Effect of variability in lighting and temperature environments for mature gilts housed in gestation crates on measures of reproduction and animal well-being

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ABSTRACT: The effects of room temperature and light intensity before breeding and into early gestation were evaluated on the reproductive performance and well-being of gilts housed individually in crates. In eight replicates, estrus was synchronized in mature gilts (n = 198) and after last feeding of Matrix were randomly assigned to a room temperature of 15°C (COLD), 21°C (NEUTRAL), or 30°C (HOT) and a light intensity of 11 (DIM) or 433 (BRIGHT) lx. Estrous detection was performed daily and gilts inseminated twice. Blood samples were collected before and after breeding for determination of immune measures and cortisol concentrations. Gilt ADFI, BW, and body temperature were measured. On d 30 postbreeding, gilts were slaughtered to recover reproductive tracts to evaluate pregnancy and litter characteristics. There were no temperature × light intensity interactions for any response variable. Reproductive measures of follicle development, expression of estrus, ovulation rate, pregnancy rate (83.2%), litter size (14.3 ± 0.5), and fetal measures were not affected by temperature or lighting (P > 0.10). Gilts in COLD (37.6°C) had a lower (P < 0.05) rectal temperature than those in NEUTRAL (38.2°C) and HOT (38.6 ± 0.04°C). Both BW gain and final BW were greater (P < 0.0001) for gilts kept in HOT than those in NEUTRAL or COLD environments. Cortisol was greater (P < 0.01) for gilts kept in COLD compared with those kept in the HOT room. Gilts housed in the HOT environment made more postural changes (P < 0.05) than did those kept in either COLD or NEUTRAL temperatures. Gilts kept in the HOT temperature spent more total time lying and more time lying ventrally compared with those gilts housed in the NEUTRAL or COLD rooms. Total white blood cells and the percentage of neutrophils as well as neutrophil-to-lymphocyte ratio were all influenced (P < 0.05) by temperature but there was no effect (P > 0.10) of light or interaction with temperature on other immune cells or measures. These results indicate that temperatures in the range of 15 to 30°C or light intensity at 11 to 433 lx do not impact reproduction during the follicular phase and into early gestation for mature gilts housed in gestation crates. However, room temperature does impact physiological, behavioral, and immune responses of mature gilts and should be considered as a potential factor that may influence gilt well-being during the first 30 d postbreeding.

Key words: fertility, gestation crate, gilts, lighting, temperature, well-being


INTRODUCTION

Unexplained reproductive failure is common in swine breeding herds and could be related to variation in environmental factors such as temperature and light intensity. High temperatures have been shown to affect puberty (Flowers et al., 1989), litter size, pregnancy rate (Edwards et al., 1968; Omtvedt et al., 1971), feed intake, body temperature, plasma cortisol concentration, and immune function (Abilay et al., 1975; Oki and Atkinson, 2004). Light intensity has...
also been shown to affect age at puberty (Diekman and Grieger, 1988) and cortisol (Leproult et al., 2001). However, the relationship between temperature and light intensity and interactive effects on fertility and physiology of female swine remains unknown.

A temperature range of 13 to 29°C with a minimum light intensity of 162 lx is the current recommendation for housing breeding swine in confinement (Midwest Plan Service, 2001) but new European Union requirements set 40 lx as the minimum lighting level. Despite the ability of modern confinement systems to regulate temperature and lighting, there is considerable variation within an individual animal housing system. For example, variation has been reported for the temperature of sows in different crate locations within a building (Verstegen and Curtis, 1988). Unpublished data from our laboratory also indicates variation within breeding and gestation facilities with individual crate temperature varying ±13°C (range: 12 to 26°C) and light intensity varying by ±233 lx (range: 10 to 243 lx). With this potential variation in temperature and light intensity for individually housed breeding swine, it is important to ascertain whether the microenvironment for breeding females housed in crates is related to unexplained failures in reproduction and reduced well-being. This is especially important because most breeding females in North America are located on large farms (PigCHAMP, 2010; USDA-NASS, 2010) with approximately 70% of sows housed in gestation crates. In crates, females have only limited ability to react to thermal or lighting stressors (Verstegen and Curtis, 1988).

The objectives of this study were to evaluate the impact of different temperature and light intensities on reproductive fertility and behavioral and immune responses for mature gilts housed in crates from the initiation of the follicular phase through breeding and early gestation.

