

# Raw milk: Is it good for you?

N French, J Benschop, J Marshall

<sup>m</sup>EpiLab, Infectious Disease Research Centre, Institute for Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North

## Abstract

Pasteurisation of milk was introduced to reduce the risk of diseases such as tuberculosis, Q-fever, brucellosis, campylobacteriosis and salmonellosis, and has been highly effective as a control measure<sup>1</sup>. However, as part of a growing trend in the consumption of raw foods, and with the often firmly held belief that ‘raw milk is better for you’, there has been an increasing demand for unpasteurised (raw) milk in New Zealand, as in many other countries.

This article summarises the evidence both for and against the consumption of raw milk. Although many studies have demonstrated an association between raw milk consumption and lower rates of diseases such as allergies and asthma, the evidence to date is still considered inconclusive, with observed associations being prone to confounding by other exposures. In contrast, the evidence that the consumption of raw milk is associated with ill-health is indisputable - the consumption of unpasteurised milk has been associated with a large number of outbreaks of infectious disease around the world, including New Zealand. It is, therefore, essential that more rigorous studies are conducted to examine potential positive health benefits, whilst ensuring the potentially tragic consequences of consuming raw milk are made clear to those who choose to drink it, or provide it for others to consume.

## Introduction

The sale of raw milk is illegal in many countries, and in a recent article it was reported that virtually all advisory and regulatory committees related to food safety around the world have “strongly endorsed the principles of consuming only pasteurised milk and milk products”. These include the American Medical Association, the American Veterinary Medical Association, the International Association for Food Protection, and the World Health Organisation (Anon 2014). In 2012, the US federal government turned down a petition requesting legalisation of raw milk sales at the federal-level, based on its analysis of the scientific basis for the food safety risks associated with raw milk consumption and the benefits of pasteurisation.

The sale of raw milk at retail outlets is not permitted in New Zealand. However, under the *Food Act 1981* the purchase of up to five litres from the farm gate is allowed if the consumers intend to drink it themselves, or provide it for their family to consume. Such milk must have been harvested and stored in accordance with an approved Risk Management Programme (RMP) that covers risks associated with supplying raw milk for drinking under the *Animal Products Act 1999*; however, it is questionable whether these RMP adequately address the risks associated with farm gate sales. Currently registered RMP only cover the production of raw milk intended for further treatment (e.g. pasteurisation) and not the sale of raw milk for drinking.

There are issues with the interpretation and enforcement of current legislation in New Zealand, and these are likely to have contributed to an increase in the number of sales occurring outside the limits provided in the law; for

<sup>1</sup>2014 is the 150<sup>th</sup> anniversary of pasteurisation, invented by Louis Pasteur in 1864.

example, internet sales and the subsequent collection of milk outside farm gates. Some raw milk suppliers report supplying increasingly large numbers of customers, utilising retail pick-up points in urban areas, and openly admit to illegally selling up to 16 litres at one time.<sup>2</sup>

## The consumption of raw milk in New Zealand

The practice of drinking raw milk amongst dairy farming households is much more common than in New Zealand households overall. In a 2007-10 survey of New Zealand dairy farmers, 858 of 1337 (64%) reported drinking raw milk (McFadden *et al.* 2012). In a national control bank of 506 persons developed for a 2011-12 case control study of Shiga toxin-producing *Escherichia coli* (STEC), 3% (16/506) reported this practice, which would equate to ~100,000 raw milk consumers in New Zealand. These figures are similar to those reported in the United States where consumption of raw milk amongst farming families was reported as 35% to 60% whilst only 3.5% of the general US population consumed raw milk (LeJeune and Rajala-Shultz 2009).

