Risk factors for acute salmonellosis in dairy herds: A case-control study in New Zealand 2011–12

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On 19 December 2011, the Ministry for Primary Industries (MPI) reported that the National Animal Health Information Surveillance programme had detected a change in the pattern of diagnosis of salmonellosis in dairy cattle, 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 infectious disease syndrome in New Zealand dairy cattle, a liaison group was formed in early January 2012 comprising representatives from MPI, the Dairy Companies Association of New Zealand, dairy veterinarians, NZVA and Massey University. The mandate of this group was to coordinate investigations into the epidemiology of the disease in New Zealand dairy cattle and the development of evidence-based control strategies. This article describes the main activity carried out by the liaison group in 2012, a case-control study to identify herd-level risk factors for acute salmonellosis.

Methods

Data for the study were collected between 1 April and 30 June 2012. Case herds were those where the herd manager reported clinical signs consistent with the case definition of acute salmonellosis (Stevenson, 2012) and where the date of onset of clinical signs in the index animal occurred between 1 July 2011 and 31 March 2012.

A set of controls (Kelsey et al, 1986) was selected from a sampling frame comprising dairy herd suppliers to the Fonterra Dairy Co-operative for the season starting on 1 July 2011. A questionnaire requesting details of herd demographics, nutritional management (amount and type of feeds offered, including mineral supplements and the storage of feed ingredients) and effluent management was modified from a pilot case-control study that had been carried out in Taranaki in December 2011 (Stevenson et al, 2012). The time frame of interest for questions relating to the use of supplementary feeds and effluent management was October 2011. We reasoned that asking questions about how individual herds were managed at this (important) stage of the production cycle (peak lactation) would minimise the impact of recall bias due to the unavoidable delay between the timing of the exposures that were being asked about and administration of the questionnaire.

Analyses were undertaken to identify explanatory variables associated with a herd being salmonella positive. To select those explanatory variables that best explained the probability of a herd's salmonella status, a logistic regression modelling approach was used. This allowed us to quantify the influence of explanatory variables on salmonella risk, adjusted for the presence of known confounding variables in the data.

Results

Data from 43 case and 79 control herds were available for analysis, a ratio of 1:1.8. For case herds, the median onset date was 4 October 2011. The range was from 1 July to 15 December 2011.

Median herd size, the number of full-time equivalent staff per 100 cows and stocking rate were all numerically greater in case herds compared with controls, but the differences among groups were not significant at the alpha level of 0.05. Expected average total lactation milksolids yield per cow was significantly greater in case herds compared with controls (t test statistic 2.35; $df = 116$; $p = 0.02$).

In the logistic regression analysis, three variables were statistically significant and remained in the final model: use of continuous troughs, use of magnesium supplementation in a pelletised form and use of palm kernel meal. The odds of using palm kernel meal were 8.7 (95% CI 2.5 to 30) times greater in case herds compared with controls. The odds of using magnesium supplementation in a pelletised form were 10 (95% CI 3.3 to 33) times greater in case herds compared with controls. The odds of using continuous troughs were 6.2 (95% CI 2.0 to 20) times greater in case herds compared with controls.

Discussion

With continuous troughs, several cows have access to feed at a single point in time whereas with individual feed troughs (as the name suggests) access is for single cows. Compared with controls, case herds were more likely to use continuous feed troughs (OR 6.2, 95% CI 2.0 to 20). With continuous troughs, it is likely that the amount of supplementary feed consumed by individual cows will vary, with dominant cows consuming more than their allotted daily feed allowance and submissive cows consuming less. Fluctuations in supplementary feed intake could therefore affect the balance of rumen microflora, allowing salmonella to multiply and trigger clinical disease. In a study comparing dairy herds with low and high within-herd incidence risks of salmonellosis in Victoria, Australia, Morton (Morton, 1993) showed that odds of using continuous troughs were greater in herds with a high incidence of salmonellosis cases compared with those with a low incidence. The biological plausibility of the association reported in our study and the consistency of our findings with those of Morton (1993) indicate that systems that provide better control over individual cow feed intakes (such as individual troughs) should assist in reducing the risk of acute salmonellosis on dairy farms. An additional benefit of this approach is that it is likely to reduce the likelihood of other, feed-related problems in intensively managed dairy herds such as clinical and subclinical rumenal acidosis.

Most herd managers who responded to the questionnaire (88 of 122, 72%) indicated that their herds were supplemented with magnesium during the first two weeks of

October 2011. Ninety-two percent (113 of 122) said they routinely used magnesium either as prills, pellets, as a loose mix or in the drinking water throughout the milking season. We found no significant association between the use of magnesium in the form of prills, powder or in the drinking water and salmonella risk. In the multivariable model, the odds of using pelletised magnesium supplements were 10 times greater in case herds compared with controls (OR 10, 95% CI 3.3 to 33). Similar findings were again reported by Morton (1993). In that study, however, magnesium oxide (a fine powder) was the only form of magnesium supplementation used. A marked dose-response effect was identified, with herds with a high individual animal incidence of salmonellosis being more likely to have inclusion rates of 20 grams per cow per day or greater compared with low-incidence herds.