**MATERIALS AND METHODS**

The use of animals for this experiment was approved by the institutional animal care and use committee of the University of Illinois.

**Experimental Design**

This experiment was performed in 8 replicates between September 2008 and February 2010. The gilts used ($n = 198$) were PIC C-22 (replicate 1, $n = 36$), PIC C-29 (replicates 2 to 6, $n = 18$/replicate), and Genetiporc Fertilis 25 (replicates 7 to 8, $n = 36$/replicate). At approximately 160 d of age, gilts were moved from a finishing barn to a breeding and gestation facility where they were maintained in pens during the selection process. Animals with known estrous events were then moved into individual crates located within the gestation barn and estrus synchronized by feeding 15 mg/gilt per day a synthetic progestagen as a top dress on a small amount of feed for 14 consecutive days (Matrix; Merck Animal Health, Summit, NJ). Three days before last feeding of Matrix (LFM), BW and rectal temperature were obtained as well as blood samples for baseline cortisol and immune measures. At 0700 h after LFM, gilts were randomly assigned to treatment by BW and moved into individual crates within their assigned treatment room. Gilts were assigned using a $3 \times 2$ factorial arrangement of treatments to 1 of 3 temperature levels (COLD: 15°C, NEUTRAL: 21°C, and HOT: 30°C) and 1 of 2 light treatments (DIM: 11 lx and BRIGHT: 433 lx). Each treatment room was set at the desired temperature and each room (within temperature treatment) was divided in half for the different light treatments. Lights were automatically set to turn on at 0600 h and turn off at 1800 h to provide a 12/12 h lighting regimen. Gilts were individually fed 2.73 kg of a standard gestation diet once daily at 0600 h and provided ad libitum access to water.

After LFM, gilts were checked for estrus once daily at 1500 h using 2 min fence-line exposure to a mature boar with application of the back-pressure test. To assess follicle growth, transrectal real-time ultrasonography was performed at 1400 h every other day from LFM until onset of estrus using an Aloka SSD-500 (Tokyo, Japan) with a 7.5 MHz linear transducer (Knox and Althouse, 1999). At the onset of estrus, ultrasonography was performed daily at 1400 h to assess number and size of follicles and determine time of ovulation. Gilts were checked for estrus once daily at 1500 h and hand AI was performed at 0 and 24 h after onset of estrus. Gilts were inseminated using pooled semen (ejaculates from 3 to 5 boars) from PIC or Genetiporc commercial boar studs with each dose containing approximately $3.0 \times 10^9$ motile sperm/dose. Any gilt not detected in estrus by d 8 after LFM was considered anestral. All animals were maintained in their crate in the treatment rooms for approximately 5 wk. On d 14 after detection of estrus, gilts were nose snared in their crate for ≤2 min as a blood sample was collected by jugular venipuncture into a Vacutainer (Becton Dickinson, Franklin Lakes, NJ) tube. Blood samples were allowed to clot at room temperature for 1 h and were stored at 4°C for 12 h before centrifugation at $400 \times g$ at 4°C for 15 min. Serum was transferred into polypropylene tubes for storage at −20°C until analysis for progesterone concentration. Pregnancy status was assessed on d 26 using transabdominal ultrasonography. Gilts were sent to a local abattoir at approximately d 30 of gestation and reproductive tracts were collected for determining ovarian and pregnancy status, litter size and fetal measures. Day 30 was chosen
Variation in temperature and light on gilts

Variation in temperature and light on gilts

as the end point for this study to determine whether any reproductive abnormalities could be associated with the most commonly reported reproductive failures of anestrus, regular and irregular returns, early pregnancy failure, or embryo loss (Teague et al., 1968; Omtvedt et al., 1971; Griffith and Minton, 1992; Love et al., 1993; Dalin et al., 1997; Koketsu et al., 1997; Knox et al., 2012). Ovaries and associated structures were analyzed for number of corpora lutea and abnormalities. These abnormalities could include bursal cysts on the oviduct, thin walled follicular cysts >12 mm on the ovaries, or luteal cysts, which were corpora lutea ≥12 mm that had thick luteinized walls with a fluid-filled cavity. Uteri were also analyzed for structural malformations or infection. Healthy fetuses were removed from pregnant uteri and counted and weighed (±0.01 g), and crown-rump length was measured using a caliper (±1.0 mm). Degenerating fetuses were also counted, weighed, and measured when possible and were identified by smaller size and weight (≤1 SD below the average healthy fetal litter weight and size) and darker color.