Although a much smaller proportion of urban dwellers drink raw milk in New Zealand, the absolute number of urban dwellers is relatively high. Further, for a given exposure, the urban population is likely to be at greater risk of illnesses such as campylobacteriosis, as acquired immunity, such as might be obtained through living on a farm, exerts a strong influence on the epidemiology of this disease (Hill *et al.* 2012). Within New Zealand, the reasons for wanting to consume raw milk include perceived health benefits such as “reduced eczema, asthma and hay fever symptoms”, “improved skin and immune systems” and the ability “to drink raw milk although they previously had been lactose/dairy intolerant”<sup>3</sup>. Given the health status of these individuals it is, therefore, likely that raw milk will be consumed by those most at risk from pathogens present in the product.

## Consuming raw milk: the association with ill-health

Even with the best hygiene practices, it is currently impossible to produce raw milk that is free from bacterial contamination; it is an inevitable consequence of the milking process. This can result from general contamination, from the environment in the milking shed and from faecal contamination of the udders and teats, to specific events, such as gross contamination of milking clusters leading to larger quantities of faecal material being drawn into the bulk milk tank (Blowey and Edmondson 2010, Elmoslemany *et al.* 2010, Galton *et al.* 1986, Galton *et al.* 1984, Pankey 1989). If the faecal contamination is sufficiently large, and cows in the herd are shedding pathogenic bacteria, single portions of unpasteurised milk will contain doses of faecal bacteria sufficient to cause illness - even with the high level of dilution that occurs in bulk milk tanks.

## Pathogens in dairy cattle and bulk milk

Many have been involved in outbreaks of raw milk-associated disease, and most are bacteria. These include STEC O157 (Denny *et al.* 2008, Guh *et al.* 2010, Keene *et al.* 1997, Langer *et al.* 2012), *Campylobacter* spp. (Fahey *et al.* 1995, Gillespie *et al.* 2003, Langer *et al.* 2012), *Coxiella burnetii* (the agent that causes Q fever) (Signs *et al.* 2012), *Brucella* spp. (Langer *et al.* 2012), *Salmonella* spp. (Gillespie 2003, Langer 2012) and *Listeria* spp. (Langer 2012) Although some of these pathogens are absent from New Zealand, such as *C. burnetii* (Signs *et al.* 2012), many are shed in the faeces of dairy cattle, including the important agents of notifiable diseases such as campylobacteriosis (Grinberg *et al.* 2005, Moriarty *et al.* 2008, Rapp *et al.* 2014, Rapp *et al.* 2012), STEC O157 infection (Buncic and Avery 1997, Irshad *et al.* 2012) and salmonellosis Clark *et al.* 2004, Stevenson 2012). As a result, even small samples (e.g. 25ml) taken in surveys of large bulk milk vats have tested positive for known pathogens in New Zealand (Hill *et al.* 2012)<sup>4</sup> and overseas (Amagliani *et al.* 2012, Bianchini *et al.* 2014, van Kessel *et al.* 2004). Importantly, most milk in New Zealand is pasteurised before consumption, and milk from farms sampled in the two recent bulk tank surveys was intended for further processing (Hill *et al.* 2012)<sup>4</sup>. A recent review highlights several surveys in the United States where the presence of STEC O157, *Campylobacter jejuni*, *Salmonella* spp. and *Listeria monocytogenes* as well as other pathogenic bacteria, were detected in bulk tank raw

---

<sup>2</sup> <http://www.stuff.co.nz/business/farming/7131704/Dairy-farmers-go-back-to-basics>

<sup>3</sup> Ministry for Primary Industries 2012 “Summary of Submissions on the Proposals for Continuing to Legally Provide for Farm Gate Sales of Raw Drinking Milk” MPI Information Paper

<sup>4</sup> <https://www.foodprotection.org/downloads/library/soboleva.pdf>

milk (Oliver *et al.* 2009, van Kessel *et al.* 2004). Similarly, these pathogens have been found in raw milk in Finland (Ruusunen *et al.* 2013), Italy (Amagliani *et al.* 2012, Bianchi *et al.* 2013, Bianchini *et al.* 2014), China (Ning *et al.* 2013) and the United Kingdom (Baylis 2009).

