw milk from selected farms in the Camembert region of Normandy. *Journal of Applied Microbiology* 83, 53-58, 1997

Dorjee S, Ridler A, Collins JM, Midwinter A, West DM, Heuer C, Jackson R. Leptospirosis in sheep in New Zealand. In: Proceedings of the Food Safety & Biosecurity, and Epidemiology & Animal Health Management Branches of the NZVA. Pp 19-31. (Foundation for Continuing Education) 2005

Ekperigin HE, Nagaraja KV. Microbial food borne pathogens. Salmonella. *Veterinary Clinics of North America Food Animal Practice* 14, 17-29, 1998

Fenwick SG. Food-borne pathogens and the role of animal sources. *Proceedings of the Second Pan-Pacific Veterinary Conference: Cattle sessions- Incorporating the 13th Annual Seminar of the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association* 13, 41-47, 1996

Fleisch F, Zimmerman-Baer U, Zbinden R, Bischoff G, Arlettaz R, Waldvogel K, Nadal D, Ruef C. Three consecutive outbreaks of Serratia marcescens in a neonatal intensive care unit. *Clinical Infectious Diseases* 34, 767-73, 2002

Fonterra. *Suppliers' Handbook*, 2007a

Fonterra. *Procedures Booklet*, 2007b

Forshell LP, Wierup M. Salmonella contamination: a significant challenge to the global marketing of animal food products. *Revue Scientifique Et Technique-Office International Des Epizooties* 25, 541-54, 2006

Galton DM, Adkinson RW, Thomas CV, Smith TW. Effects of premilking udder preparation on environmental bacterial contamination of milk. *Journal of Dairy Science* 65, 1540-3, 1982

Galton DM, Petersson LG, Merrill WG, Bandler DK, Shuster DE. Effects of premilking udder preparation on bacterial population, sediment, and iodine residue in milk. *Journal of Dairy Science* 67, 2580-9, 1984

George G. Listeriosis: an emerging concern. *Surveillance* 14, 7-8, 1987

Gillespie IA, Adak GK, O'Brien SJ, Bolton FJ. Milkborne general outbreaks of infectious intestinal disease, England and Wales, 1992-2000. *Epidemiology and Infection* 130, 461-68, 2003

Goulet V, Jacquet C, Vaillant V, Rebiere I, Mouret E, Lorente C, Maillot E, Stainer F, Rocourt J. Listeriosis from consumption of raw-milk cheese. *Lancet* 345, 1581-2, 1995

Hassan L, Mohammad HO, McDonough PL, Gonzalez RN. A cross-sectional study on the prevalence of Listeria monocytogenes and Salmonella in New York dairy herds. *Journal of Dairy Science* 83, 2441-47, 2000

Hassan L, Mohammed HO, McDonough PL. Farm-management and milking practices associated with the presence of Listeria monocytogenes in New York state dairy herds. *Preventive Veterinary Medicine* 51, 63-73, 2001

Hill FL. Zoonotic diseases of ruminants in New Zealand. *Surveillance* 21, 25-27, 1994

Hogan JS, Gonzalez RN, Harmon RJ, Nickerson SC, Oliver SP, Pankey JW, Smith KL. *Laboratory Handbook on Bovine Mastitis*, National Mastitis Council Inc., Madison, WI, 1999

Holsinger VH, Rajkowski KT, Stabel JR. Milk pasteurisation and safety: a brief history and update. *Revue Scientifique Et Technique De L Office International Des Epizooties* 16, 441-51, 1997

Howard P. Mastitis pathogens present in bulk tank milk from seven dairy herds in the Waikato region, New Zealand. *New Zealand Veterinary Journal* 54, 41-43, 2006

Husu JR. Epidemiological studies on the occurrence of Listeria monocytogenes in the feces of dairy cattle. *Journal of Veterinary Medicine. Series B* 37, 276-82, 1990

International Dairy Federation, Food and Agriculture Organization of the United Nations. Guide to good dairy farming practice. Rome, 2004

Jayarao BM, Henning DR. Prevalence of foodborne pathogens in bulk tank milk. *Journal of Dairy Science* 84, 2157-62, 2001

Jayarao BM, Pillai SR, Sawant AA, Wolfgang DR, Hegde NV. Guidelines for monitoring bulk tank milk somatic cell and bacterial counts. *Journal of Dairy Science* 87, 3561-73, 2004

Jayarao BM, Donaldson SC, Straley BA, Sawant AA, Hegde NV, Brown JL. A survey of foodborne pathogens in bulk tank milk and raw milk consumption among farm families in Pennsylvania. *Journal of Dairy Science* 89, 2451-58, 2006

