Effect of Daily Fluctuations in Ambient Temperature on Reproductive Failure Traits of Landrace and Yorkshire Sows under Thai Tropical Environmental Conditions

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Abstract

The aim of this study was to determine the effects of daily ranges and maximum ambient temperatures, and other risk factors on reproductive failure of Landrace (L) and Yorkshire (Y) sows under open-house system in Thailand. Daily ambient temperatures were added to information on 35,579 litters from 5,929 L sows and 1,057 Y sows from three commercial herds. The average daily temperature ranges (ADT) and the average daily maximum temperatures (PEAK) in three gestation periods from the 35th day of gestation to parturition were classified. The considered reproductive failure traits were the occurrences of mummified fetuses (MM), stillborn piglets (STB), piglet death losses (PDL), and an indicator trait for number of piglets born alive below the population mean (LBA). A multiple logistic regression model included farrowing herd-year-season (HYS), breed group of sow (BG), parity group (PAR), number of total piglets born (NTB), ADT1, ADT2, ADT3, PEAK1, PEAK2, and PEAK3 as fixed effects, while random effects were animal, repeated observations, and residual. Yorkshire sows had a higher occurrence of LBA than L sows (P = 0.01). Second-to-fifth parities sows had lower reproductive failures than other parities. The NTB regression coefficients of log-odds were positive (P<0.01) for all traits. Narrower ranges of ADT3 increased the occurrence of MM, STB, and PDL (P<0.01), while higher PEAK3 increased the occurrence of MM, STB, PDL, and LBA (P<0.001). To reduce the risk of reproductive failures, particularly late in gestation, producers would need to closely monitor their temperature management strategies.

Keywords: Risk factors, Reproduction, Ambient temperature, Swine, Tropic

Introduction

Thailand is a tropical country in Southeast Asia that generally has high ambient temperatures and high relative humidity (Thai Meteorological Department, 2013). Fluctuations in ambient temperature in Thailand could induce stress in pig raised in open-house system, especially for both gestating gilts and sows (Tantasuparuk et al., 2000; Tummaruk et al., 2004). Gilts are more susceptible to thermal stress (Tummaruk et al., 2010) and changes in daily environmental temperature (Bloemholf et al., 2013) than sows. Thermal stress could reduce appetite and body reserve mobilization of sows in order to limit heat production (Nardone et al., 2010). Deficient nutrition, poor health and insufficient hormone concentration in sows affected follicle development (Campos et al., 2012). Then, incomplete follicle development led to an increase in the occurrence of mummified fetuses, stillborn piglets, and piglet death losses.

During gestation, mummification begins at approximately 35 days of gestation due to the accumulation of calcium in embryos (Christianson, 1992). Daily ambient temperature changes from day 35 of gestation to farrowing day may create stressful conditions that could result in reproductive failure. However, associations between daily ambient temperature fluctuations and reproductive failure traits in sows raised under tropical conditions has not been reported. Thus, the objective of this study was to determine the effects of daily ranges and maximum ambient temperatures and other risk factors on reproductive failure traits including the occurrence of mummified fetuses, stillborn piglets, piglet death losses, and an indicator trait for number of piglets born alive below the population mean in Landrace and Yorkshire sows raised under an open-house system in three commercial pig farms in Thailand.

Materials and Methods

Data

Pedigree and reproductive performance information on 35,579 litters from 5,929 Landrace (L) sows and 1,057 Yorkshire (Y) sows raised in three commercial herds (i.e., Northern (herd A), North eastern (herd B), and Central (herd C) Thailand). Sows farrowed from 2003 to 2013. The pedigree information included sow, sire and dam identifications, and breed group (Landrace, Yorkshire). The performance records were farrowing date, parity, number of mummified fetuses, number of stillborn piglets, number of piglet death losses, number of piglets born alive, and litter birth weight (weight of all piglets born alive was taken immediately after parturition). Descriptive statistics for variables related to reproductive failure traits in three commercial swine herds are shown in Table 1.

