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Monitoring breeding herd production data to detect PRRSV outbreaks

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ABSTRACT

Porcine reproductive and respiratory syndrome virus (PRRSv) causes substantial economic impact due to significant losses in productivity. Thus, measuring changes in farm productivity before and after PRRS infection enables quantifying the production and economic impact of outbreaks. This study assessed the application of exponentially weighted moving average (EWMA), a statistical process control method, on selected production data (number of abortions, pre-weaning mortality rate and prenatal losses) to supplement PRRS surveillance programs by detecting significant deviations on productivity in a production system with 55,000 sows in 14 breed-to-wean herds in Minnesota, U.S.A. Weekly data from diagnostic monitoring program (available through the Morrison's Swine Health Monitoring Project) implemented on the same herds was used as reference for PRRS status. The time-to-detect, percentage of early detection of PRRSv-associated productivity deviations, and relative sensitivity and specificity of the production data monitoring system were determined relative to the MSHMP. The time-to-detect deviations on productivity associated with PRRS outbreaks using the EWMA method was −4 to −1 weeks (interquartile range) for the number of abortions, 0–0 for preweaning mortality and −1 to 3 weeks for prenatal losses compared to the date it was reported in the MSHMP database. Overall, the models had high relative sensitivity (range 85.7–100%) and specificity (range 98.5%–99.6%) when comparing to the changes in PRRS status reported in the MSHMP database. In summary, the use of systematic data monitoring showed a high concordance compared to the MSHMP-reported outbreaks indicating that on-farm staff and veterinary oversight were efficient to detect PRRSv, but can be more efficient if they were monitoring closely the frequency of abortions. The systematic monitoring of production indicators using EWMA offers opportunity to standardize and semi-automate the detection of deviations on productivity associated with PRRS infection, offering opportunity to early detect outbreaks and/or to quantify the production losses attributed to PRRS infection.

1. Introduction

Porcine reproductive and respiratory syndrome (PRRS) was first reported in the USA swine industry in 1989 (Keffaber, 1989) and remains a challenge causing substantial economic losses due to significant changes in productivity parameters (Holtkamp et al., 2013). Although the apparent incidence in breeding herds has declined in recent years (Morrison et al., 2015), the prevalence continues to increase over time (SHMP, 2017), which may be related to increasing attempts to control rather than eliminate PRRS from breeding herds.

One of the objectives of ongoing surveillance of livestock operations is to early detect pathogen introduction allowing rapid response by implementing measures to control the infection and/or prevent spread to other sites (Salman, 2013). Conventional PRRS monitoring systems include routine diagnostic testing for PRRSv nucleic acid (by PCR based assays) and/or for anti-PRRSv-antibodies (by serology) using biological samples including serum samples (Dewey and Straw, 2006) or oral fluids (Prickett et al., 2008). Efficient surveillance enabling early detection of PRRS in breeding herds may contribute to reduce PRRS incidence by adopting practices to prevent direct and or indirect transmission to other herds at risk.

Since PRRSv infection in breeding herds is characterized by significant changes in productivity including increased abortions, preweaning mortality and neonatal losses, measuring significant deviations in production records would enable assessing the production and economic impact (De Vries and Reneau, 2010). The applicability of monitoring production indicators or animal behavior has been described as a proxy of animal health or disorder (Weary et al., 2009).

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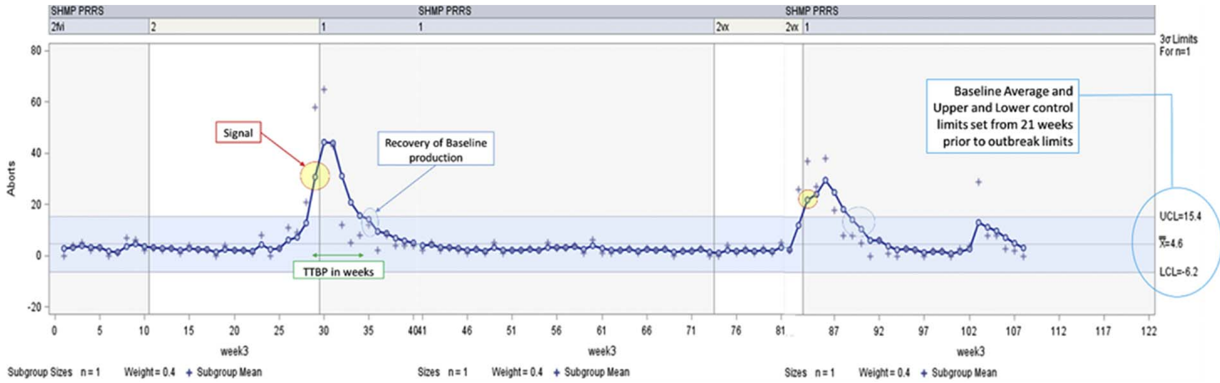

