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Economic aspects of Q fever control in dairy goats

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ABSTRACT

This paper presents an economic analysis of Q fever control strategies in dairy goat herds in The Netherlands. Evaluated control strategies involved vaccination strategies (being either preventive or reactive) and reactive non-vaccination strategies (i.e., culling or breeding prohibition). Reactive strategies were initiated after PCR positive bulk tank milk or after an abortion storm (abortion percentage in the herd of 5% or more). Preventive vaccination eradicates Q fever in a herd on average within 2 and 7 years (depending on breeding style and vaccination strategy). Economic outcomes reveal that preventive vaccination is always the preferred Q fever control strategy on infected farms and this even holds for a partial analysis if only on-farm costs and benefits are accounted for and human health costs are ignored. Averted human health costs depend to a large extend on the number of infected human cases per infected farm or animal. Much is yet unknown with respect to goat–human transmission rates. When the pathogen is absent in both livestock and farm environment then the “freedom of Q fever disease” is achieved. This would enable a return to non-vaccinated herds but more insight is required with respect to the mechanisms and probability of re-infection.

1. Introduction

Q fever is a zoonotic disease caused by the bacterium *Coxiella burnetii* wereby infected pregnant animals shed *C. burnetii* bacteria around partus and abortion. Sheep, goats, and cattle are the primary reservoirs although a variety of other species may be infected as well. The most common signs of Q fever in sheep, goats and cattle are abortion during late pregnancy or weak offspring (Arricau-Bouvery and Rodolakis, 2005). However, most infections are subclinical (OIE, 2010). Q fever is transmissible to humans. Infection of humans usually occurs by inhalation of bacteria from air that contains airborne barnyard dust contaminated by dried placental material, birth fluids, and excreta of infected animals (Arricau-Bouvery and Rodolakis, 2005). Q fever has become a major public health concern in the Netherlands, with a peak of notified human Q fever cases in 2009 (Schimmer et al., 2009; Hoek et al., 2010). Abortion waves on dairy goat farms were the primary source of infection for humans living in proximity to positive farms (Hoek et al., 2010). Q fever became notifiable in The Netherlands for small ruminants kept for milk production in June 2008 (Roest et al., 2011). It seems that the epidemic is under control from 2012 onwards as a result of the mix of implemented control strategies (Van Asseldonk et al., 2013b). First a stringent hygiene protocol was made mandatory for all professional dairy goat and dairy sheep farms. In 2008, a voluntary vaccination campaign started that became mandatory in high risk areas in 2009. In addition, a transport ban of animals and a visitor ban was issued for all Q fever positive farms. From December 2009 up to 2010 all pregnant goats and sheep were culled on Q fever positive farms (Hogerwerf et al., 2011; Roest et al., 2011). A breeding prohibition period on infected farms was enforced at farms with more than 50 dairy goats (or dairy sheep). From 2010 onwards vaccination is mandatory on dairy goat and dairy sheep farms with more than 50 animals and on petting zoos. Finally, a rigorous surveillance procedure is mandatory including bulk tank milk (BTM) monitoring based on PCR testing. If BTM tests are positive then more strict bio-security measures are enforced.

Economic impact studies of controlling the Q fever epidemic during 2007–2011 in the Netherlands revealed that costs were substantial, although the infected dairy goat sector is relatively small with approximately 300 specialised farms. In the study of Tem-

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pelman total estimated loss ranged between 161 million Euro and 336 million Euro (Tempelman et al., 2011). In the study of Morroy et al., (2012), the projected losses ranged from 250 million Euro to 600 million Euro. In the study of Van Asseldonk et al., (2013b), the loss was estimated to be approximately 307 million Euro. The difference between the studies mainly originates from the fact that Tempelman et al., (2011) accounted 67 up to 145 million Euro for lost quality of human life. Also Morroy et al., (2012) included the lost quality of life in monetary terms. These subjective assumptions were indirectly accounted for by Van Asseldonk et al. (2005) by means of a cost–utility approach (Van Asseldonk et al., 2013b).

All three studies on this Dutch outbreak conclude that whereas most of the long-term benefits of the implemented control program stem from reduced disease burden and human health costs, the majority of short-term intervention costs were incurred in the dairy goat sector. The Q fever outbreak has shown that it will pose a serious long-term burden on patients and society due to lasting chronic conditions in patients. The real impact of a zoonosis epidemic only becomes apparent when combining human health, societal and veterinary costs. Veterinary costs are immediate, apparent and proportionally small. Due to a gradual effects over a decade, human cost and societal implications are often underestimated. Finding the balance between economic livestock interests and human health remains a challenge when controlling epidemics of zoonotic diseases (Morroy et al., 2013).

