PROSPECTS FOR SALMONELLA CONTROL IN CATTLE

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Salmonella infections appear to be increasing in animals and humans at a time in history when many other infectious diseases are being satisfactorily controlled (1). There have been large and well publicized outbreaks of human salmonellosis (2-5), and an increase in the number of isolations reported from both animals (6) and humans (7). While there are over 2200 serotypes of Salmonella recognized, the good news is that 5 or 6 serotypes consistently cause most of the problem in cattle. These serotypes are S. typhimurium, S. dublin, S. newport, S. montevideo, and S. anatum. A recent survey employing serologic methods found that over 70% of dairies in California had evidence of Salmonella infection (8). In order to examine the prospects for control of Salmonella in cattle, one must try to understand why this high prevalence rate of Salmonella infection exists.

Cattle have been bred for increasing production. Meat breeds now gain faster, more efficiently and at an earlier age than did previous generations, and dairy breeds produce much larger volumes of milk than did their ancestors. In California, the average Holstein now produces about 18,600 pounds (8454 kg) per 305 day lactation. To do this, each cow must consume huge amounts of high energy and high protein feeds. So much is demanded metabolically that many cows lose a considerable amount of body condition during peak lactation, mobilizing fat reserves to meet energy demands. The highest producing cows are on a tightrope, with ketosis and fatty liver ready to push them toward anorexia and illness if the *slightest upset in feed intake occurs*. Being an opportunistic infection, Salmonella can take advantage of a loss of competitive gut flora and depressed immune function to proliferate, resulting in clinical disease. Outbreaks of Salmonella diarrhea in adult dairy cows frequently involve the highest producing fresh cows, as well as the cows with a displaced abomasum or other significant problem.

S. dublin is a cause of abortion in adult cattle (9,10) and septicemia in calves under 10 weeks of age (9). Outbreaks of Salmonella diarrhea and/or septicemia frequently involve calves (9) with other concurrent diseases (such as rotavirus or cryptosporidiosis), illustrating again how salmonellosis takes advantage of weakened animals and deranged gut flora. If the challenge dose of a virulent Salmonella is large enough, salmonellosis may occur as a primary disease in seemingly healthy cattle.

But what is the source of Salmonella which infects these cattle? Although the number of control points is relatively great (Fig. 1), probably 3 main sources of Salmonella can be blamed. (1) The first is rodents and birds (11,12) which bring in Salmonella from outside sources or which act to maintain infection on premises and to vector the organism into cattle feed, (2) the second is contaminated feed sources (13,14), especially high moisture commodities in which Salmonella readily multiply after contamination during manufacture or by birds, rodents, or equipment, and (3) the third is infected cattle, either asymptomatic carrier cattle or ill and recovering animals, which magnify the number of Salmonella in the environment (9,15). Carriers are especially important for the host adapted serotype S. dublin (9). Almost all isolates of S. dublin come from cattle. One asymptomatic carrier cow can shed over 10 billion S. dublin per day (10^6 per gram of feces x 10 kg. feces) in the environment (16). Mice and rats may also be infected with S. dublin and need to be eradicated as part of the control program (12).

Carrier cows may also be infected in the mammary gland and infect calves (or humans) via milk (16). Cattle with clinical disease shed tremendous numbers of organisms into the environment, and must be carefully isolated to a hospital area. It therefore follows that any prospects for control of Salmonella must include attention to these aspects, plus good general sanitation on the farm.

When feeds are contaminated by rodents, birds or equipment, multiplication of Salmonella in areas of high moisture (>5%) occurs (14). Even feeds which come Salmonella-free from the manufacturer/renderer are prone to recontamination (13,14). The industry-wide incidence of by product

recontamination for poultry renderers in the U.S. in 1989 was 49% (17). In 1991, 21% of samples from United States renderers and 51% of samples from protein blenders were positive for Salmonella (13). The United States government is currently exploring adoption of a zero tolerance for Salmonella in animal feeds (14).

Reduction of Salmonella in feeds is possible by use of organic acids (18). Elimination of Salmonella from feeds will probably require high temperature pelleting or irradiation, together with dehydration to reduce moisture content below 5% and proper handling to prevent wetting and recontamination (14,19). In a recent paper the FDA states, "There appear to be no remaining technical barriers to the goal of achieving Salmonella free feed" (14). Production of Salmonella free animals is possible. When Salmonella free turkeys were placed in clean premises and a closed flock produced, 3 generations of turkeys over 4 years remained free of infection. When Salmonella was isolated from premises and birds after 4 years, 90% of all isolates were of serotypes first found in the feed (20).

