

Epidemiological investigations of salmonellosis in New Zealand dairy herds, 2011–2012

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Introduction

On 19 December 2011 the New Zealand Ministry of Agriculture and Forestry (MAF) reported that the National Animal Health Information Surveillance programme had detected a change in the pattern of diagnosis of salmonellosis in dairy cattle in New Zealand. The change was evidenced by an increase in the incidence of uncommonly reported *Salmonella* serotypes in cattle and a moderate increase in laboratory case counts for *Salmonella* spp. in cattle (Anonymous 2011).

To deal with what appeared to be an emerging disease syndrome in New Zealand dairy cattle, a liaison group was formed in early January 2012 comprised of representatives from MAF, the Dairy Companies Association of New Zealand, dairy veterinarians, the New Zealand Veterinary Association and Massey University. The mandate of this group was to coordinate activities related to learning more about the epidemiology of the disease in New Zealand dairy cattle and development of evidence-based control strategies. This paper provides an outline of the investigational approach taken to achieve the group's objectives and a qualitative summary and interpretation of the key findings to date.

Background

In cattle salmonellosis can vary from an asymptomatic carrier state through to clinical disease characterised by severe diarrhoea, toxæmia, and fever (Radostits *et al.* 2007). Infected animals excrete organisms and infect other animals, directly or indirectly by contamination of the environment, particularly via feed and water supplies.

Salmonellae are facultative intracellular organisms that survive in the phagolysosome of macrophages. As a result, they can evade the bactericidal effects of antibody and complement. Persistence of infection in carrier animals is therefore an important epidemiological feature of the disease. Unlike *S. dublin*, where animals can persist in the carrier state for extended periods of time (years) the carrier state for *S. typhimurium* is relatively short, lasting up to 10 weeks. The portal of infection is almost always oral so the severity of the disease in an individual or group depends on how heavily the environment is contaminated as well as conditions of temperature and dryness that determine bacterial survival time.

The pH of rumen contents has been shown to affect the number of salmonellae surviving passage through the rumen into the abomasum and small intestine. A high volatile fatty acid content and low pH, such as that which occurs when an animal is on full feed, provides unfavourable conditions for salmonellae to pass through the fore stomachs. Conversely, as rumen pH increases salmonellae have been shown to grow more vigorously (Mattila *et al.* 1988, Bender *et al.* 1997).

Except in the newborn, infection with *Salmonella spp.* is usually not a sufficient cause of clinical disease. The response to infection with a *Salmonella sp.* varies depending on the size of the challenge dose and the immunological status of the animal, itself dependent on previous exposure to infection and the presence of stressors.

Investigational approach

The sequence of steps that have been taken to resolve this problem at the population level follow closely those that would be taken when carrying out an epidemiological investigation of any infectious and non-infectious disease outbreak. The reader is referred to Kelsey *et al.* (2006) for a comprehensive review of outbreak investigation methods.

Do we have a problem?

A number of data sources provided evidence that the incidence and severity of salmonellosis in New Zealand dairy cattle had increased between 2009 and 2011.

Laboratory data from the Institute of Environmental Science and Research Ltd (ESR, Wallaceville) showed an increase in the incidence of unusual *Salmonella* serotypes in cattle and an increase in the number of laboratory submissions for *Salmonella* typing from cattle (Figure 1). In addition, MAF's Investigation and Diagnostic Centre (IDC, Wallaceville) received a number of reports from veterinarians between 2009 and 2011 regarding outbreaks of salmonellosis in adult dairy cattle where mortality was a feature. Several case studies describing these unusual outbreak presentations were also reported in the literature (Cullwick 2009, Teague 2011).

During the first six months of the 2011 milking season, four Taranaki dairy practitioners reported 16 laboratory confirmed (herd) outbreaks of salmonellosis among a client base comprised of approximately 1600 dairy herds. Prior to 2009, each practitioner estimated that their practice diagnosed, on average, two cases of salmonellosis every five years.

The presence of similar indicators of a change in disease frequency from at least three independent information sources (Stevenson *et al.* 2007) provided sufficient evidence to conclude that in 2011 the frequency of salmonellosis had changed and that an 'outbreak' situation did, in fact, exist.

Case definition

Given the large number of individuals contributing information used to better understand the epidemiological behaviour of this disease (herd managers, veterinarians), uniformity in the criteria used to identify affected herds is important. Use of a common case definition allows for standardisation of cases both within a single outbreak investigation and between outbreak investigations that differ over time and/or geographic location. The following herd-level case definition for salmonellosis in dairy cattle was proposed in a letter to the Editor of the New Zealand Veterinary Journal in March 2012 (Stevenson *et al.* 2012).

The clinical description includes acute onset of diarrhoea and debility affecting more than 5% of the milking herd over a 10-14 day period. In affected animals there is initially high fever (rectal temperature 40-41°C) that subsides with the onset of diarrhoea. Diarrhoea is severe and accompanied occasionally by dysentery and tenesmus. The crude mortality rate in affected herds is less than 2%.

The laboratory criteria for diagnosis include isolation of *S. typhimurium*, *S. mbandaka*, and/or *S. bovismorbificans* from faecal samples from clinical cases.