## Illness associated with the consumption of raw milk

Given the prevalence of pathogen-positive herds, and their detection in bulk milk, it is, therefore, not surprising that there have been many outbreaks of disease associated with the consumption of raw, unpasteurised milk around the world (Gillespie *et al.* 2003, Langer *et al.* 2012, LeJuene and Rajala-Schultz 2009) involving a wide range of bacterial pathogens.

## International outbreaks

In the United States, a recent review of dairy-associated outbreaks of human disease during 1993 - 2006 identified 43 outbreaks involving raw milk, resulting in 930 illnesses and 71 hospitalisations (Langer *et al.* 2012). This is a cause of concern in the US given the number and scale of reported outbreaks, and the increasing consumption of raw milk (Jay-Russell 2010, LeJuene and Rajala-Schultz 2009) (in a recent study 3.4% of consumers in the US reported drinking raw milk in the previous seven days (Buzby *et al.* 2013)). States that restricted sale of unpasteurised products had fewer outbreaks and illnesses, leading to the recommendation that stronger restrictions and enforcement should be considered (Langer 2012).

A similar association between raw milk availability to consumers and outbreaks of foodborne illness has been noted in reports from the United Kingdom and Italy. In England and Wales, the majority of milk-borne outbreaks from 1980-1990 were attributed to the consumption of raw milk (Barrett 1986, Galbraith *et al.* 1982, Stevenson 2012). In Scotland, a similar situation existed until the sale of unpasteurised milk was prohibited in 1983, which led to a significant drop of the incidence of diseases related to liquid milk consumption (Signs *et al.* 2012). In Italy, the introduction of raw milk vending machines saw cases of haemolytic uraemic syndrome (HUS) in children attributed to raw milk increase significantly (Scavia *et al.* 2009).

## New Zealand outbreaks between 2006 and 2013

In New Zealand, the identification and investigation of sporadic cases and outbreaks of notifiable communicable (including potentially foodborne) diseases are the responsibility of the Ministry of Health, the Public Health Services within District Health Boards (DHB) and the Institute of Environmental Science & Research Ltd (ESR). Outbreaks and case investigations are recorded in the EpiSurv database. Since 2006, ESR has reported 21 clusters or outbreaks of human illness where raw milk was recorded as a risk factor. Over the same time period, no clusters associated with pasteurised liquid milk were recorded.

Of the 21 outbreaks recorded in EpiSurv between January 2006 and February 2013, strong evidence for an association with raw milk consumption was found for two campylobacteriosis outbreaks (involving 16 and 9 cases respectively) and very strong evidence was found for one outbreak of salmonellosis (involving four cases). For the remaining 18 outbreaks recorded in EpiSurv, the link with raw milk consumption was suggestive only, due to the presence of other concurrent risk factors and/or lack of pathogen identification. The description of the algorithm to assess the strength of link to raw milk is presented in the Appendix.

The raw milk associated cluster of nine campylobacteriosis cases occurred in May/June 2011 in Palmerston North (French and Marshall 2012) but was not detected at the time the outbreak occurred. It was identified when EpiSurv data were linked with the genotyping data as part of the annual Manawatu campylobacteriosis sentinel site reporting for the Ministry for Primary Industries. The cases were all infected with the same ruminant associated strain (ST 520) and were identified over a two-week period between 23 May and 7 June 2011. Those affected were aged between 20 and 70 years of age and all had consumed unpasteurised milk. At least seven of the people involved sourced their milk from the same farm. Five purchased milk from an outlet in Palmerston North supplied by a single farm and two reported purchasing milk directly from the same farm (the other two were unsure of the supplier). It was highly likely that this cluster of cases was the result of a major faecal contamination event, possibly occurring during a single milking. On interview, most of the cases had little understanding of the potential

health risks associated with raw milk consumption.

