

# The effect of porcine epidemic diarrhea (PED) on ovarian function and reproductive performance after weaning in Berkshire sows

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Received: 27 June 2016 / Accepted: 23 February 2017 / Published online: 10 March 2017  
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**Abstract** The purpose of this study was to investigate the ovarian condition at weaning and subsequent reproductive performance of Berkshire sows following an outbreak of PED. This study was conducted on a farrow-to-finish farm that experienced a PED outbreak beginning on January 6, 2014. Blood samples were collected at weaning from 19 to 20 sows every month from July 2013 until July 2014 to investigate the ovarian condition. The mean progesterone concentration was numerically higher during January 2014 than the other months, but this difference was not significant. The mean estradiol-17 $\beta$  concentration was higher during January 2014 than during July and October 2013 ( $P < 0.05$ ). In addition, reproductive performance was compared during January, February, and March before (2013) and after (2014) the PED outbreak. Sows that farrowed in January had higher preweaning mortality in 2014 than in 2013 ( $P < 0.05$ ), but sows that farrowed in February and March had similar preweaning mortality in 2013 and 2014 ( $P > 0.10$ ). Sows that farrowed between January and March 2014 had 15% lower farrowing rate than those that farrowed during the same months in 2013 ( $P < 0.05$ ). In conclusion, our results demonstrate poorer

reproductive performance of Berkshire sows after a PED outbreak compared with before the outbreak.

**Keywords** Berkshire · Ovary · Porcine epidemic diarrhea · Reproductive performance

## Introduction

Porcine epidemic diarrhea (PED) is caused by a porcine coronavirus in the Coronaviridae family, a group of single-stranded, positive-sense RNA viruses (Saif et al. 2012). A global outbreak of PED began in 2013, and the disease has been reported in many countries around world. In Japan, the first case of PED to occur in Japan in 7 years was reported in October 2013 and PED then spread across the country. During the acute phase of a PED outbreak, the mortality rate of infected piglets is very high and may reach 100%. Reduction and/or loss of suckling stimulation from piglets during lactation strongly influence sow ovarian follicular development, which is associated with changes in reproductive hormone secretion (Langendijk et al. 2007). There has been only one published report investigating the relationship between PED and reproductive performance (Olanratmanee et al. 2010), and to our knowledge there have been no other investigations into the influence of piglet loss due to PED on the ovaries of the sow at weaning and her subsequent reproductive performance.

Kagoshima Prefecture, located on the southeastern coast of Kyushu Island, Japan, has extratropical climates and produces large amounts of pork in Japan. The traditional purebred Kagoshima Berkshire pig, which is a famous Japanese pork breed (sold under the trademarked name Kagoshima Kurobuta), was developed in Kagoshima from animals that originated in Berkshire county, England. Berkshire sows have

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a lower litter size and reduced fertility relative to the F<sub>1</sub> cross-bred animals that predominate on Japanese pig farms (Sasaki et al. 2014); thus, the loss of piglets due to the PED outbreak severely impacted the profitability of purebred Kagoshima Berkshire herds.

Thus, the aim of this study was to investigate the ovarian condition and subsequent reproductive performance of Kagoshima Berkshire sows following an outbreak of PED.

## Materials and Methods

All animal procedures were reviewed and approved by the Animal Experiment Care and Use Committee of the Kagoshima University, Kagoshima, Japan.

This study was conducted on an approximately 500-sow commercial farrow-to-finish farm having purebred Kagoshima Berkshire pigs in Kagoshima Prefecture, Japan. We conducted two separate studies: study 1 investigated the effect of the PED outbreak on sow ovarian condition at weaning, and study 2 investigated the effect of the PED outbreak on reproductive performance by comparing production variables before and after the outbreak. On the studied farm, the PED outbreak began in the gestation barn on January 6, 2014, and spread to the farrowing barn in January 9. Herd immunization was immediately performed using natural exposure methods; the intestines of infected piglets were obtained, ground, mixed well, and fed to the pregnant gilts and sows, weaned sows, and replacement gilts.

In study 1, 19 to 20 sows were randomly selected in each month from July 2013 to July 2014, which included the 6 months before and after the start of the PED outbreak, to collect blood samples at weaning (on average  $27.3 \pm 0.2$  days after parturition) from jugular venous. Serum concentrations of progesterone (secreted from functional corpora lutea (CL)) and estradiol-17 $\beta$  (secreted from large mature follicles) were measured by time-resolved fluoroimmunoassay (Tr-FIA) using a Tr-FIA kit (DELFLIA estradiol and progesterone kits; PerkinElmer Japan, Yokohama, Japan) as previously reported (Noguchi et al. 2007). The intra- and inter-assay CVs were 7.1 and 12.6% for estradiol-17 $\beta$  and 10.0 and 9.1% for progesterone, respectively. Functional CL or mature follicles were considered to be present if progesterone concentrations were greater than 5 ng/ml or estradiol-17 $\beta$  concentrations were greater than 10 pg/ml, respectively (Noguchi et al. 2010, 2011).