The case classification for a probable case herd is a herd with clinical signs consistent with those listed above; for a confirmed case herd is a herd meeting the prescribed clinical description and laboratory criteria for diagnosis.

Descriptive studies

A description of some of the key features of the epidemiology of salmonellosis in New Zealand dairy herds was provided by a MAF-Fonterra funded cross-sectional study that was carried out in December 2011 and January 2012 (McFadden *et al.* 2012).

In this study the target population comprised all dairy cattle herds in New Zealand with the study group limited to dairy herds that supplied raw milk to Fonterra (Auckland, New Zealand). A web based questionnaire was developed and made available to Fonterra suppliers for the period 21 December 2011 to 30 January 2012. Herd

managers were asked to provide details relating to salmonella outbreaks in dairy livestock, the estimated costs of outbreaks and effects on people associated with the herd in which outbreaks occurred. A key point is that the cases reported in this study were herd manager diagnoses and did not make use of the case definition cited above.

The response fraction was 14% (1337 completed surveys from 10,500 Fonterra suppliers). Of the 1337 herd managers that responded 174 (13%) indicated that they had experienced one or more outbreaks of salmonellosis between 2007 and 2011. Sixty five of 1337 (5%) indicated that they had had outbreaks of salmonellosis in multiple years.

In all stock classes a progressive increase in the incidence of disease was evident over time (Figure 2). Within a given year the greatest number of outbreaks occurred in cows and calves during the late winter and early spring. There was no obvious peak in outbreaks in young stock, although the number of outbreaks occurring in this stock class was low.

Prior to 2009 the median within-herd morbidity risk in affected herds was 0.5 (Q1 0.3, Q3 1.4) cases per 100 cows. For 2009, 2010 and 2011 the median within-herd morbidity risk increased to 1.7 (Q1 0.4, Q3 14) cases per 100 cows.

Analytical studies

Taranaki case-control study

Concurrent to the Fonterra cross-sectional study a case-control study designed to identify herd-level risk factors for salmonellosis was carried out in December 2011. Here, cases comprised the 16 dairy herds (laboratory) confirmed as salmonella-positive by the four Taranaki dairy practitioners. Eligible controls were dairy herds that received a visit by a veterinarian from the same practice on the day before the index salmonella visit to each case herd. Two controls were selected per case ($n=32$).

Between 19 December and 23 December 2011 herd managers of case and control herds were contacted by telephone and asked if they would consent to participating in the study. All of those who could be contacted by telephone ($n=16$ cases and $n=16$ controls) agreed to take part. A questionnaire comprised of 43 questions requesting details of herd demographics, nutritional management (amount and type of feeds offered, including mineral supplements) and effluent management was then administered.

Of the fourteen herd-level factors that were assessed, three were significantly associated with the risk being salmonella positive: (1) use of supplementary feeds apart from palm kernel meal (e.g. wheat bran, kibbled maize, biscuit meal); (2) use of a pelletised mineral supplement containing magnesium oxide; and (3) home mixing mineral supplements (as opposed to mineral supplements being pre-mixed with concentrate feeds by a feed compounder). Our interpretations of the study findings are as follows:

- The increased risk of disease associated with the use of supplementary feeds apart from palm kernel meal might be explained by a greater likelihood of feeds of this type being contaminated with *Salmonella spp.* during transport and/or storage. Starchy, carbohydrate rich feeds such as wheat bran, kibbled maize and biscuit meal are attractive to birds and rodents (more so than palm kernel meal) so faecal contamination of these materials is likely to be common.
- The increased risk of disease associated with home mixing of minerals and use of a pelletised formulation of mineral supplement point to dietary magnesium (and particularly this formulation of magnesium) playing a causal role in this outbreak. To the best of our knowledge this association has not been previously reported in the peer-reviewed literature although high magnesium oxide inclusion rates were identified as a risk factor for disease in a similar outbreak that occurred in Victoria, Australia in the early 1990's (Morton 1993) and in 1999 an outbreak of salmonellosis in a dairy herd arising from high magnesium oxide inclusion rates was reported by Thurston (1999). As mentioned earlier, rumen pH influences the number of salmonellae surviving passage through the rumen (Mattila *et al.* 1988, Bender *et al.* 1997). A plausible hypothesis is that relatively high levels of dietary magnesium oxide increase rumen-gut pH, making it easier for salmonellae to proliferate and then trigger disease.

Although the Taranaki case-control study provided useful information, its limited geographic extent and the relatively small number of case herds available for analysis meant that only those risk factors that were strongly associated with the outcome could be detected. To address this issue and to confirm the study findings, a

nationwide case-control study funded by MAF, Fonterra and the Society of Dairy Cattle Veterinarians of the New Zealand Veterinary Association was instigated in April 2011.

National case-control study

Case herds for the national case-control study were identified using responses to the Fonterra cross-sectional study. Fifty five dairy herds from the Fonterra cross-sectional study met the criteria to be defined as cases in 2011.