Animal Housing and Climate Control

The experiment was conducted in a specifically designed single structure research facility subdivided into 3 identical rooms and located within an environmentally controlled swine gestation facility at the University of Illinois Swine Research Center. Figure 1 illustrates the layout of the experimental facility. The rooms were identical in layout, air control, curtains, flooring, space, equipment, lighting, and wall insulation (r > 11). The rooms shared a common pit and air supply system. Due to practical considerations for temperature control throughout all seasons of the year and system design limitations, it was necessary to choose the north room as HOT, the center room as NEUTRAL, and the south room as COLD. This allowed consistent temperature control with and without animals in the rooms for the 7 wk experimental periods. Each room was 6.71 by 6.40 m and constructed over a partially slatted concrete floor. A common drainage pit spanned the entire length of the facility, but airflow between the different rooms was prevented using vinyl curtains that were submerged 60 cm into the liquid in the pit at the interface between the rooms. The pit liquid level was maintained to reach the desired level of the pit curtain for all replicates. The pit was not emptied or charged during a replicate and most of the fluid below the pit curtain was free to flow along the length of the building. Each room contained 12 crates with each crate measuring 0.61 by 2.13 m. The front of the crate was mounted on solid concrete flooring and the rear of the crate was positioned over concrete slats. A black polyethylene and nylon curtain (0.48 kg/m²) was used to divide each treatment room in half for application of DIM or BRIGHT light intensities. Air temperature for the 3 rooms was provided by a direct expansion refrigeration system with a single air cooled condensing unit located outside the barn. This unit varied the cooling capacity to match the demands from the individual rooms. Each room contained a ceiling mounted forced air system with cooling coils. Each room had its own thermostatic control system, valves, electric reheat, exhaust fans, dampers, and aluminum fresh air ducting. The heating and cooling system was calibrated to turn on or off when air temperature at the sensor located on the ceiling deviated

Figure 1. Layout of treatment facility. A. Measurements of room and crate size. B. Placement of regulation devices: fluorescent lighting installed in all sections, supplemental lighting using hanging fluorescent light fixtures in 433 lx (BRIGHT) treatments only, pit curtain to prevent air flow between rooms through pit space, heating/cooling unit attached to ceiling and spans both lighting treatments, 2 fans per lighting treatment to maintain room temperature, exhaust vents to expel circulated air into gestation room, and 1 door per room section. C. Arrows indicate animal orientation within the facility and crate location over partially slatted floors.
>0.55°C from the treatment set temperature. The ceiling mounted temperature control unit was installed in the center of the room with symmetric orientation to allow the curtain to separate the room in half to allow equal airflow on both sides of the curtain. The system was designed to provide a minimum 0.94 m³/s of circulating air and a minimum 0.094 m³/s of fresh air, introduced into the discharge airstream of each room to mix with conditioned air. The fresh air provided with a single fan blower unit was tempered with proportional electric heat at entering temperatures below 15°C to minimize cold air drafts and air stratification within the rooms. The supply air was balanced with dampers for equal distribution between the 3 rooms. During a pretrial test period with animals in the rooms, 12 air quality measures were obtained from each treatment (temperature × lx) location. We obtained a mean 20.4 ± 0.3% O₂, 2.1 ± 1.4% CO, and 16.8 ± 2.3% NH₃. Based on these data we did not measure these variables throughout the study. During the experiment, there was no evidence of poor air quality with pigs showing signs of watery eyes, ocular discharges, respiratory distress, or poor health. There was also no evidence of a strong smell of ammonia detected by the investigators or farm personnel. Fluorescent light fixtures were installed over all alleyways to provide uniform lighting at each pig space. Supplemental fluorescent light fixtures were installed above the front of the crates to achieve the greater lighting intensity (433 lx) at the eye level of the pig.