Identification and removal of chronic S. dublin carriers is an important step in controlling this serotype (9,16,21,22,23). Any purchased herd replacements or bulls must be checked serologically and by culture. Culture is necessary to prevent introduction of recently infected animals which are not yet seropositive. A 3 week quarantine of new stock pending results of tests should be mandatory. To examine a herd for carriers, milk or serum from lactating cows and serum from dry cows and young stock should be tested for IgG ELISA antibodies directed against S. dublin lipopolysaccharide (LPS) antigen (22,23,24). Animals positive on the initial screening are considered suspects, because a single seropositive test may be a result of Salmonella vaccination, recent infection followed by recovery, or may indicate carrier status. To determine whether it indicates carrier status, a second titer is determined at least 60 days after the initial test date. Virulent infections may result in titers that persist for up to 140 days. Carriers remain persistently seropositive, whereas the other categories become seronegative (22,23,24). Because S. dublin is the host adapted serotype, it should be the most readily controlled of the 10 most frequently isolated Salmonella serotypes. According to the National Veterinary Services Laboratory, S. dublin (plus nonmotile group D1 Salmonella) make up 24% of all Salmonella isolated from cattle in 1991 (25). In California, S. dublin has accounted for 49% to 79% a year of all Salmonella isolations from cattle between 1985 and 1991 (26). There are strong indications that nonmotile group D1 Salmonella from cattle are really S. dublin which are not expressing flagella. Selection for spontaneous motility in semisolid media yields S. dublin (Stocker BAD and Smith BP, unpublished observations).

Serotesting can also be used to detect herd and individual infections by Salmonella serotypes other than S. dublin. While many of the 2200 existing serotypes of Salmonella may result in infection in cattle, only a few serotypes (serogroup in parenthesis) seem to do this consistently, namely S. dublin (D1), S. typhimurium (B), S. newport (C2) and S. montevideo (C1). These four serotypes account for almost all of the isolates causing disease in California. Others making the U.S. top 10 list include S. cerro (K), S. anatum (E1), S. enteritidis (D1), and S. agona (B).

Thus, in California, we can use a screening antigen containing LPS from 4 common serotypes to detect infection on a large farm. Once an animal is found to be persistently seropositive (and thus worthy of culling or isolation), serology using individual antigens can be used to determine the serogroup infecting that individual. The prospects for Salmonella control have improved with the development of sensitive and specific ELISA techniques. These tests are not yet commercially available, but requests for testing can be made by contacting the author.

Figure 1 gives a schematic look at some of the critical control points for Salmonella on a dairy. Many of the principles also apply to feedlots or other confinement facilities. By applying sound management practices and good sanitation with the specific controls, prevention of clinical salmonellosis and reduction of infection rate should be feasible. Specific control point recommendations include:

1. Serotesting of all cattle and culling carriers.
2. Purchased replacement stock should be serotested, cultured, and quarantined.
3. Feed only Salmonella free feeds. New FDA rules will require testing of feeds to demonstrate that no Salmonella are present. Each manager should request written assurances from his feed supplier

that they have met this level of quality assurance. Use proper storage to prevent wetting, spoilage, and contamination by animals or equipment. Loaders used for feed should not be used to move manure or dead animals.

4. Isolate sick cows and calves to minimize herd exposure.
5. Avoid wet areas, provide dry areas such as free stalls for loafing, and clean and disinfect calf pens and maternity area between calves.
6. If flush water is used, use only "clean" wash water from the milking parlor. Do not use recycled lagoon water.
7. Use bait stations to control rodents. Wild birds are much more difficult to control. Request help from local experts.
8. Rendering trucks and other vehicles which may be contaminated or carry infectious material should not be allowed on the farm near animals or feed. Dead animals should be placed at a site away from animals and feed so that they can be picked up easily. Front-end loaders used for dead animals or manure should not be used for feed.
9. Avoid overuse and routine or prophylactic use of antimicrobials, as this promotes bacterial resistance and may harm competitive gut flora, predisposing to Salmonella infection.
10. On dairies with clinical salmonellosis, vaccinate dry cows with a killed Salmonella bacterin specific for the serotype isolated.

