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Influence of husbandry and control measures on porcine circovirus type 2 (PCV-2) dynamics within a farrow-to-finish pig farm: A modelling approach

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ABSTRACT

We assessed, using a modelling approach, the influence of several management practices within a farrow-to-finish farm on the age of PCV-2 infection. The impact of PCV-2 vaccination with different vaccination schemes on infection dynamics, was also tested. A stochastic individual-based model describing the population dynamics in a typical French farrow-to-finish pig farm was built and coupled with an epidemiological model of PCV-2 infection. The parameters of the infectious model were mainly obtained from previous transmission experiments. Results were subjected to a survival analysis of time-to-infection. For each comparison, the reference situation was no vaccination followed by random mixing of piglets after birth and after weaning. The risk of early infection was significantly reduced when mixing of piglets was reduced at different stages (avoiding cross-fostering and grouping piglets by litters in small pens after weaning, hazard ratio (HR) = 0.52 [0.46; 0.59]). Sow-targeted vaccination delayed the infectious process until the waning of passive immunity and piglet-targeted vaccination considerably decreased the force of infection leading to a dramatic decrease of the total number of infections (HR = 0.44 [0.37; 0.54]). The effect was even more pronounced when strict management measures were applied (HR = 0.24 [0.19; 0.31]). Changing from a low (3%) prevalence of PCV-2-infected semen to a higher one (18%) significantly increased the risk of early infections (HR = 1.36 [1.2; 1.53]), whereas reducing replacement rate or changing sow housing from individual crates to group housing had a limited impact on PCV-2 dynamics.

1. Introduction

Porcine circovirus type 2 (PCV-2) is a small single-stranded DNA virus involved in Post-weaning Multi-systemic Wasting Syndrome (PMWS). This disease is of great economic importance in the majority of pig-producing countries throughout the world because of the increased mortality in severely affected farms and growth retardations in the case of sub-clinical infection. PCV-2 is also reported to be involved in other syndromes such as Porcine Dermatitis Nephritis Syndrome (PDNS) (Smith et al., 1993; Thompson et al., 2000; Wellenberg et al., 2004), Porcine Respiratory Disease Complex (PRDC) (Kim et al., 2003) and reproductive disorders (West et al., 1999; Pittman, 2008). PMWS was first described in the mid-90s in Canada. However, there is evidence that PCV-2 has been present in the field for at least two decades without any reported clinical consequences. Even if PCV-2 has been demonstrated as the aetiological agent of PMWS, additional factors seem to be necessary for clinical signs to develop. Epidemiological studies of risk factors for PMWS clearly evidenced the dynamics of PCV-2 infection in growing pigs as a pivotal event: the earlier the infection, the higher the risk (Rose et al., 2003, 2009; Lopez-Soria

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et al., 2005). Deviations in management procedures in the early life of growing pigs such as increased cross-fostering rate, mingling practices in nursery facilities or rearing pigs in large pens after weaning were identified as risk factors for PMWS and suggested that these conditions favoured pathogen transmission between pigs. Given the possible pseudo-vertical (semen-related) transmission of PCV-2 and the importance of passive immunity (Rose et al., 2007), cross-fostering practices were suspected to enhance PCV-2 transmission between litters with different immune status i.e., from an infected litter to a susceptible one without passive immunity. However, to the best of our knowledge, it has not been possible to assess the relationship between identified risk factors for PMWS and changes in PCV-2 course of infection from observational studies.

Given that PCV-2 has been widespread for decades, the reasons for disease emergence are still subject to debate. In the absence of evidence for an unknown but necessary triggering factor (agent 'X'), the only explanation for emergence of the syndrome is a sudden increase in early PCV-2 infections due to modifications in the course of PCV-2 infection at the herd-level. Although different PCV-2 genotypes, with possibly different pathogenicities, have been distinguished recently (Opriessnig et al., 2006; Grau-Roma et al., 2008), a clear demonstration of strain-related virulence is lacking. This suggests that emergence of the syndrome may be due to a sudden modification in the PCV-2 course of infection i.e., it may not necessarily involve a different strain but simply be due to an increased entry of virus within the herd or to a modification in the structure of the pig population that affects virus dynamics.