For each replicate, weekly room temperature, humidity, and light intensity measurements were obtained for each room during the 5 wk treatment period. Measurements were obtained at pig level (approximately 0.6 m from the floor) at each individual crate location. Humidity and temperature readings within each room were obtained using an Omegaette reader (Omega Engineering, Inc., Stamford, CT) with an accuracy of ±0.7°C for temperature and ±2.5% for relative humidity. Averaged over all replicates, the temperatures (mean ± SE) within each of the treatment rooms were 29.8 ± 0.1°C for HOT (CV = 1.5%), 20.3 ± 0.2°C for NEUTRAL (CV = 3.1%), and 13.9 ± 0.2°C for COLD (CV = 3.9%). Humidity measurements averaged 78.3 ± 0.4% for HOT (CV = 5.9%), 80.3 ± 0.3% for NEUTRAL (CV = 5.2%), and 75.6 ± 0.5% for COLD (CV = 8.3%). Light intensity was measured using a Lux Meter-Foot Candle Meter (Sper Scientific, Scottsdale, AZ) with an operational detection limit of 0 to 400,000 lx (accuracy range: ± 0.5 to 3.5%). Throughout the study, light intensity for DIM rooms averaged 10.9 ± 0.3 lx (CV = 32.6%) and the light intensity for BRIGHT rooms averaged 432.7 ± 3.8 lx (CV = 11.4%).

Physiological Measurements

All gilts were weighed 3 d before treatment allotment and once again before slaughter to determine starting and ending BW and total BW gain. Rectal temperature was measured using a veterinary digital thermometer (accurate to ±0.2°C; Model TM99A; Cooper Instruments Corp., CT) with the gilt unrestrained and standing. Body temperature was recorded before the experimental period and then on d 0, 6, 13, 20, 27, and 34 during the treatment period. Average daily feed intake was estimated by weight of feed delivered and residual feed 24 h later on d 6, 13, 20, 27, and 34. Plasma cortisol was measured on a random subset of gilts (12 gilts/treatment) on d –2, 5, 12, 19, 26, and 33 posttreatment. Blood samples (4 mL) were collected as previously described using heparin-coated Vacutainer tubes (Becton Dickinson). Heparin tubes were then centrifuged at 400 × g for 15 min at 4°C to collect plasma for storage at –20°C until analysis.

Behavior Measures

Postural changes were obtained on the same subset of gilts (n = 12 gilts/treatment) used for cortisol measures. Our choice for behavioral measures to assess for gilt behavior related to housing and stress was based on selected measures from previously published studies (Bergeron et al., 1996; Anil et al., 2002; Boyle et al., 2002; McGlone et al., 2004). Observations related to postural changes were initiated at 0630 h and continued until 1800 h on each Monday and Tuesday during the 5-wk treatment period. Two video cameras were used for each temperature and lighting treatment location with cameras placed in the corners at ceiling height to allow all the animals to be viewed at the same time. Cameras for each room recorded onto a single tape using a multiplexer. The video tapes were played and used to visually record the occurrence of postures and the associated time on the video tape. Data were then copied into a spreadsheet and calculations performed to determine the duration and proportion of recorded time in a particular posture. All observation and duration measures for postures were standardized to 24 h to account for differences when the actual recording time or useable video was less than the 24 h session. Position changes were determined for the number and times an individual pig changed positions between standing, sitting, and lying. Within the lying position, animals were further classified by occurrence and time lying in the ventral or lateral position and by the type and duration of contact they had with a neighboring lying pig. Time of lying was classified as either lateral or ventral and further classified by contact with neighboring gilts as 1) Full (majority of dorsal surface in contact with adjacent gilt), 2) Moderate (some dorsal contact with adjacent...
gilt but lying in an angled position), and 3) None (no dorsal contact with adjacent gilt).

**Immune Cell Function**

The same subset of gilts used for behavioral and cortisol measures \((n = 12/\text{treatment})\) was used for immune cell measurements. Gilts were nose snared and blood samples (6 mL) collected via jugular venipuncture using vacuum tubes with EDTA (1.8 mg/mL) on d –2, 5, 12, 19, 26, and 33 of treatment. Samples were kept on ice until processing. Total white blood cell counts were made electronically using a Coulter Z1 particle counter (Beckman Coulter, Inc., Miami, FL) by adding 10 μL of whole blood to Isoloflow (10 mL; Beckman Coulter), and red blood cells were lysed with Zap-o-globin (Beckman Coulter). Whole blood smears were made, fixed in methanol, stained with Hema-3 staining system (Fisher Scientific, Houston, TX), and viewed under a light microscope to determine leukocyte differential counts.