Because it was of interest to rule out the presence of spatial clustering of disease, control herds were selected to ensure that their spatial distribution matched the spatial distribution of the underlying dairy herd population at risk using Generalised Random Tessellation Stratified (GRTS) methods (Stevens and Olsen 2004). Assuming the control response rate to a mail-out questionnaire would be in the order of 20% and to ensure that we would have at least one control for every case, 407 control herds were selected from the Fonterra supplier data frame.

The questionnaire developed for the Taranaki case-control study was revised to solicit more detailed information about supplementary feeds, in particular how they are stored on farm, how they are delivered to stock, and how minerals are measured and mixed with supplementary feed components. For case herds, herd managers were asked to provide details of the outbreak that occurred in their herd, including the number of animals that developed clinical signs on each day of the outbreak.

Administration of the nationwide case-control study was carried out by the Fonterra Service Team, a group of eight individuals based in Hamilton whose routine tasks are to manage milk quality and compliance issues on farm. Questionnaires were mailed out to the managers of case and control herds during the second week of April 2012. At the time of writing, approximately 60 case and control questionnaires have been returned to Fonterra Service Team staff.

Conclusions

Much has been learnt about the epidemiology of salmonellosis over a relatively short period of time and we anticipate that the national case-control study will provide information that will allow us to make more specific interventions to reduce the incidence of disease. At this stage our inferences, based on a review of the relevant literature and findings from the studies conducted to date, are as follows:

- Supplementary feeds need to be stored and handled appropriately to reduce the likelihood of faecal contamination from birds and rodents. This recommendation applies to feed importers, feed compounders as well as dairy herd managers.
- Both the amount and formulation of magnesium used on-farm appears to play a role in the aetiology of this syndrome. We stress that magnesium supplementation is necessary for pasture based dairy herds and that herd managers should talk to their veterinarian, farm adviser and/or nutritionist about appropriate mineral formulations and inclusion rates, particularly if supplementary feeds are used.
- Of particular note is that the manufacturer of the pelletised mineral supplement withdrew the product from the market promptly in response to the Taranaki case-control study findings and has since carried out a program of rigorous product re-development. In this regard, the New Zealand salmonella outbreak provides a great example of clinicians, researchers, industry and government working together to solve problems and improve herd productivity.

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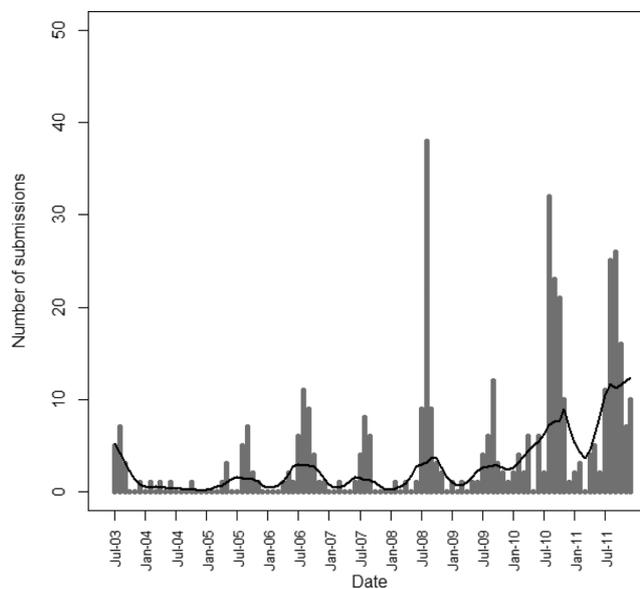


Figure 1. Frequency histogram showing monthly counts of laboratory submissions for salmonellosis as a function of calendar time, July 2003 to December 2011. Superimposed is a lowess smoothed plot fitted to the monthly submission counts. Source: Ministry of Agriculture and Forestry

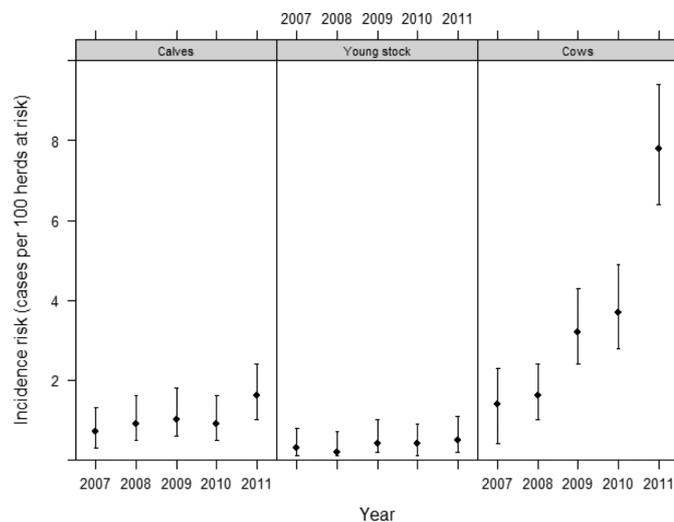


Figure 2. Trellis plot showing the incidence risk of salmonellosis (and their 95% confidence intervals), 2007 to 2011 for calves, young stock and cows. Source: McFadden et al. (2012).