## New Zealand outbreaks in 2014

In Timaru in April 2014, there was a cluster of cases of campylobacteriosis in people that had consumed raw milk from a supplier who had recently installed a raw milk vending machine at the farm gate. Although the farmer suggested the town water supply was a likely source of milk contamination<sup>5</sup>, it is more likely that the source was faecal shedding of *Campylobacter* in the milking cows. The farm's bimonthly testing is unlikely to be sensitive enough to detect and manage the risk.

This campylobacteriosis outbreak was shortly followed by four cases arising from another farm in Timaru, where a party of school children were offered raw milk<sup>6</sup>. This time the pathogen was STEC O157 and two children were hospitalised.

## Consuming raw milk: the perceived benefits

There are many reasons why New Zealanders and consumers elsewhere choose to purchase raw milk. The perceived health benefits include reduced eczema, asthma and hay fever symptoms, and individuals previously diagnosed as lactose/dairy intolerant cite lower symptoms when they drink raw milk compared to pasteurised milk. In a recent newspaper article describing one of the two raw-milk associated outbreaks in Timaru in 2014<sup>7</sup>, a regular consumer of raw milk claimed "It's amazing when you hear the benefits of it..." and "People would not buy it if it wasn't working." The article cited improvements for Parkinsons, Alzheimer's, eczema and asthma sufferers as "just some of the anecdotal stories".

A peer-reviewed journal article in 2010 entitled "Can farm milk consumption prevent allergic diseases?" appears to support these anecdotal claims, stating "... the epidemiological evidence consistently suggests a protective role of unprocessed cow's milk consumption on the development of asthma, hay fever and atopic sensitisation..." (Braun-Fahrlander and von Mutius 2011). Further, one of the most recent (2012) articles in the *Journal of Allergy and Clinical Immunology* entitled "Which factors in raw cow's milk contribute to protection against allergies?" states that "several factors in bovine milk have been described that might explain how raw cow's milk consumption can decrease the risk of allergies". However, the first article concludes "...the underlying mechanisms are not yet understood and the consumption of raw milk cannot be recommended as a preventive measure for allergic diseases" and the second article concludes "no controlled studies on raw milk consumption have been performed to formally demonstrate this effect."

Although new studies continue to explore the immunological mechanisms for observed associations between raw milk consumption and reduced allergies in childhood (Lluis *et al.* 2014), the evidence is still considered inconclusive. The lack of firm evidence was summarised in the most recent review and policy statement on raw milk consumption and health published in the journal *Pediatrics* (published in January 2014) which concluded that claims that consumption of raw milk was less likely to be associated with lactose intolerance than pasteurised milk "have not been substantiated by independent studies". Further, the article states "other claims purporting links between pasteurised milk and autism, allergic reactions, and asthma have largely been based on testimonials or anecdotes and have not been demonstrated based on scientific data". (Anon 2014)

A systematic review and meta-analysis conducted in 2011 summarised available evidence for claims that "pasteurisation destroys important vitamins and that raw milk consumption can prevent and treat allergies, cancer, and lactose intolerance" (MacDonald *et al.* 2011). The authors urged caution with the interpretation of the studies citing the poor quality of the methodology used in many studies. Their analysis revealed no significant effect of pasteurisation on vitamin B6 concentrations, but a decrease in concentrations of vitamins B1, B2, C and folate was reported. However, they concluded that "the effect of pasteurisation on milk's nutritive value was minimal because many of these vitamins are naturally found in relatively low levels". The authors did highlight milk as an important dietary source of vitamin B2, and suggested the impact of heat treatment should be further considered. Concerning

---

<sup>5</sup> <http://agrihq.co.nz/article/raw-milk-confidence-despite-outbreak?p=7>

<sup>6</sup> <http://www.stuff.co.nz/the-press/news/9925602/Timaru-pupils-ill-after-drinking-raw-milk>

<sup>7</sup> <http://www.stuff.co.nz/timaru-herald/news/9881896/Raw-milk-blamed-for-illness-outbreak>

other health claims, they concluded that: “Raw milk consumption may have a protective association with allergy development (six studies), although this relationship may be potentially confounded by other farming-related factors. Raw milk consumption was not associated with cancer or lactose intolerance” (MacDonald *et al.* 2011).