Existing killed vaccines[a] have limited efficacy against salmonellosis. First, the serologic response is short lived, lasting only a few weeks (23,24). Second, the protection to the calf against Salmonella offered by passive colostral antibody is minimal, lasts only about 3 weeks, and can be relatively easily overcome by a large or virulent challenge (27). There is some evidence that use of a nonspecific vaccine which induces production of antibodies directed against gram-negative common core antigens will decrease severity of clinical salmonellosis and increase survival (28). Modified live Salmonella vaccines, while still experimental, generally induce a greater degree of protection than do killed vaccines (29-32). Vaccines should probably be used to decrease clinical illness only in the initial phases of a control program. Once the prevalence of Salmonella is sufficiently reduced and reintroduction of infection controlled, vaccination with formalin killed bacterins is unlikely to be cost effective, and it makes interpretation of serology more difficult. Adverse reactions to killed Salmonella bacterins can result in death. It appears that these reactions are not dependent on having received prior doses of vaccine (they frequently occur on the first dose), are much more likely to be severe if cattle are vaccinated in hot weather, and are most likely due to free endotoxin (bacterial lipopolysaccharide) in the vaccine (33). These adverse reactions to vaccination can occur with any gram-negative bacterial vaccine. For these reasons Salmonella vaccines should be administered only in cool or moderate weather and other gram-negative vaccines such as E. coli bacterins or Brucella abortus live vaccine should not be administered at the same time. Although not directly relevant to on farm animal health, reduction of Salmonella in meat for human consumption also requires that trucks used to ship cattle to slaughter be cleaned and disinfected, that slaughter houses use rigid sanitation, and that sensitive monitoring for contamination be applied to finished products.

Salmonella is so widespread that it cannot be eradicated, but it can certainly be controlled. We can most easily control the host-adapted serotype, S. dublin, by identifying and culling carriers. Next, we can go after the other serotypes most commonly isolated from cattle, simultaneously removing carriers, improving pest control, and improving farm sanitation. And finally, we can control the introduction of other exotic serotypes onto the farm by addressing feed-borne Salmonella. To do so will require rethinking the way in which we house and handle livestock and livestock feeds. We must stop recycling Salmonella from byproduct to animal feed back to animal.

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[a]S. dublin-S. typhimurium bacterin, Colorado Serum Co., Denver CO 80216.