The implemented intervention program entailed several components including culling of infected animals, vaccination and a breeding ban. As a result, the aforementioned economic assessments did not isolate the economic impact of each component. The reason for this is that the applied control approach during the epidemic was evolving more or less on an ad-hoc basis without relying on a detailed contingency plan designed in peace time. For example, at the start of the control program a registered vaccine for goats was not available, relying on off-label use of vaccine, of which insufficient dosages were available. Applying a simulation modelling approach of Q fever in a dairy goat herd will enable to evaluate alternative control strategies, being either different vaccination protocols, breeding bans or culling strategies.

The objective of the research was to evaluate the economic impact of different Q fever control strategies on on-farm costs and human health costs. This can contribute to the decision making process of policy makers in government and sector.

2. Material and methods

In the current research, the economic differences between the evaluated Q fever control strategies were estimated by means of a stochastic model. The within-herd transmission dynamics of Q fever in a goat herd was simulated by means of a stochastic SIRS model (Bontje et al., 2015). Outcomes of this model were used as input for the economical evaluation. In total 7 control strategies were evaluated, each under 3 different goat breeding strategies.

2.1. Impact assessment and control strategies

From a farmer's perspective, the rational of decreasing *Coxiella burnetii* prevalence in the dairy goat herd is to enhance production results. Therefor the on-farm impact is assessed by a partial budget model (Dijkhuizen and Morris, 1997) to account for decremental or incremental changes in cost or income. In addition, a complementary analysis is conducted to derive the minimum duration of disease free status necessary to set off on-farm control costs. However, for zoonotic infectious livestock diseases, as Q fever, the rational for society is to decrease the dual burden for animal and human health. If the decision has only monetary components, the intervention strategy with the highest net impact of the partial budget components should be preferred. However, preferences will be different and alternative control strategies might prevail if (human) life and death outcomes are involved. Within this dual decision framework, controversial other values related to public health need to be considered too (Van Asseldonk et al., 2013a). In the current analysis, we apply an efficiency frontier approach to quantify the set of dominating control strategies (Van Asseldonk et al., 2005; Hardaker et al., 2004) in terms of on-farm control costs and bacterial excretion level as an indicator of risk posing to humans. Moreover, a sensitivity analysis is conducted with respect to the rate of goat–human infection to link averted human health costs and on-farm costs per control strategy.

The impact of one preventive control strategy, five reactive control strategies and one strategy without control measures are analyzed for a time horizon of ten years. Given a preventive vaccination strategy (hence referred to as "Vacc_Prev") all animals in the herd including newly introduced animals are vaccinated. The two reactive vaccination strategies are initiated after PCR positive BTM ("Vacc_BTM") or after an abortion storm of unusual high abortion percentage of 5% or more ("Vacc_Abort"). In both strategies, vaccination is repeated every year onwards once triggered. For all vaccination strategies, an efficacy of 90% is assumed which means that nine out of ten animals are administered correctly and also will develop an effective immune response (Bontje et al., 2015). One non-vaccination strategy was based on a permanent breeding ban strategy for all animals present after a positive BTM test ("Breedingban_BTM"). Selective culling for any lactating infected animal detected with PCR ("Searchdestroy_BTM") is analyzed as an alternative non-vaccination strategy. Due to intermittent shedding of Q fever bacteria in milk a 50% probability of detection is assumed (Bontje et al., 2015). The testing of individual animals is annually repeated if BTM is found positive. The "Culling_Abort" strategy entailed that all remaining pregnant animals in the herd are culled instantly if at the start of the kidding season 5% or more of all conceived goats have aborted. New arrivals are postponed for one year and this culling strategy is repeated any year an abortion storm occurs. Within the "Nocontrol" strategy the disease runs its course without enforcing any intervention.

The effectiveness of any control strategy depends on the frequency of breeding since infected pregnant goats shed *C. burnetii* bacteria around partus. Milk production of dairy goats is (in contrary to dairy cows) persistent and as a result a wide range of breeding strategies is observed in Dutch dairy goat farming. At present, approximately 80% of the Dutch dairy goat farmers apply some kind of endurance milking strategy (Bekkers, 2010). An endurance milking strategy can be beneficial in dairy goat farming mainly because of reduced cost for raising kids. Therefore each control strategy is evaluated under three different breeding management styles. In all breeding management styles goats give their first birth at approximately 12 months of age. Subsequently, goats are bred every year onwards (hence referred to as breeding management style "Every year pregnant"), or less frequently. Either goats give birth on their odd years of age ("Every two years pregnant") or at one-year and two-years of age and not anymore at older age ("First two years pregnant").

3. Epidemiological simulation model

The current economic analysis is based on output of a SIR within-herd transmission model of Q fever in dairy goats which is described in detail by Bontje et al., (2015) and summarized in a flow diagram of the model (Fig. 1). Variables are mentioned in [squared brackets] and parameters in (parentheses). A goat can be susceptible, infected or recovered and pregnant or non-pregnant. These combinations lead to the following six state variables: susceptible non-pregnant