A number of studies have found evidence that farming families appear to have a lower risk of allergies and asthma compared with the general population. These apparent protective effects have been observed in New Zealand (Douwes *et al.* 2009, 2088, 2007) and factors associated with these reduced risks include microbial exposure, contact with livestock and the consumption of raw cow’s milk (Douwes 2009).

Several studies have shown an apparent protective effect of unprocessed cow’s milk on asthma, hay fever, atopy and dermatitis. A study in Germany, Austria and Switzerland of 812 school age children (Riedler *et al.* 2001) and a subsequent large European multicentre study in 14,893 children (the PARSIFAL study) (Waser *et al.* 2007) showed a strongly reduced risk of asthma, hay fever and atopy with “farm milk” consumption. In these studies, the apparent protective effects were reported to be independent of other exposure variables, including “growing up on a farm”. In the former study, the authors state that farm milk “is usually raw” (Riedler *et al.* 2001). However, the authors of the latter study indicate: “The present study does not allow evaluating the effect of pasteurised vs. raw milk consumption because no objective confirmation of the raw milk status of the farm milk samples was available. Parental answers to a question on consumption of boiled versus raw farm milk are likely to be biased due to the social desirability of responses because raw milk consumption is not recommended especially for young children. About half of the parents indicated that they usually did not boil the milk before consumption but no differential effects were observed between those boiling and those not boiling the milk” (Waser *et al.* 2007). To date, few studies in adults have been conducted, and currently it is unclear whether any protective effects are sustained into adulthood and/or whether current exposure in adulthood also confers protection.

## Concluding comment

In a recent newspaper article, a New Zealand dairy farmer stated “We had been hoping to sell raw milk by now but we are taking a slow and measured approach to it. We have to get it right. The stakes are too high if you get it wrong”.<sup>8</sup> The stakes are indeed high. The death of a child with Haemolytic Uraemic Syndrome, or a child left with permanent renal failure for which the only option is a kidney transplant, is a potentially avoidable consequence of the consumption of raw milk. The real-life stories viewable on <http://www.realrawmilkfacts.com/> are a sobering reminder of the potential consequences of raw milk consumption. It is essential that if this practice is allowed to continue in New Zealand, those choosing to drink raw milk, and those who sell or provide it to others, are fully aware of the ‘high stakes’, and information for consumers, both for and against this practice, is provided in an appropriate way.

## Acknowledgement

The authors would like to thank Dr Tanya Soboleva, MPI, Food Science and Risk Assessment group, for her helpful comments on this manuscript.

## References

- Amagliani G, Petruzzelli A, Omiccioli E, Tonucci F, Magnani M, Brandi G.** Microbiological surveillance of a bovine raw milk farm through multiplex real-time PCR. *Foodborne Pathogens and Disease* 9, 406-411, 2012
- Anon.** Committee on Infectious Diseases and Committee on Nutrition. Consumption of raw or unpasteurized milk and milk products by pregnant women and children. *Pediatrics* 133, 175-179, 2014
- Barrett NJ.** Communicable disease associated with milk and dairy products in England and Wales: 1983-1984. *J Infect* 12, 265-272, 1986

<sup>8</sup> <http://www.stuff.co.nz/nelson-mail/news/9883233/Raw-milk-contamination-was-down-to-human-error>