In study 2, data from after the PED outbreak began were collected from sows farrowed from January 6 until March 2014. To minimize potentially confounding seasonal effects on reproductive performance, the before-PED outbreak data were collected from January until March 2013 and compared for each month. In total, this study used reproductive data from 521 farrowing records and 658 mating records.

As statistical analysis, continuous data were analyzed using general linear mixed model and binomial data were analyzed using a mixed effects logistic regression model (SAS Institute Inc., Cary, NC, USA). In study 1, ovarian condition (progesterone and estradiol-17 $\beta$  concentrations), lactation length, and number of piglets weaned were compared by the month. In study 2, reproductive performance was compared by the month (January, February, or March), year (2013 or 2014), and the interaction between the month and year. In both studies, parity, lactation length, and number of piglets weaned were accordingly included in the model as a covariate and so was included as a random effect.

## Results

In study 1, the mean serum concentrations ( $\pm$ SEM) of progesterone and estradiol-17 $\beta$  were  $0.81 \pm 0.32$  ng/ml and  $2.04 \pm 0.43$  pg/ml, respectively. The percentages of sows with functional CL were 5% (1/20) in November and December 2013, 10% (2/20) in February 2014, and 15% (3/20) in January 2014, the first month of the PED outbreak. The percentages of sows with mature follicles were 5% (1/20) in February 2014 and 10% (2/20) in November and December 2013 and January 2014. The mean progesterone concentration during January 2014 was numerically higher than during the other months, but this difference was not significant (Table 1). In contrast, the estradiol-17 $\beta$  concentration during January 2014 was significantly higher than during July and October 2013 ( $P < 0.05$ ). There was no significant difference in lactation length between the months. The number of pigs weaned during January 2014 was significantly lower than during any of the other months studied ( $P < 0.05$ ).

In study 2, there were significant differences between years in preweaning mortality, number of piglets weaned, and farrowing rate ( $P < 0.05$ ; Table 2). In addition, the interaction between the year and month significantly affected preweaning mortality, number of piglets weaned, weaning-to-first mating interval, and farrowing rate ( $P < 0.05$ ; Table 2). In January, preweaning mortality was higher during 2014 than 2013 ( $P < 0.05$ ), but there were no between-year differences in February or March. The number of piglets weaned during January and February 2013 were higher than during the same months in 2014 ( $P < 0.05$ ). For each month from January to March, the farrowing rate in 2013 was higher than in 2014 ( $P < 0.05$ ).

## Discussion

Preweaning mortality was high during the month that PED occurred, reaching approximately 40%. This is consistent with values reported by Stevenson et al. (2013) and Carvajal et al.

**Table 1** Change of concentrations of progesterone and estradiol-17 $\beta$ , lactation length, and number of pigs weaned before and after porcine epidemic diarrhea (PED) outbreak

Month of weaning	Number	Progesterone concentration	Estradiol-17 $\beta$ concentration	Lactation length, day	Number of pigs weaned
Jul. 13	20	0.33 $\pm$ 0.03	0.53 $\pm$ 0.10b	27.9 $\pm$ 0.2	7.8 $\pm$ 0.3a
Aug. 13	19	0.29 $\pm$ 0.03	0.85 $\pm$ 0.08ab	26.7 $\pm$ 0.6	7.5 $\pm$ 0.1a
Sep. 13	20	0.29 $\pm$ 0.06	0.99 $\pm$ 0.11ab	28.2 $\pm$ 0.4	6.9 $\pm$ 0.3ab
Oct. 13	20	0.23 $\pm$ 0.04	0.79 $\pm$ 0.13b	27.8 $\pm$ 0.5	7.4 $\pm$ 0.3a
Nov. 13	20	1.01 $\pm$ 0.54	3.48 $\pm$ 0.99a	27.7 $\pm$ 0.5	6.7 $\pm$ 0.3ab
Dec. 13	20	1.40 $\pm$ 0.80	4.26 $\pm$ 1.35a	26.4 $\pm$ 0.6	5.8 $\pm$ 0.4ab
Jan. 14 (PED outbreak)	20	1.99 $\pm$ 0.95	3.16 $\pm$ 0.93a	27.0 $\pm$ 0.9	3.3 $\pm$ 0.4c
Feb. 14	20	2.23 $\pm$ 1.19	2.34 $\pm$ 0.63ab	26.8 $\pm$ 0.8	5.2 $\pm$ 0.7b
Mar. 14	20	0.45 $\pm$ 0.05	1.03 $\pm$ 0.26ab	25.7 $\pm$ 0.8	8.2 $\pm$ 0.5a
Apr. 14	20	0.47 $\pm$ 0.16	2.27 $\pm$ 0.27ab	27.4 $\pm$ 0.5	7.7 $\pm$ 0.3a
May 14	20	0.21 $\pm$ 0.03	1.22 $\pm$ 0.15ab	29.0 $\pm$ 1.1	7.4 $\pm$ 0.4a
Jun. 14	20	0.47 $\pm$ 0.11	2.11 $\pm$ 0.26ab	27.2 $\pm$ 0.4	7.9 $\pm$ 0.4a
Jul. 14	20	1.14 $\pm$ 0.19	3.48 $\pm$ 0.34a	27.4 $\pm$ 0.7	8.1 $\pm$ 0.3a