Figure 1. Critical Control Points in Controlling Salmonella in Cattle

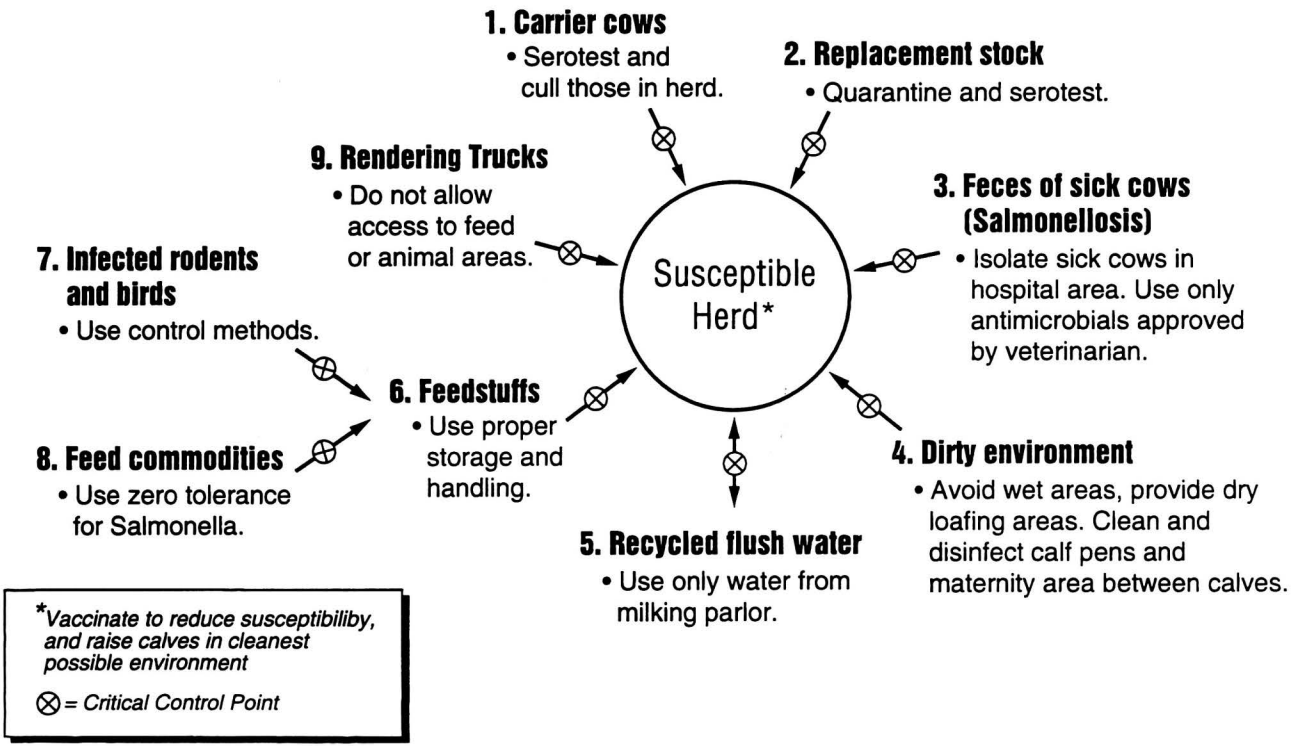


Figure 2 MEAN SERUM IgG ELISA TITERS OF SALMONELLA MAMMARY CARRIERS (■) AND UNINFECTED CONTROL COWS (•)

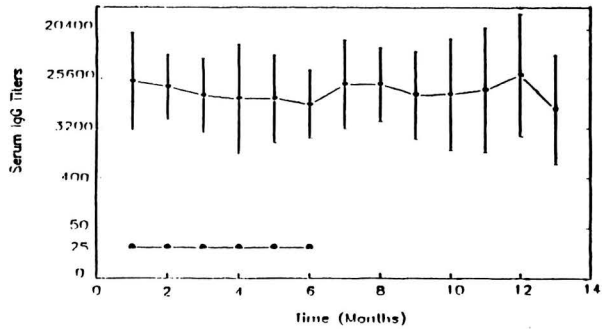


Figure 3 MEAN SERUM IgG ELISA TITERS OF FECAL CARRIERS

plus and minus two standard errors of the mean

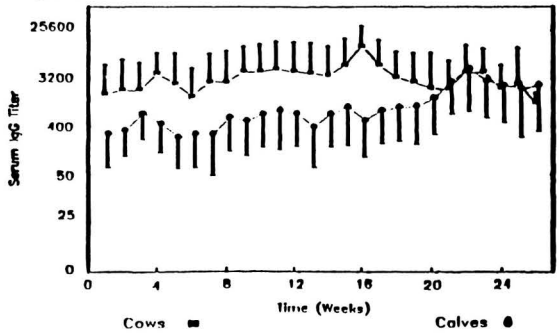
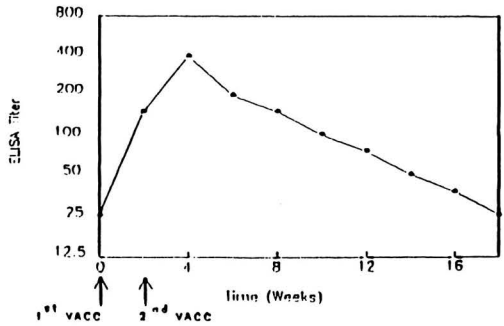


Figure 4 MEAN SERUM IgG ELISA RESPONSE OF COWS VACCINATED WITH KILLED SALMONELLA BACTERIN



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Summary

Prospects for control of Salmonella in cattle are now better than ever due to the development of serologic testing procedures capable of identifying S. dublin carriers, and to the recent interest by regulatory agencies in monitoring animal feeds to ensure that the feeds are free of Salmonella. Steps necessary to control Salmonella in cattle include serotesting and culling carriers, purchasing only sero tested replacement stock, feeding salmonella free feeds, controlling rodents and birds, isolating sick cows, maintaining a clean dry environment, using only clean flush water on dairies, keeping contaminated vehicles such as renderers trucks away from animal and feed areas, and using vaccination initially to help lower the incidence of clinical disease. Salmonella cannot be eradicated, but its impact on livestock and human health can certainly be controlled.