General management

All sows from three commercial herds were raised in an open-house system, where they exposed directly to ambient temperatures. Management strategies to reduce ambient temperature inside barns differed among herds. Steam fans were activated when the ambient temperature was higher than 33ºC in herds A and C, whereas in herd B, traditional fans were activated only in the summer season (March to June) from 9:30 am to 3:30 pm.

All farms used boar exposure for estrus detection in gilts and sows every day. Gilts were artificially inseminated on the second observed estrus. Gestating gilts and sows were kept in individual stalls during the mating and gestating periods, and subsequently moved to individual farrowing pens at approximately one week before the expected farrowing date. All farms provided similar feeding programs to all sows. Gestating gilts and sows were fed approximately 2.0 to 2.5 kg of a 16% protein ration per day, whereas lactating sows were fed approximately 6 kg of an 18% protein ration per day. Vaccinations against foot and mouth disease (FMD), Aujeszky's disease (AD), swine fever (SF), porcine parvovirus (PPV) and porcine circovirus (PCV) were programmed and given by veterinarians. Information on infections and disease was not reported by all farms. Body weight, number of teats, backfat thickness, leg conformation, and general appearance were considered as selection criteria for replacement gilts.

Meteorological data

Daily ambient temperatures from 2003 to 2013 were provided by Thai Meteorological Department (2013). These data were collected by meteorological stations near three commercial pig farms. The distance between the meteorological stations and farms were 36.6 km for herd A, 4.4 km for herd B, and 50.3 km for herd C. The average ambient temperature during the study period was 27.5°C (14.6°C to 35.5°C). Seasons in Thailand can be classified as summer (March to June), rainy (July to October) and winter (November to February). The daily range in ambient temperature was calculated as the difference between the daily minimum and maximum temperatures.

Statistical analysis

The reproductive failure traits were occurrence of mummified fetuses (MM), stillborn piglets (STB), piglet death losses (PDL; combination between mummified fetuses and stillborn piglets) and an indicator trait for number of piglets born alive below the population mean (LBA; 1 if below the mean; 0 if equal or above the mean). The population mean for the number of piglets born alive (NBA) was equal to the pooled mean over the three herds (9.9 ± 2.7 piglets; Table 1). Thus, the value of 9.9 was used to define LBA in this study. Because mummified fetuses are generally found at 35 days of gestation or later (Christianson, 1992), data on daily ranges in ambient temperature, daily maximum in ambient temperature, and sow reproductive performance for gilts and sows were merged starting at 35 days of gestation until parturition for the statistical analysis.

Average daily ranges in ambient temperature (ADT) and average daily maximum in ambient temperature (PEAK) during different periods of gestation (35^{th} to 60^{th}, 61^{st} to 90^{th}, and 91^{st} to 114^{th} days of gestation) was calculated and merged into individual sow performance. The ADT was classified as ADT1 (35^{th} to 60^{th} days of gestation), ADT2 (61^{st} to 90^{th} days of gestation), and ADT3 (91^{st} to 114^{th} days of gestation). Similarly, PEAK was classified as PEAK1 (35^{th} to 60^{th} days of gestation), PEAK2 (61^{st} to 90^{th} days of gestation), and PEAK3 (91^{st} to 114^{th} days of gestation). Parities (PAR) were classified into PAR_1 (1^{st} parity), PAR_{2to5} (2^{nd} to 5^{th} parity), and PAR_{6to13} (6^{th} to 13^{rd} parity).

The statistical analysis was carried out by ASREML software (Gilmour et al., 2009). The multiple logistic regression model included farrowing herd-year-season (HYS), breed group of sow (BG), PAR, number of total piglets born (NTB), ADT1, ADT2, ADT3, PEAK1, PEAK2, and PEAK3 as fixed effects, while random effects were animal, repeated observations and residual. Random animal effects contained additive genetic effects. Additive relationships among animals were accounted for. Repeated observations effects contained nonadditive genetic and permanent environmental effects. Residual effects contained temporary environmental effects. This model was used to evaluate log-odds ratios. The log-odds ratios were transformed to odds ratios (OR) by exponential function. The OR were used to quantify how strongly the occurrence or non-occurrence of reproductive failure traits in this population. The reference levels were winter of 2003 for HYS, Landrace for BG, and first-parity of sow for PAR. Statistical tests for OR and regression coefficients of log-odds were done using Bonferroni t-tests.