- Baylis CL.** Raw milk and raw milk cheeses as vehicles for infection by Verocytotoxin-producing *Escherichia coli*. *International Journal of Dairy Technology* 62, 293-307, 2009
- Bianchi DM, Barbaro A, Gallina S, Vitale N, Chiavacci L, Caramelli M, Decastelli L.** Monitoring of foodborne pathogenic bacteria in vending machine raw milk in Piedmont, Italy. *Food Control* 32, 435-439, 2013
- Bianchini V, Borella L, Benedetti V, Parisi A, Miccolupo A, Santoro E, Recordati C, Luini M.** Prevalence in bulk tank milk and epidemiology of *Campylobacter jejuni* in dairy herds in Northern Italy. *Appl Environ Microbiol* 80, 1832-1837, 2014
- Blowey R, Edmondson P.** *Mastitis control in dairy herds*. (CABI Publishing, 2010)
- Braun-Fahrlander C, von Mutius E.** Can farm milk consumption prevent allergic diseases? *Clinical and experimental allergy :Journal of the British Society for Allergy and Clinical Immunology* 41, 29-35, 2011
- Buncic S, Avery SM.** *Escherichia coli* O157:H7 in healthy dairy cows. *New Zealand Veterinary Journal* 45, 45-48, 1997
- Buzby JC, Hannah Gould L, Kendall ME, Jones TF, Robinson T, Blayney DP.** Characteristics of Consumers of Unpasteurized Milk in the United States. *Journal of Consumer Affairs*, 2013
- Clark R, Fenwick S, Nicol C, Marchant R, Swanney S, Gill J, Holmes J, Leyland M, Davies P.** Salmonella Brandenburg-emergence of a new strain affecting stock and humans in the South Island of New Zealand. *New Zealand Veterinary Journal* 52, 26-36, 2004
- Denny J, Bhat M, Eckmann K.** Outbreak of *Escherichia coli* O157: H7 associated with raw milk consumption in the Pacific Northwest. *Foodborne Pathogens and Disease* 5, 321-328, 2008
- Douwes J, Brooks C, Pearce N.** Protective effects of farming on allergies and asthma: have we learnt anything since 1873? *Expert Review of Clinical Immunology* 5, 213-219, 2009
- Douwes J, Cheng S, Travier N, Cohet C, Niesink A, McKenzie J, Cunningham C, Le Gros G, von Mutius E, Pearce N.** Farm exposure in utero may protect against asthma, hay fever and eczema. *The European Respiratory Journal* 32, 603-611, 2008
- Douwes J, Travier N, Huang K, Cheng S, McKenzie J, Le Gros G, von Mutius E, Pearce N.** Lifelong farm exposure may strongly reduce the risk of asthma in adults. *Allergy* 62, 1158-1165, 2007
- Elmoslemany AM, Keefe G, Dohoo I, Wichtel J, Stryhn H, Dingwell R.** The association between bulk tank milk analysis for raw milk quality and on-farm management practices. *Preventive Veterinary Medicine* 95, 32, 2010
- Fahey T, Morgan D, Gunneburg C, Adak GK, Majid F, Kaczmarek E.** An Outbreak of *Campylobacter jejuni* Enteritis Associated with Failed Milk Pasteurization. *Journal of Infection*. 31, 137-143, 1995
- French N, Marshall J.** Final Report: Source attribution October 2011 to December 2012 of human *Campylobacter jejuni* cases from the Manawatu., Massey University, 2012
- Galbraith NS, Forbes P, Clifford C.** Communicable disease associated with milk and dairy products in England and Wales 1951-80. *British Medical Journal (Clinical research ed.)* 284, 1761-1765, 1982
- Galton D, Petersson L, Merrill W.** Effects of premilking udder preparation practices on bacterial counts in milk and on teats. *Journal of Dairy Science* 69, 260-266, 1986
- Galton D, Petersson L, Merrill W, Bandler D, Shuster D.** Effects of premilking udder preparation on bacterial population, sediment, and iodine residue in milk. *Journal of Dairy Science* 67, 2580-2589, 1984