Fig. 1. Example of detecting significant deviation in abortions and change in PRRS status over time. The change of PRRS status over time is described on the top section of the figure: status 2fvi means stable breeding herds with ongoing field virus inoculation, 2 means stable herds and 2vx means stable herds with ongoing exposure of breeding females to a modified live virus vaccine. Changes to status 1 means that the herd had a PRRS outbreak. A signal represents a point of the smoothed line (blue) out of the upper control limit. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Statistical process control (SPC) charts are widely used to evaluate variations in industrial processes (Montgomery, 2009), health-care and public-health surveillance (Woodall and Tech, 2006). Within agriculture, they have been described for dairy production (de Vries and Conlin, 2003; Lukas et al., 2005; Reneau and Kinsel, 2001). There is still only a limited number of reports of applying SPC tools to swine herds to measure production losses due to diseases (Cornou et al., 2008; Engler et al., 2009) and some of these applications were based on simulation data (Kirchner et al., 2006; Krieter et al., 2009). Thus, the implementation of SPC can provide helpful orientation to managers by monitoring the patterns of production and potential disease outbreaks.

The objective of this study was to assess the feasibility of systematically monitoring key production indicators using a SPC method to detect PRRS outbreaks in breed-to-wean pig herds. Furthermore, we assessed the effectiveness of SPC to detect of PRRSv outbreaks in relation to the MSHMP, a voluntary disease reporting program that monitors changes in PRRS status in US breeding herds.

2. Material and methods

2.1. Study design

This was a retrospective observational study that used selected key production indicators and pre-defined SPC analysis to detect significant deviations from herd-specific baseline. Deviations (signals) were compared to herd PRRS status by week, which was based on routine diagnostic monitoring. We described the relative sensitivity, specificity and time-to-detect outbreaks using a SPC method, as compared to documented PRRS outbreaks reported to the MSHMP.

2.2. PRRSv status, eligibility criteria and source population

The Morrison's Swine Health Monitoring Project (MSHMP) is a network of U.S.A. swine producers. MSHMP represents a convenience sample of 910 sow herds including a total of approximately 2.3 million sows. Veterinarians represent each herd and voluntarily report diagnostic status for PRRSV and PEDV on a weekly basis (Goede and Morrison, 2016; Tousignant et al., 2015). Diagnostic records were not audited and veterinarians' reports were considered correct. This included the diagnosis of PRRSV and the status of the herd for the disease following herd classification guidelines described previously (Holtkamp et al., 2011). According to MSHMP, a PRRS outbreak is confirmed by positive PCR and virus isolation, which is required after farmers detected signals suggesting virus circulation (e.g. clinical signs, production data or routine monitoring).

To address our objective, we sought production system from the MSHMP system fulfilling the following eligibility criteria: (a) availability of weekly PRRS and PED status; (b) willingness of producer to share weekly production data; (c) continuous breed-to-wean operation; (d) herd having at least 21 weeks with no PRRS and PED outbreak to create baseline References

A production system with 55,000 sows consisting of 14 breeding herds located in Minnesota, US was enrolled in the study. The weekly production data was extracted from a commercial record keeping system (PigCHAMP 4.5.4, PigCHAMP Inc, Ames, IA). The final database had 108 weeks per herd (1512 herd-weeks) and weekly PRRSV.

2.3. Production indicators

The parameters were selected based on the most common clinical signs on herds affected by PRRSV infection (Pozzi and Alborali, 2012; Zimmerman et al., 2012). More specifically, significant changes were monitored on a week basis for number of abortions, pre-weaning mortality rate (PWM) and prenatal losses (difference between 'total number of pigs born per litter' and 'number of pigs born alive per litter').

2.4. Statistical process control method

Exponentially weighted moving average (EWMA) was the SPC method selected to implement and measure the outcomes. The chart parameters were set with the intent to minimize false-alarm rate (high specificity) and detect large shifts, thus the sigma (σ) was set to 3 and smoothing parameter (λ) was set to 0.40. It is not the intention of the study evaluate different parameters to test is validity, and the chart parameters we test was already used (Goede et al., 2015; Krieter et al., 2009; Linhares et al., 2014). A chart example can be seen in Fig. 1. The models were implemented using Proc MACONTROL from SAS version 9.4 software (SAS Institute Inc., Cary, North Carolina).

2.5. Outcomes

The outcomes used to report effectiveness of SPC analysis compared to conventional routine diagnostic monitoring of PRRS included: percentage of early detection of PRRS outbreaks, time-to-detect (TTD) PRRSV outbreak and time to recover baseline production (TTBP). These outcomes were calculated for each production parameter in each herd monitored (n = 14) herd, and the median results, along with interquartile ranges are reported. Early detection was defined as detecting a significant SPC signal at least 1 week before a PRRS outbreak was recorded in the MSHMP database. TTD (also known as average time to signal (De Vries and Reneau, 2010)) was defined as the difference in weeks between the change of MSHMP PRRS status and the detection of a SPC signal. TTBP represented the number of weeks that the herd took