Results and Discussion

Effect of herd-year-season

The OR for reproductive failure traits varied across herd-year-season subclasses ($P<0.001$). The estimated OR across herds ranged from 0.19 times (2003-Winter) to 0.57 times (2006-Winter) for MM, 0.56 times (2004-Winter) to 1.48 times (2004-Summer) for STB, 0.55 times (2004-Winter) to 1.26 times (2006-Winter) for PDL, and 0.41 times (2008-Rainy) to 0.81 times (2010-Winter) for LBA. Larger OR ranges for MM (0.53 times to 2.11 times) and STB (0.42 times to 1.63 times) were reported by Thiengpimol et al. (2011) for Landrace and Yorkshire sows in a single commercial swine operation. Differences in MM and STB ranges may have been due to dissimilarities in routine management used to decrease daily ambient temperatures (steam and traditional fans vs. dripping water), quality and quantity of feeding in farrowing barns (concentrate produced in house vs. purchased concentrate) compared to those herd in Thiengpimol et al. (2011).

The OR estimates across year-season subclasses varied among farms for all traits. These results indicated that management quality across year-season subclasses differed among farms. Because of the open-house production system, different environmental conditions (e.g., ambient temperature, humidity) likely existed among farms. Average temperatures were 26.6°C (15.7°C to 35.1°C) for herd A, 27.17°C (14.6°C to 35.5°C) for herd B, and 28.3°C (17.8°C to 34.2°C) for herd C, whereas average humidity was 72.9% (35.0% to 99%) for herd A, 71.6% (37% to 99%) for herd B and 74.3% (33% to 98%) for herd C during the period of this study. These diverse environmental conditions as well as variation in feed quantity and quality may have affected the number of viable embryos at pre-parturition, number of piglets born alive, and number of piglets lost post-partum (Campos et al., 2012).

Effect of breed group of sow

Breed group of sows had not significant effect on MM (*P*=0.092), STB (*P*=0.135), and PDL (*P*=0.157), except for LBA (*P*=0.012). The risk of the occurrence LBA in Y sows was higher 34% than L sows (Table 2). In addition, Y sows had higher prevalence of LBA than L sows (4% in herd A, 4.9% in herd B, 11.9% in herd C, and 5.1% in the pooled herds). Similarly, Y sows had 0.5 lower piglets born alive per litter than L sows (8.4 piglets vs. 8.9 piglets; *P*<0.001) in Central Thailand (Tantasuparuk et al., 2000), and Y sows had lower number of piglets born alive per litter than L sows (10.58 piglets vs.10.94 piglets; *P*<0.001) in Sweden (Tummaruk et al., 2000). However, Tummaruk et al. (2004) reported that Y sows had nearly the same number of piglets born alive per litter as L sows (9.0 piglets vs. 8.9 piglets; *P*>0.05) in two nucleus herds in Thailand. These results highlighted the importance of both genetics and environment on the variability in the occurrence of reproductive failure traits in different pig populations.

Effect of number of total piglets born

Number of total piglets born was important for reproductive failure traits (*P*<0.001). The NTB regression coefficients of log-odds were 0.177 ± 0.006 for MM, 0.257 ± 0.05 for STB, and 0.266 ± 0.05 for PDL. The corresponding regression coefficients of the odds were 1.19 for MM, 1.29 for STB, and 1.30 for PDL. This indicated risk increases of 19% for MM, 29% for STB, and 30% for PDL as NTB increased by one piglet in this population. This result agreed with outcomes in temperate (Lucia Jr. et al., 2002; Borges et al., 2005) and tropical (Thiengpimon et al., 2011; Segura-Correa and Solorio-Rivera, 2013) environments. These risk increases are likely due to an excessive number of fetuses relative to sow uterine capacity that has a negative effect on fetal growth and muscle fiber development (Foxcroft et al., 2006). When fetuses begin to develop into piglets, the space and length in the uterine horns would be inadequate to accommodate all piglets. Thus, fetuses would become mummified after incomplete development into piglets occurred (Pardo et al., 2013).

