Use of an individual-based stochastic modeling approach to assess the impact of an imperfect vaccine on a small dairy herd: a case study of Salmonella cerro infection

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Salmonella spp. are a leading cause of bacterial foodborne disease for humans. Infections in cattle with Salmonella also have the potential to cause foodborne disease. Vaccines have been applied as a control measure to reduce the prevalence of *Salmonella* in dairy herds. Here we use Salmonella vaccination as a model for bacterial vaccines in dairy herds. For a small herd, the stochastic effect on the dynamics of infection may be large as fadeout of infection cannot be properly accounted for by a deterministic modeling approach. Typically, *Salmonella* vaccines are imperfect, i.e., their effectiveness wanes over time. Also, multiple vaccine effects such as a reduction in susceptibility, a reduction in the degree of infectiousness (a lower shedding level), and a shortening of the duration of the infectious period may simultaneously exist. In this study, we applied an individual-based stochastic modeling approach to a small US dairy herd to analyze the stochastic effects and fadeout of infection. In this stochastic model, multiple effects of imperfect *Salmonella* vaccines were explicitly considered. To assess the effectiveness of imperfect *Salmonella* vaccines with a simulated vaccination program, we studied the impact of *Salmonella* vaccines on the basic reproduction ratio, infection fadeout, and persistence. We also performed global parameter uncertainty and sensitivity analyses to identify key parameters for efficiently preventing *Salmonella* infection. Our results show that (1) prevalence of *Salmonella* in a small herd has a large variance due to the random events; (2) prevalence decreases and the chance of fadeout increases when *Salmonella* vaccines are applied; (3) control of *Salmonella* using vaccines depends on the particular vaccine effect of the vaccine under consideration and maybe different at different stages of a Salmonella outbreak (endemic vs epidemic).