- 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, 461-468, 2003
- Grinberg A, Pomroy W, Weston J, Ayanegui-Alcerreca A, Knight D.** The occurrence of *Cryptosporidium parvum*, *Campylobacter* and *Salmonella* in newborn dairy calves in the Manawatu region of New Zealand. *New Zealand Veterinary Journal* 53, 315-320, 2005
- Guh A, Phan Q, Randall N, Purviance K, Milardo E, Kinney S, Mshar P, Kasacek W, Cartter M.** Outbreak of *Escherichia coli* O157 associated with raw milk, Connecticut, 2008. *Clinical Infectious Diseases* 51, 1411-1417, 2010
- Havelaar AH, van Pelt W, Ang CW, Wagenaar JA, van Putten JP, Gross U, Newell DG.** Immunity to *Campylobacter*: its role in risk assessment and epidemiology. *Critical Reviews in Microbiology* 35, 1-22, 2009
- Hill B, Smythe B, Lindsay D, Shepherd J.** Microbiology of raw milk in New Zealand. *International Journal of Food Microbiology*, 2012
- Irshad H, Cookson A, Hotter G, Besser T, On S, French N.** Epidemiology of Shiga toxin-producing *Escherichia coli* O157 in very young calves in the North Island of New Zealand. *New Zealand Veterinary Journal* 60, 21-26, 2012
- Jay-Russell M. T.** Raw (Unpasteurized) Milk: Are Health-Conscious Consumers Making an Unhealthy Choice? *Clinical Infectious Diseases* 51, 1418-1419, 2010
- Keene WE, Hedberg K, Herriott DE, Hancock DD, McKay RW, Barrett TJ, Fleming DW.** A prolonged outbreak of *Escherichia coli* O157: H7 infections caused by commercially distributed raw milk. *Journal of Infectious Diseases* 176, 815-818, 1997
- Langer AJ, Ayers T, Grass J, Lynch M, Angulo FJ, Mahon BE.** Nonpasteurized dairy products, disease outbreaks, and state laws-United States, 1993-2006. *Emerging Infectious Diseases* 18, 385-391, 2012
- LeJeune JT, Rajala-Schultz PJ.** Unpasteurized milk: a continued public health threat. *Clinical Infectious Diseases* 48, 93-100, 2009
- Lluis A, Depner M, Gaugler B, Saas P, Casaca VI, Raedler D, Michel S, Tost J, Liu J, Genuneit J, Pfefferle P, Roponen M, Weber J, Braun-Fahrlander C, Riedler J, Lauener R, Vuitton DA, Dalphin JC, Pekkanen J, von Mutius E, Schaub B.** Increased regulatory T-cell numbers are associated with farm milk exposure and lower atopic sensitization and asthma in childhood. *The Journal of Allergy and Clinical Immunology* 133, 551-559 e510, 2014
- Macdonald LE, Brett J, Kelton D, Majowicz SE, Snedeker K, Sargeant JM.** A systematic review and meta-analysis of the effects of pasteurization on milk vitamins, and evidence for raw milk consumption and other health-related outcomes. *Journal of Food Protection* 74, 1814-1832, 2011
- McFadden A, Owen K, McIntyre L, L B.** Spatial and temporal trends of salmonellosis in dairy cattle in New Zealand 2007-2010. Technical Report for the Ministry for Primary Industries and Fonterra. 2012
- Moriarty E, Sinton L, Mackenzie M, Karki N, Wood D.** A survey of enteric bacteria and protozoans in fresh bovine faeces on New Zealand dairy farms. *Journal of Applied Microbiology*. 105, 2015-2025, 2008
- Ning P, Guo K, Cheng L, Xu L, Zhang C, Cui H, Cheng Y, Xu R, Liu W, Lv Q.** Pilot survey of raw whole milk in China for *Listeria monocytogenes* using PCR. *Food Control* 31, 176-179, 2013
- Oliver SP, Boor KJ, Murphy SC, Murinda SE.** Food safety hazards associated with consumption of raw milk. *Foodborne Pathogens and Disease* 6, 793-806, 2009
- Pankey J.** Premilking udder hygiene. *Journal of Dairy Science* 72, 1308-1312, 1989