Whole blood was diluted with Roswell Park Memorial Institute (RPMI) medium (Gibco, Carlsbad, CA) layered over Histopaque 1077 (density = 1.077 g/mL; Sigma Aldrich) and 1119 (density = 1.119 g/mL; Sigma Aldrich) and centrifuged at 700 × g for 30 min at 25°C. Lymphocytes were removed from the 1077 layer and neutrophils were removed from the 1119 layer. Isolated cells were washed twice in RPMI medium, resuspended, and counted. For neutrophils, red blood cells were lysed. Cell concentrations were adjusted with RPMI medium based on the respective requirements of the specific immune assay.

Neutrophil chemotaxis was measured using an assay previously described (Salak et al., 1993). Briefly, neutrophils were used at a concentration of \(3 \times 10^6\) cells/mL. Both recombinant human complement-5a \((10^{-7} M; \text{Sigma Aldrich})\) and recombinant human IL-8 (100 μg/mL; Sigma Aldrich) were used as chemoattractants. Neutrophil phagocytosis was measured using a flow cytometry-based assay as previously described (Jolie et al., 1999) with minor modifications described (Niekamp et al., 2006). Fluorescent beads were pre-incubated 30 min with nonheat-inactivated porcine serum, and then beads were added to samples at a 10:1 (beads:neutrophils) ratio and samples were incubated for 45 min. The percentage of engulfment of beads by cells was evaluated using a flow cytometer.

A mitogen-induced lymphocyte proliferation assay was performed using a CellTiter 96 nonradioactive cell proliferation assay (Promega, Madison, WI) using the manufacturer’s protocol with minor modification as previously described by Sutherland et al. (2005). Briefly, porcine lymphocytes were pipetted in triplicate into a sterile 96-well flat-bottom plate at cell concentration of \(5 \times 10^6\) cells/mL. Concanavalin A (Sigma Aldrich) and lipopolysaccharide (Sigma Aldrich) were used as mitogens (0, 25, and 50 μg/mL) to stimulate T and B cells, respectively. Plates were incubated 68 h at 37°C in a 5% CO₂ humidified incubator and 20 μL MTT (3-[4, 5-dimethylthiazol-2-yl]-2, 5-diphenyl tetrazolium bromide; Sigma Aldrich) was added to each well, and the plates were incubated 4 h. Acidified isopropanol (100 μL 0.1 N HCl in anhydrous isopropanol) was added, and the plates were incubated overnight at 37°C and then read using a microplate reader (BIO-TEK Instruments, Winooski, VT) at wavelength 550 nm with reference wavelength 690 nm. The results are expressed as a proliferation index: optical density \((550/690 \text{ nm})\) stimulated cells/optical density \((550/690 \text{ nm})\) nonstimulated cells.

**Hormone Assays**

Plasma cortisol was measured using a commercially available RIA cortisol kit (Coat-A-Count; Siemens Diagnostic Products, Los Angeles, CA). Intra- and interassay CV were 6.9 and 16.0%, respectively, and the minimal detectable concentration was 2 ng/mL. Progesterone samples were evaluated using an RIA kit and procedure previously described (Printz et al., 1994). This kit was validated using charcoal-stripped, pooled, porcine serum (Coat-A-Count; Siemens Diagnostic Products) with a minimum detectable limit of 31 pg/mL and an intra- and interassay CV of 4.5 and 13.3%, respectively.

**Statistical Analysis**

Data were subjected to ANOVA. Continuous response measures were analyzed using the PROC MIXED procedures (SAS Inst., Cary, NC) for significance of the main effects using the \(F\)-test and differences between least squares means identified using the \(t\) test. Binary response measures were analyzed using PROC GENMOD and significant effects of treatment and differences between least square means identified using the \(\chi^2\) test. This analysis was performed using a binary distribution and a logit-link. The models for the dependent variables included the main effects of temperature (3 levels), light intensity (2 levels), and their interaction. Replicate was included in all models. Repeated measures analyses were also performed for data obtained from the same animals over weeks using the “repeated” statement with the “ar” classification. Baseline measures were included as a covariate and gilt within treatment and replicate was used as the error term. The assumptions of ANOVA for normal distribution of data were evaluated and tested using PROC UNIVARIATE and for homogeneity of variance using
Levene’s test. Data that could not meet the assumptions were log or rank transformed for analysis. Differences between means were significant at \( P < 0.05 \). Trends for significance were identified when \( P > 0.05 \) but less than or \( P = 0.10 \).