The increase in OR for STB as NTB increased estimated here agreed with similar reports for swine populations in the Netherlands (Leenhouwers et al., 1999), Brazil (Lucia Jr. et al., 2002; Borges et al., 2005), Mexico (Segura-Correa and Solorio-Rivera, 2013), and Thailand (Thiengpimon et al., 2011). An increased risk of STB was likely to have occurred because of prolonged duration of parturition (Rutherford et al., 2013) that may have caused asphyxia in piglets (Herpin et al., 2001). Farrowing supervision and assistance could reduce the occurrence of STB when sows have high piglet production as reported by Rutherford et al. (2013). This is in contrast with Lucia Jr. et al. (2002), who suggested that vaginal palpation could induce the occurrence of STB. Thus, proper assistance need to be used only in extreme situations or when there is no possibility of successful farrowing.

Effect of parity group of sows

Reproductive failure traits were significantly influenced by PAR (*P*<0.01). Gestating sows in PAR_{2to5} had lower risk of occurrence of MM, STB, PDL and LBA than gestating gilts in PAR_1 (Table 2). This indicated that gestating gilts were more sensitive to physiological changes (Bloemhof et al., 2013). Further, gestating gilts could easily be stressed by environmental conditions such as housing and social interactions, less boar exposure, and low hormonal concentrations (Vanderhaeghe et al., 2013). The concentration of progesterone produced by the corpora lutea in gilts was lower than in older sows (Ziecik et al., 2011). Because progesterone concentration influences the maintenance and survival of embryos during gestation (Ziecik et al., 2011), lower progesterone concentration in gilts than in sows may have contributed to the higher OR values of MM than in sows in this population.

The OR for STB in gestating gilts was lower than gestating sows in PAR_{6to13} (Table 2). High-parity sows in this population had higher risk of STB in agree with previous studies (Leenhouwers et al., 1999; Lucia Jr. et al., 2002; Borges et al., 2005). It was suggested in these studies that the number of stillborn piglets increased as parities increased because of an increase in pathological changes in the reproductive tract and poorer uterine muscle tone as sows aged that led to a lengthening of parturition. Similarly, high-parity sows had a higher risk of PDL in this population. This likely occurred because PDL and STB are highly correlated traits (r = 0.82; *P*<0.001).

Effect of average daily ambient temperatures

The effect of ADT3 (Table 3) was significant for MM (*P*=0.001), STB (*P*<0.001) and PDL (*P*<0.001), but not for LBA (*P*=0.060). The ADT3 regression coefficients of log-odds were all negative indicating that for every 1°C decrease of ADT3 there was an increase of 7% for MM, 6% for STB, and 8% for PDL. Additionally, the effect of PEAK3 (Table 3) was significant for MM (*P*=0.015), STB (*P*=0.018), PDL (*P*<0.001), and LBA (*P*=0.014). Regression coefficients of log-odds for PEAK3 were all positive indicating that for every 1°C increase in PEAK3 there were increases of 5% for MM, 3% for STB, 5% for PDL, and 3% for LBA. These results indicated that narrower ambient temperature ranges and higher maximum ambient temperatures during the third gestation period markedly increased thermal stress on sows resulting in higher rates of reproductive failures.

Thus, the ADT3 and PEAK3 experienced by sows in this research induced stress during the third period of gestation in both of gestating gilts and sows. Similarly, Tummaruk et al. (2004, 2010), and Bloemhof et al. (2013) reported that gestating gilts and sows in both temperate and tropical conditions had lower litter size when raised in high ambient temperature. The stress from thermal conditions of ADT3 and PEAK3 led to reduced appetite in gilts and sows to limit their heat production (Nardone et al., 2010) resulting in poor health and subsequently had high reproductive failures (Campos et al., 2012). In addition, Einarsson et al. (2008) explained that thermal stress was associated with impairment of embryonic development which is associated with MM. The effect of stress from thermal conditions was also related to the occurrence of STB. Thermal stress may reduce the development of reproductive system and affects oxytocin concentration (von Borell et al., 2007), which is released before and during parturition. Lower oxytocin concentrations could impair contraction of the uterus in gestating gilts and sows leading to prolonged parturitions. Moreover, Vanderhaeghe et al. (2013) indicated that ambient temperature and other environmental factors such as type of pen and handling were associated with aggressive behavior in sows and increased STB during parturition.