The strong association between a herd being salmonella-positive and the use of pelletised magnesium supplementation is a novel finding. Selection bias might have been important if an unusually large proportion of those who responded to the initial cross-sectional study (from which case herds were identified) were pelletised magnesium users. This situation could have arisen if herd managers believed that by responding to the questionnaire they might have been eligible for some form of compensation. Our argument against this as being the sole explanation for the findings reported here is that in a pilot case-control study carried out in Taranaki in December 2011 using 16 case herds identified by the four veterinary practitioners mentioned earlier and 16 controls (Stevenson et al, 2012) a strong association between herd salmonella status and pelletised magnesium use was also found. The key issue with the Taranaki study was that the practitioners were from four veterinary practices that serviced the majority of dairy herds in the region and, as a result, one can be reasonably confident that the 16 cases of salmonellosis represented most (if not all) incident cases of disease that occurred in the region during the period 1 July and 1 December 2011.

It is likely that the true association between pelletised magnesium use and salmonella risk may have been actually greater than that reported in this study.

Bias arising from differential misclassification was a potential problem (as it is with many case-control studies) because herd managers of case herds were likely to have a different level of recall of past exposures compared with managers of control herds (Dwyer et al, 1998). To reduce the impact of this, our approach was to focus questioning on peak lactation, an important time of the year (Blake, 2010). We reasoned that recall of the feeding regime at peak lactation would have been better compared with the alternative, which was to ask specific questions about ration components in the month (say) before the date of onset. It should be noted that some case herds with an onset date before October 2011 had used pelletised magnesium earlier in the season but had stopped using it by 1 October. The impact of this on our results was to bias the association between pelletised magnesium use and salmonella risk towards the null. This being the case, it is likely that the true association between pelletised magnesium use and salmonella risk may have been actually greater than that reported in this study.

Confounding was a second, non-causal explanation for our findings. Herd production level was the only obvious contender here, with high-producing herds having a greater risk of being salmonella positive, high-producing herds being more likely to be pelletised magnesium users, and the physiologic mechanism of each of these effects on the risk of disease operating on two separate causal pathways. Inclusion of a term in the multivariable model to account for herd production produced no significant change in the strength of association between pelletised magnesium use and salmonella risk, effectively ruling out herd production as an important confounder.

If pelletised magnesium is causally associated with salmonella risk, the precise physiological mechanism by which this occurs is, at present, unknown. The pH of the rumen contents has been shown to affect the number of salmonellae surviving passage through the rumen into the abomasum and small intestine.

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A high rumen volatile fatty acid content and low pH, such as that which occurs when an animal is on full feed, provides unfavourable

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conditions for salmonellae to pass through the fore stomachs. Magnesium oxide and lime flour (the main constituents of the leading brand of pelletised magnesium supplement in our study) is a rumen alkalinising agent and it has been shown that as rumen pH increases salmonellae grow more vigorously (Mattila et al, 1988; Bender et al, 1997). The leading brand of pelletised magnesium was known to be poorly soluble in the digestive tract and this property may have had an influence on the growth of salmonellae within the rumen, even though the absolute quantity of magnesium fed might have been within recommended daily requirements. The manufacturer of the leading brand of pelletised magnesium supplement withdrew their product from the market in response to the findings reported in the pilot case-control study carried out in Taranaki in December 2011 (Stevenson et al, 2012). Assuming a causal association between pelletised magnesium supplement use and salmonella risk then, the population attributable fractions estimated for pelletised magnesium indicate that the expected reduction in the incidence of acute salmonellosis during the 2012–13 milking season should be in the order of 22% (95% CI 8% to 31%).

The odds of using palm kernel meal as a supplement in case herds were 8.7 (95% CI 2.5 to 30) times that of controls. This finding could be the result of one of two scenarios:

1. palm kernel meal is a vehicle by which salmonella organisms are introduced onto previously uninfected farms; or
2. palm kernel meal may be a proxy variable representing more intensively managed herds and the risk of disease was greater in more intensively managed herds rather than entirely due to palm kernel meal use alone.

Supplementary feeds used on dairy farms (regardless of type) need to be stored and handled appropriately to reduce the likelihood of contamination, typically from birds and rodents.

Mixing the most commonly used pelletised magnesium supplement with palm kernel meal improved its flow through feed delivery equipment on farm. We quantified the association between the use of palm kernel meal as a supplement and use of pelletised magnesium and found no significant association (OR 1.7, 95% CI 0.70 to 4.4). An interaction term was developed to test the hypothesis that the use of palm kernel meal and pelletised magnesium supplementation increased the risk of salmonellosis beyond that expected from addition of the estimated risks arising from the two factors working alone. The interaction term was not significant at the alpha level of 0.05 and inclusion of the term provided little improvement to overall model fit.

Conclusions

Supplementary feed use and the way supplementary feed delivery methods were delivered to cattle on-farm were risk factors for acute salmonellosis in New Zealand dairy farms in 2011–12. We conclude that supplementary feeds used on dairy farms (regardless of type) need to be stored and handled appropriately to reduce the likelihood of contamination, typically from birds and rodents. This recommendation applies to all involved in provision of supplementary feeds to dairy cattle: those sourcing commodity feeds off shore, feed transporters, feed compounders and dairy herd managers. The formulation of magnesium supplementation used on-farm appears to play a role in the aetiology of this syndrome. While magnesium supplementation continues to be necessary for pasture-based dairy herds, we recommend that herd managers should seek advice from their veterinarian, farm adviser or nutritionist about appropriate mineral formulations and inclusion rates, particularly if supplementary feeds are used. ■

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