Jemmi T, Stephan R. Listeria monocytogenes: food-borne pathogen and hygiene indicator. *Revue Scientifique Et Technique-Office International Des Epizooties* 25, 571-80, 2006

Jorgensen HJ, Mork T, Rorvik LM. The occurrence of Staphylococcus aureus on a farm with small-scale production of raw milk cheese. *Journal of Dairy Science* 88, 3810-17, 2005

Juhasz-Kaszanyitzky E, Janosi S, Somogyi P, Dan A, van der Graaf-van Bloois L, van Duijkeren E, Wagenaar JA. MRSA transmission between cows and humans. *Emerging Infectious Diseases* 13, 630-2, 2007

Leclerc V, Dufour B, Lombard B, Gauchard F, Garin-Bastuji B, Salvat G, Brisabois A, Poumeyrol A, De Buyser ML, Gnanou-Besse N, Lahellec C. Pathogens in meat and milk products: surveillance and impact on human health in France. *Livestock Production Science* 76, 195-202, 2002

Lin S, Schraft H, Odumeru JA, Griffiths MW. Identification of contamination sources of Bacillus cereus in pasteurized milk. *International Journal of Food Microbiology* 43, 159-71, 1998

Linnan MJ, Mascola L, Lou XD, Goulet V, May S, Salminen C, Hird DW, Yonekura ML, Hayes P, Weaver R, et al. Epidemic listeriosis associated with Mexican-style cheese. *New England Journal of Medicine* 319, 823-8, 1988

Magnusson M, Christiansson A, Svensson B, Kolstrup C. Effect of different premilking manual teat-cleaning methods on bacterial spores in milk. *Journal of Dairy Science* 89, 3866-75, 2006

Magnusson M, Christiansson A, Svensson B. Bacillus cereus spores during housing of dairy cows: factors affecting contamination of raw milk. *Journal of Dairy Science* 90, 2745-54, 2007a

Magnusson M, Svensson B, Kolstrup C, Christiansson A. Bacillus cereus in free-stall bedding. *Journal of Dairy Science* 90, 5473-82, 2007b

McDougall S. Efficacy of two antibiotic treatments in curing clinical and subclinical mastitis in lactating dairy cows. *New Zealand Veterinary Journal* 46, 226-32, 1998

McDougall S. Prevalence of clinical mastitis in 38 Waikato dairy herds in early lactation. *New Zealand Veterinary Journal* 47, 143-49, 1999

McDougall S, Arthur DG, Bryan MA, Vermunt JJ, Weir AM. Clinical and bacteriological response to treatment of clinical mastitis with one of three intramammary antibiotics. *New Zealand Veterinary Journal* 55, 161-70, 2007

National Mastitis Advisory Committee. SAMM Plan Explanatory Booklet. 2006

Neave FK, Dodd FH, Kingwill RG. A method of controlling udder disease. *The Veterinary Record* 78, 521-23, 1966

New Zealand Food Safety Authority. Regulatory control of antibiotics to manage antibiotic resistance: Progress report December 2003. 2003

New Zealand Food Safety Authority. DPC 2: Animal Products (Dairy) Approved Criteria for Farm Dairies. In: (Ed. Ministry of Agriculture and Forestry). 2006a

New Zealand Food Safety Authority. Animal Products (Dairy Processing Specifications) Notice 2006. In: (Ed. Ministry of Agriculture and Forestry). 2006b

New Zealand Food Safety Authority. DPC 2: Animal Products (Dairy) Approved Criteria for Farm Dairies Draft Amendments December 2007. In: (Ed. Ministry of Agriculture and Forestry). 2007a

New Zealand Food Safety Authority. NZCP1: Code of Practice for the Design and Operation of Farm Dairies Version 5. In: (Ed. Ministry of Agriculture and Forestry). 2007b

Nieminen T, Rintaluoma N, Andersson M, Taimisto AM, Ali-Vehmas T, Seppala A, Priha O, Salkinoja-Salonen M. Toxinogenic Bacillus pumilus and Bacillus licheniformis from mastitic milk. *Veterinary Microbiology* 124, 329-39, 2007

Nightingale KK, Schukken YH, Nightingale CR, Fortes ED, Ho AJ, Her Z, Grohn YT, McDonough PL, Wiedmann M. Ecology and transmission of Listeria monocytogenes infecting ruminants and in the farm environment. *Applied and Environmental Microbiology* 70, 8, 2004