**RESULTS**

There was no temperature \( \times \) lighting effects for any measures assessed in this study (\( P > 0.10 \)). Therefore, only the main effects of temperature and light intensity on response measures are presented. Of the 198 gilts initially assigned to treatment, 194 were included in the final analysis. Animals were excluded for problems unrelated to treatment. Two gilts were excluded for the presence of corpora lutea as detected by ultrasound after LFM and 2 additional gilts were excluded at approximately 12 d postbreeding after a diagnosis of vaginal discharge and uterine infection.

**Reproductive Responses to Treatment**

Results for reproductive measures in response to treatment are shown in Table 1. Expression of estrus within 8 d after LFM averaged 93.3% and the interval from LFM to estrus was 145.8 ± 2.7 h but neither was affected by treatment. Duration of estrus tended to be longer (\( P = 0.10 \)) for gilts in BRIGHT compared with gilts in DIM lighting, but temperature had no effect. Treatment had no effect on the interval from estrus to ovulation (40.6 ± 2.0 h) or progesterone concentrations (31.9 ± 1.7 ng/mL) on d 14 of gestation. Also, number of corpora lutea (18.2 ± 0.6), pregnancy rate (87.0%), and embryo survival (79.1%) were all similar among treatment groups.

The effects of treatment on litter traits are shown in Table 2. There were no treatment effects on number of healthy fetuses at d 30 (14.3 ± 0.5/litter), number of degenerating fetuses (0.2 ± 0.04/litter), or average fetal weight (11.4 ± 0.3 g) or fetal length (44.9 ± 0.3 mm). On d 30, within litter variation for fetal weight (1.2 ± 0.08 g) and fetal length (2.2 ± 0.1 mm) were also not different among treatment groups.

**Gilt BW and Rectal Temperature**

The main effects of temperature and lighting on gilt performance and rectal temperature are shown in Table 3. Final gilt BW and total BW gain were both affected by temperature (\( P < 0.0001 \)) with final BW and total BW gain being greatest for gilts housed in the HOT environment compared with gilts kept in NEUTRAL and COLD environments. Rectal temperature was greater (\( P < 0.0001 \)) for gilts kept in the HOT environment compared with the other treatments and lowest for those gilts in COLD. Light intensity had no effect on any measures (Table 3).

**Postural Behaviors and Position Changes**

The main effects of temperature and lighting treatments on postural behaviors of gilts are presented in Table 4. Number of postural changes and proportion of time spent standing or lying were affected by temperature. Gilts kept in the HOT environment made more (\( P < 0.0001 \)) postural changes than did gilts in either the NEUTRAL or COLD environments. Percentage of time gilts spent lying was greater (\( P < 0.0001 \)) among gilts in the HOT environment compared with gilts in either NEUTRAL or COLD environments. Lying position of the gilt was also affected by temperature, with those gilts kept in the COLD environment spending a greater proportion of time in the ventral position whereas gilts in HOT room spent more time lying laterally (\( P < 0.0001 \)).