Values within a column without a common letter (a–c) were significantly different ( $P < 0.05$ )

(2015), although those reports were based on F<sub>1</sub> crossbred pigs. After the initial month of the PED outbreak, preweaning mortality returned to levels not significantly higher than before the outbreak. This result suggests that the response to the PED outbreak, including herd immunization, intensive cleaning, and disinfection, and early weaning programs effectively controlled the outbreak so that during the next few months the sows and their litters experienced low effects of PED. In contrast, monthly differences in farrowing rates before and after the PED outbreak were significant in January, February, and March. These results indicate that the PED outbreak negatively influenced sow fertility, an effect likely to

last for some time. Thus, it is necessary to monitor the sows that were infected with PED around the time of weaning and mating to avoid an increase in nonproductive days.

Our results showed that a higher proportion of sows had functional CL at weaning after the PED outbreak than before it. In addition, during January 2014, the month that the PED outbreak started, the percentages of sows that had ovulated (15%) or had mature follicles on their ovaries (10%) at weaning were both high compared to during the other months studied. Stimulation from suckling piglets suppresses follicular development, onset of estrus, and ovulation during lactation (Quesnel and Prunier 1995). Our results suggest that a

**Table 2** Comparisons of reproductive performance between 2013 (before PED outbreak) and 2014 (after PED outbreak) in January, February, and March

	All		January		February		March	
	N	Mean $\pm$ SEM	N	Mean $\pm$ SEM	N	Mean $\pm$ SEM	N	Mean $\pm$ SEM
Preweaning mortality, %								
2013 (before PED outbreak)	229	5.7 $\pm$ 1.0b	54	2.6 $\pm$ 1.0b	106	6.5 $\pm$ 1.6	69	6.8 $\pm$ 1.9
2014 (after PED outbreak)	265	19.0 $\pm$ 2.4a	97	37.6 $\pm$ 4.9a	63	6.0 $\pm$ 1.9	105	9.7 $\pm$ 3.3
Number of pigs weaned, pig								
2013 (before PED outbreak)	243	7.7 $\pm$ 0.1a	58	7.3 $\pm$ 0.2a	112	7.8 $\pm$ 0.2a	73	8.0 $\pm$ 0.3
2014 (after PED outbreak)	278	6.3 $\pm$ 0.2b	107	4.4 $\pm$ 0.3b	65	7.1 $\pm$ 0.4b	106	7.6 $\pm$ 0.2
Weaning-to-first mating interval, day								
2013 (before PED outbreak)	221	4.5 $\pm$ 0.4	51	4.0 $\pm$ 0.1b	112	4.0 $\pm$ 0.1	58	6.0 $\pm$ 1.6
2014 (after PED outbreak)	223	5.2 $\pm$ 0.6	106	6.4 $\pm$ 1.2a	59	4.1 $\pm$ 0.1	58	4.0 $\pm$ 0.1
Farrowing rate, %								
2013 (before PED outbreak)	302	79.8 $\pm$ 2.3a	85	78.8 $\pm$ 4.5a	74	78.4 $\pm$ 4.8a	143	81.1 $\pm$ 3.3a
2014 (after PED outbreak)	356	63.8 $\pm$ 2.6b	96	57.3 $\pm$ 5.1b	161	64.0 $\pm$ 3.8b	99	69.7 $\pm$ 4.6b

Means within year and month without a common letter (a–b) are significantly different ( $P < 0.05$ )

decrease in and/or lack of stimulation from suckling piglets, due the PED infection, increased the occurrence of large mature follicles and preweaning ovulation. In general, follicular development and maturation is associated with gonadotrophin (LH and FSH) stimulation. Estradiol-17 $\beta$  is secreted from mature follicles greater than 6 mm in diameter; follicles of this size are close to ovulation (Noguchi et al. 2010). In addition, low suckling stimulation may result in lactational estrus and extend the weaning-to-first mating interval; indeed, this period was longer in sows exposed to PED than in sows not exposed to PED. Normally, sows do not experience lactational ovulation because during lactation, the peripheral concentration and pulsatility of LH are suppressed due to suckling-induced inhibition of the GnRH-pulse generator (De Rensis et al. 1993) and also to the negative energy balance of the sow during lactation (van den Brand et al. 2000), both of which inhibit follicle growth and ovulation. However, when suckling intensity is reduced, follicle growth and ovulation can occur during lactation (Soede et al. 2011).

In conclusion, our results show that a PED outbreak led to poorer reproductive performance in Berkshire sows. These findings help to quantify the impact of PED infection in Japan and, ultimately, contribute to our knowledge of the cost-effectiveness of disease prevention and control measures.

**Acknowledgements** The authors gratefully thank the swine producers and staff for their cooperation for the project. This work was supported by JSPS KAKENHI Grant Number 26870454 and a grant from the Ito Kinen Foundation.

#### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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