Conclusions

Different farm managements affected the occurrence of MM, STB, PDL, and LBA. Yorkshire sows had higher risk of LBA than L sows. The highest sow production was found in second-to-fifth parity sows. High NTB sows had higher risk of occurrences of MM, STB, and PDL. Narrow daily ranges and high maximum ambient temperatures would increase the risk of reproductive failures in gestating gilts and sows. To reduce the risk of reproductive failures particularly in the last three weeks of gestation, producers would need to closely monitor their temperature management strategies.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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Table 1 Descriptive statistics of variables related to reproductive failure traits in swine commercial herds in Thailand

Variables	N	Min	Max	Med	Mean	SD
Parity	35,579	1	13	3	3.5	2.1
Mummified fetuses (piglets)	35,579	0	15	0	0.3	0.9
Stillborn piglets (piglets)	35,579	0	15	0	0.8	1.3
Piglet death losses (piglets)	35,579	0	19	1	1.1	1.6
Number of piglets born alive (piglets)	35,381	1	21	10	9.9	2.7
Number of total born piglets (piglets)	35,578	1	25	11	11.0	2.9
Litter birth weight (kg)	35,376	1.0	34.0	15.1	15.2	4.4

Table 2 Odds ratios (OR) and standard errors (SE) for breed group and parity group of sows on number of mummified fetuses (MM), number of stillborn piglets (STB), number of piglet death losses (PDL), and an indicator trait for number of piglets born alive below the population mean (LBA)

Factors	MM			STB			PDL			LBA		
	OR	SE	P-value	OR	SE	P-value	OR	SE	P-value	OR	SE	P-value
Breed group												
Landrace[R]	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-
Yorkshire	0.94	0.06	0.092	1.09	0.05	0.135	1.06	0.05	0.157	1.34	0.05	0.012
Parity group												
PAR_1 [R]	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-
PAR_{2to5}	0.79	0.05	<0.001	0.82	0.03	<0.001	0.76	0.03	<0.001	0.56	0.03	<0.001
PAR_{6to13}	1.03	0.09	0.549	1.32	0.04	<0.001	1.20	0.04	<0.001	0.83	0.04	<0.001

[R] Reference group

Table 3 Regression coefficients of log-odds (b) and their standard errors (SE) on average daily temperature ranges in three gestation periods (ADT1, ADT2, ADT3), and average daily maximum temperatures in three gestation periods (PEAK1, PEAK2, PEAK3) for number of mummified fetuses (MM), number of stillborn piglets (STB), number of piglet death losses (PDL), and an indicator trait for number of piglets born alive below the population mean (LBA)

Factors	MM			STB			PDL			LBA		
	b	SE	P-value	b	SE	P-value	b	SE	P-value	b	SE	P-value
ADT1	-0.020	0.020	0.327	0.016	0.014	0.250	0.017	0.014	0.246	-0.002	0.014	0.881
ADT2	0.034	0.022	0.114	0.024	0.015	0.110	0.025	0.015	0.101	0.009	0.015	0.549
ADT3	-0.067	0.021	0.001	-0.061	0.014	<0.001	-0.074	0.014	<0.001	-0.027	0.014	0.060
PEAK1	0.010	0.002	0.638	-0.032	0.015	0.030	-0.031	0.015	0.036	-0.006	0.014	0.667
PEAK2	-0.034	0.021	0.116	-0.038	0.015	0.011	-0.044	0.015	0.003	-0.013	0.015	0.379
PEAK3	0.045	0.019	0.015	0.030	0.013	0.018	0.045	0.013	<0.001	0.031	0.013	0.014