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**Table 1.** Least squares means for the reproductive responses of mature, synchronized gilts in response to the main effects of housing in crates in COLD, \(^1\) NEUTRAL, or HOT rooms, each with DIM\(^2\) or BRIGHT lighting in the period from the last feeding of Matrix (LFM; Merck Animal Health, Summit, NJ) through breeding and early gestation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Temperature (temp)</th>
<th>Lux (lx)</th>
<th>( P)-value(_{\text{temp}} )</th>
<th>( P)-value(_{\text{lx}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLD</td>
<td>NEUTRAL</td>
<td>HOT</td>
<td>BRIGHT</td>
</tr>
<tr>
<td>Estrus expression within 8 d of LFM, %</td>
<td>65</td>
<td>64</td>
<td>65</td>
<td>97</td>
</tr>
<tr>
<td>LFM to estrus, h</td>
<td>94.7 ± 3.0</td>
<td>89.5 ± 3.0</td>
<td>95.7 ± 3.0</td>
<td>93.0 ± 3.0</td>
</tr>
<tr>
<td>Duration of estrus, h</td>
<td>148.5 ± 2.7</td>
<td>143.5 ± 2.8</td>
<td>145.4 ± 2.7</td>
<td>144.3 ± 2.2</td>
</tr>
<tr>
<td>Estrus to ovulation interval, h</td>
<td>57.3 ± 1.7</td>
<td>56.7 ± 1.7</td>
<td>54.8 ± 1.7</td>
<td>57.8 ± 1.4</td>
</tr>
<tr>
<td>No. of corpora lutea at d 30</td>
<td>40.3 ± 2.0</td>
<td>40.7 ± 2.1</td>
<td>40.7 ± 2.0</td>
<td>42.2 ± 1.7</td>
</tr>
<tr>
<td>D 14 progesterone, ng/mL</td>
<td>17.6 ± 0.5</td>
<td>18.9 ± 0.6</td>
<td>18.2 ± 0.6</td>
<td>18.0 ± 0.5</td>
</tr>
<tr>
<td>Pregnancy rate (d 30), %</td>
<td>31.5 ± 1.7</td>
<td>32.5 ± 1.7</td>
<td>31.6 ± 1.6</td>
<td>32.3 ± 1.4</td>
</tr>
<tr>
<td>Embryo survival (d 30), %</td>
<td>86.9 ± 5.0</td>
<td>84.4 ± 5.0</td>
<td>89.8 ± 5.0</td>
<td>85.9 ± 4.0</td>
</tr>
</tbody>
</table>

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\(^1\)COLD = 13.9 ± 0.2°C; NEUTRAL = 20.3 ± 0.2°C; HOT = 29.8 ± 0.1°C.

\(^2\)DIM = 11 lx; BRIGHT = 433 lx.
0.0001). Conversely, gilts kept in COLD environment spent more ($P < 0.0001$) time standing compared with gilts kept at NEUTRAL or HOT temperatures. Gilt body position when in the lying position with full contact with neighboring gilts tended ($P < 0.10$) to be influenced by temperature and lighting with gilts in COLD and BRIGHT having the least amount of full contact. Time spent with moderate contact with another gilt was not affected by temperature or lighting. When lying, time spent without any contact with neighboring gilts was not influenced by temperature or lighting.

**Cortisol and Immune Measures**

The main effects of temperature and lighting on cortisol and immune measures are presented in Table 5. Cortisol tended to be affected by room temperature ($P = 0.10$) but not light intensity with those gilts kept in COLD having greater cortisol than those in the HOT environment. Total white blood cells ($P < 0.05$) and percentage of neutrophils ($P < 0.01$) as well as neutrophil-to-lymphocyte ratio ($P = 0.05$) were all affected by temperature whereas number of lymphocytes showed a trend ($P = 0.06$) for an effect. There were fewer ($P < 0.05$) white blood cells for gilts kept in the HOT environment compared with other temperature treatments. Percentage of neutrophils were greater ($P < 0.05$) for gilts kept in COLD environment compared with those in NEUTRAL or HOT, which resulted in a greater neutrophil-to-lymphocyte ratio for gilts kept in COLD. The only measure affected by light intensity was percentage of eosinophils, with eosinophils (%) being greater ($P < 0.05$) for gilts kept in DIM than for gilts in BRIGHT. All other immune measures presented in Table 5 were similar among gilts kept at various environmental temperatures and light intensities.

**DISCUSSION**

This experiment was designed to determine if exposure of mature gilts housed in crates to different levels of temperature and lighting during breeding and early gestation is associated with reproductive failure, changes in performance, behavior, or immune function. There were no effects of temperature within the range 0.0001).

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**Table 2.** Least square means for litter traits of mature, synchronized gilts in response to housing in crates in COLD, NEUTRAL, or HOT rooms, each with DIM or BRIGHT lighting in the period from last feeding of Matrix (Merck Animal Health, Summit, NJ) through breeding and early gestation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Temperature (temp)</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLD 65</td>
<td>NEUTRAL 64</td>
<td>HOT 65</td>
<td>BRIGHT 97</td>
</tr>
<tr>
<td>No. of healthy fetuses</td>
<td>13.9 ± 0.5</td>
<td>14.2 ± 0.5</td>
<td>14.7 ± 0.5</td>
<td>14.1 ± 0.4</td>
</tr>
<tr>
<td>Avg. fetus weight, g</td>
<td>11.4 ± 0.3</td>
<td>11.3 ± 0.3</td>
<td>11.4 ± 0.2</td>
<td>11.5 ± 0.2</td>
</tr>
<tr>
<td>Within litter fetal weight variation, g³</td>
<td>1.2 ± 0.08</td>
<td>1.2 ± 0.08</td>
<td>1.1 ± 0.07</td>
<td>1.2 ± 0.06</td>
</tr>
<tr>
<td>Fetus length, mm</td>
<td>44.9 ± 0.3</td>
<td>44.8 ± 0.3</td>
<td>45.1 ± 0.3</td>
<td>45.0 ± 0.3</td>
</tr>
<tr>
<td>Within litter fetus length variation, mm³</td>
<td>2.1 ± 0.1</td>
<td>2.1 ± 0.1</td>
<td>2.3 ± 0.1</td>
<td>2.1 ± 0.1</td>
</tr>
</tbody>
</table>