Nightingale KK, Fortes ED, Ho AJ, Schukken YH, Grohn YT, Wiedmann M. Evaluation of farm management practices as risk factors for clinical listeriosis and fecal shedding of Listeria monocytogenes in ruminants. *Journal of the American Veterinary Medical Association* 227, 1808-14, 2005

O'Keefe JS. A brief review of the laboratory diagnosis of leptospirosis. *New Zealand Veterinary Journal* 50, 9-13, 2002

Olde Riekerink RG, Barkema HW, Kelton DF, Scholl DT. Incidence rate of clinical mastitis on Canadian dairy farms. *Journal of Dairy Science* 91, 1366-77, 2008

Oliver SP, Lewis MJ, Ingle TL, Gillespie BE, Matthews KR, Dowlen HH. Premilking teat disinfection for the prevention of environmental pathogen intramammary infections. *Journal of Food Protection* 56, 1993

Oliver SP, Gillespie BE, Lewis MJ, Ingle TL, Dowlen HH. Evaluation of chlorhexidine as a premilking teat disinfectant for the prevention of intramammary infections during lactation. *Journal of Food Protection* 57, 614-18, 1994

Ormeci E, Ozdemir H. Prevalence of thermophilic Campylobacter spp. in raw milk. *Milchwissenschaft-Milk Science International* 62, 264-65, 2007

Pankey JW, Wildman EE, Dreschler PA, Hogan JS. Field trial evaluation of pre-milking teat disinfection. *Journal of Dairy Science* 70, 867-72, 1987

Pankey JW. Premilking Udder Hygiene. *Journal of Dairy Science* 72, 1308-12, 1989

Quinn PJ, Carter ME, Markey B, Carter GR. *Clinical Veterinary Microbiology*, Mosby, Edinburgh, 1999

Radostits OM, Blood DC, Gay CC. *Veterinary Medicine: A textbook of the diseases of cattle, sheep, pigs, goats and horses*, 8th edn. Bailliere Tindall, London, 1984

Rampling A. Raw milk cheeses and Salmonella - Pasteurisation and strict hygiene prevent serious morbidity and death. *British Medical Journal* 312, 67-68, 1996

Rasmussen MD, Galton DM, Petersson LG. Effects of premilking teat preparation on spores of anaerobes, bacteria, and iodine residues in milk. *Journal of Dairy Science* 74, 2472-8, 1991

Rea MC, Cogan TM, Tobin S. Incidence of Pathogenic Bacteria in Raw-Milk in Ireland. *Journal of Applied Bacteriology* 73, 331-36, 1992

Riemann HP, Cliver DO. Microbial food borne pathogens. Escherichia coli O157:H7. *Veterinary Clinics of North America Food Animal Practice* 14, 41-8, 1998

Sanaa M, Poutrel B, Menard JL, Serieys F. Risk-Factors Associated with Contamination of Raw-Milk by Listeria-Monocytogenes in Dairy Farms. *Journal of Dairy Science* 76, 2891-98, 1993

Sanaa M, Coroller L, Cerf O. Risk assessment of listeriosis linked to the consumption of two soft cheeses made from raw milk: Camembert of Normandy and Brie of Meaux. *Risk Analysis* 24, 389-99, 2004

Schukken YH, Grommers FJ, Vandegeer D, Erb HN, Brand A. Risk-factors for clinical mastitis in herds with a low bulk milk somatic-cell count .2. Risk-factors for Escherichia-coli and Staphylococcus-aureus. *Journal of Dairy Science* 74, 826-32, 1991

Shwimmer A, Freed M, Blum S, Khatib N, Weissblit L, Friedman S, Elad D. Mastitis caused by Yersinia pseudotuberculosis in Israeli dairy cattle and public health implications. *Zoonoses and Public Health* 54, 353-57, 2007

Tollefson L, Angulo FJ, Fedorka-Cray PJ. National surveillance for antibiotic resistance in zoonotic enteric pathogens. *Veterinary Clinics of North America: Food Animal Practice* 14, 141-50, 1998

Van Kessel JS, Karns JS, Gorski L, McCluskey BJ, Perdue ML. Prevalence of salmonellae, Listeria monocytogenes, and fecal coliforms in bulk tank milk on US dairies. *Journal of Dairy Science* 87, 2822-30, 2004

Vilar MJ, Yus E, Sanjuan ML, Dieguez FJ, Rodriguez-Otero JL. Prevalence of and risk factors for Listeria species on dairy farms. *Journal of Dairy Science* 90, 5083-88, 2007

Wang HL, Magesan GN, Bolan NS. An overview of the environmental effects of land application of farm effluents. *New Zealand Journal of Agricultural Research* 47, 389-403, 2004