- Rapp D, Ross CM, Cave V, Muirhead RW.** Prevalence, concentration and genotypes of *Campylobacter jejuni* in faeces from dairy herds managed in farm systems with or without housing. *Journal of Applied Microbiology* 116, 1035-1043, 2014
- Rapp D, Ross CM, Pleydell EJ, Muirhead RW.** Differences in the fecal concentration and genetic diversity of *Campylobacter jejuni* populations among individual cows in two dairy herds. *Applied and Environmental Microbiology*, 2012
- Riedler J, Braun-Fahrlander C, Eder W, Schreuer M, Waser M, Maisch S, Carr D, Schierl R, Nowak D, von Mutius E.** Exposure to farming in early life and development of asthma and allergy: a cross-sectional survey. *Lancet* 358, 1129-1133, 2001
- Ruusunen M, Salonen M, Pulkkinen H, Huuskonen M, Hellstrom S, Revez J, Hanninen ML, Fredriksson-Ahomaa M, Lindstrom M.** Pathogenic bacteria in Finnish bulk tank milk. *Foodborne Pathogens and Disease* 10, 99-106, 2013
- Scavia G, Escher M, Baldinelli F, Pecoraro C, Caprioli A.** Consumption of unpasteurized milk as a risk factor for hemolytic uremic syndrome in Italian children. *Clinical Infectious Diseases* 48, 1637-1638, 2009
- Sharp J.** Infections associated with milk and dairy products in Europe and North America, 1980-85. *Bulletin of the World Health Organization* 65, 397, 1987
- Signs KA, Stobierski MG, Gandhi TN.** Q Fever Cluster Among Raw Milk Drinkers, Michigan, 2011. *Clinical Infectious Diseases*, 2012
- Sockett PN.** Communicable disease associated with milk and dairy products: England and Wales 1987-1989. *CDR (London, England : Review)* 1, R9-12, 1991
- Stevenson M.** A case definition for acute salmonellosis in dairy herds in New Zealand. *New Zealand Veterinary Journal* 60, 263-263, 2012
- 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, 2822-2830, 2004
- Waser M, Michels KB, Bieli C, Floistrup H, Pershagen G, von Mutius E, Ege M, Riedler J, Schram-Bijkerk D, Brunekreef B, van Hage M, Lauener R, Braun-Fahrlander C.** Inverse association of farm milk consumption with asthma and allergy in rural and suburban populations across Europe. *Clinical and experimental allergy : Journal of the British Society for Allergy and Clinical Immunology* 37, 661-670, 2007

## Appendix

The following algorithm was used to assess evidence for raw milk-associated outbreaks in New Zealand:

1. **Suggestive:** consumption of raw milk was recorded as a contributing factor
2. **Medium:** meets the criteria for weak above AND the nature of the clustering of cases in space and/or time was consistent with transmission from raw milk (for example cases report purchasing the raw milk from the same supplier and in the same week)
3. **Strong:** EITHER
  - a. Meets the criteria for medium above AND the pathogen was identified from an implicated raw milk sample taken during the incubation period of at least one of the outbreak cases, OR
  - b. Meets the criteria for medium above AND the identical specific strain of the pathogen from human cases was identified in at least 75% of human cases AND has a milk-producing animal reservoir with a probability of at least 60%. Strain here may mean multilocus sequence type or phage type or other within-pathogen species differentiation methods.
4. **Very strong:** meets the criteria for 3b above AND the identical specific strain of the pathogen from human cases with a milk-animal source was identified in an implicated raw milk sample taken during the incubation period of at least one of the outbreak cases. Strain here may mean multi-locus sequence type or phage type of other within species differentiation methods.