PCV-2 commercial vaccines (sow- or piglet-targeted) are now becoming available throughout the world. These are based on two different principles: vaccination of the sows with inactivated viral particles to protect *via* passive immunity transfer or active immunisation of young piglets with subunit or inactivated chimeric virus. Some reports have attested the efficacy of such vaccines for PMWS and maybe other PCV-2-related problems (Kixmöller et al., 2008; Opriessnig et al., 2008a). However these field observations have concerned the economic and efficacy effects on PMWS and, to the best of our knowledge, the impact of vaccination on PCV-2 dynamics under different management procedures has not been studied.

Modifications of rearing conditions, as a consequence of economic pressures and the implementation of prophylactic measures may change the epidemiology of PCV-2 infection in pig farrow-to-finish farms. By reproducing the complex system of population dynamics subjected to an infectious process, modelling studies can provide useful information about such interactions. Most pig production models were developed to study the impact of reproductive performances (Allen and Stewart, 1983; Singh, 1986) or replacement policies (Jalvingh et al., 1992; Plà et al., 2003) on economic parameters (tools for decision makers). Only a few models representing the population dynamics of pig production systems have been developed to study the process of within-herd infection with pig pathogens (Jorgensen, 2000; Lurette et al., 2007). In these studies, the animal dynamics were represented on a population-averaged basis which is inappropriate to the PCV-2 situation due to the importance of the dam-related infectious process: vertical or pseudo-vertical transmission and passive immunity intake (Ostanello et al., 2005; Park et al., 2005; Rose et al., 2007). Due to these characteristics of PCV-2 infection, the population dynamics in this model needs to be represented on an individual basis.

The aim of this work was therefore to study the influence of several husbandry practices on PCV-2 course of infection. A stochastic individual-based model describing the population dynamics in a typical farrow-to-finish farm coupled with an epidemiological model of PCV-2 infection was used to study the impact of different management policies on the course of PCV-2 infection. The epidemiological model of PCV-2 infection was built in accordance with the literature data and most of the parameters were estimated from experimental transmission trials. Factors that could influence PCV-2 dynamics were divided into different categories: (i) rearing conditions, (ii) control strategies for PCV-2 and (iii) events experienced by the herd. The impact of the different strategies on the age at which individuals become infected was studied because this is known to be a major risk factor for PMWS (Rose et al., 2009).

2. Materials and methods

2.1. Population dynamics model

A stochastic individual-based model was developed to describe population dynamics within a farrow-to-finish pig farm. This population model was built using a discrete-time simulation approach and has already been described in detail (Andraud et al., 2009a). Briefly, the herd is managed according to a 3-week batch-farrowing procedure with a 28-day lactation length and the farm is divided into one gestating, 2 farrowing-lactating, 3 nursery, and 5 fattening facilities. The durations of the gestation period and weaning-to-oestrus interval are set at 114 and 5 days, respectively. The basic production unit is the female pig and the entire herd structure is based on the sows' reproductive cycles (service, gestation, lactation, weaning, service). Eight 180-day-old gilts are introduced into the herd every 42 days and distributed between the two successive batches. These introductions avoid excessive herd ageing, so that the herd stays at a fixed size with a stable parity balance. The gilts are kept in an acclimatisation unit until sexual maturity which occurs between 210 and 240 days. Their cycles are then artificially synchronized with the batches they are due to join. After the first insemination, they are considered as nulliparous sows until first parturition. After conception, the sows are kept in individual crates in the gestating room. One week before the farrowing date, they are moved to the farrowing facilities where they are kept throughout the 28-day lactation period. After weaning, the piglets are transferred to a post-weaning room and grouped in pens until 86 days old when they are taken to the fattening facilities.

Individuals are subjected to events, such as death, culling of sows or pregnancy failure, with a daily time-step. The probabilities of event occurrence are defined as input