¹COLD = 13.9 ± 0.2°C; NEUTRAL = 20.3 ± 0.2°C; HOT = 29.8 ± 0.1°C.
²DIM = 11 lx; BRIGHT = 433 lx.
³Within litter measures evaluated at d 30.

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**Table 3.** Least squares means for performance and body temperature measures of mature, synchronized gilts in response to housing in crates in COLD, NEUTRAL, or HOT rooms, each with DIM or BRIGHT lighting in the period from last feeding of Matrix (Merck Animal Health, Summit, NJ) through breeding and early gestation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Temperature (temp)</th>
<th>Lux (lx)</th>
<th>$P$-value$_{\text{temp}}$</th>
<th>$P$-value$_{\text{lx}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLD 65</td>
<td>NEUTRAL 64</td>
<td>HOT 65</td>
<td>BRIGHT 97</td>
</tr>
<tr>
<td>Initial BW, kg</td>
<td>145.0 ± 0.5</td>
<td>145.3 ± 0.5</td>
<td>144.7 ± 0.6</td>
<td>145.0 ± 0.5</td>
</tr>
<tr>
<td>Final BW, kg</td>
<td>162.1 ± 0.8a</td>
<td>168.3 ± 0.8b</td>
<td>174.0 ± 0.8a</td>
<td>168.4 ± 0.7</td>
</tr>
<tr>
<td>BW gain, kg</td>
<td>16.6 ± 0.8a</td>
<td>22.7 ± 0.8b</td>
<td>28.4 ± 0.8a</td>
<td>22.9 ± 0.7</td>
</tr>
<tr>
<td>Daily feed intake, kg³</td>
<td>2.7 ± 0.02</td>
<td>2.7 ± 0.02</td>
<td>2.7 ± 0.02</td>
<td>2.7 ± 0.02</td>
</tr>
<tr>
<td>Rectal temperature, °C</td>
<td>37.6 ± 0.04a</td>
<td>38.2 ± 0.04b</td>
<td>38.6 ± 0.04a</td>
<td>38.1 ± 0.03</td>
</tr>
</tbody>
</table>

¹For each main effect, means with different superscripts within a row are different ($P < 0.05$).
²COLD = 13.9 ± 0.2°C; NEUTRAL = 20.3 ± 0.2°C; HOT = 29.8 ± 0.1°C.
³DIM = 11 lx; BRIGHT = 433 lx.
³Five week average of measures.
of 15 to 30°C or lighting intensity at 11 to 433 lx on any reproductive measures assessed within the present study. This leads us to conclude that reproductive failure associated with problems in follicular development, estrus or ovulation, pregnancy establishment, and embryo survival are not associated with constant exposure of gilts to these temperatures or 12 h exposure to this type of lighting. These results could be extrapolated to suggest that similar variation in temperature and lighting within commercial swine breeding facilities may not be major contributing factors associated with early estrus or pregnancy related failures in gilts or sows.

The most common causes of reproductive failure in swine are those associated with failure to detect estrus and pregnancy failure (Dalin et al., 1997; Koketsu et al., 1997; Heinonen et al., 1998; Vargas et al., 2009; Tummaruk et al., 2010). The causes for these failures are largely unknown but it is likely they are multifactorial and vary among farms (Koketsu et al., 1999). Although there are no data to suggest that ambient temperatures near the lower critical temperature of a pig cause reproductive failure, the lower critical temperature can change based on her age and weight and stage of gestation (Verstegen and Curtis, 1988). Conversely, reproductive failure in swine has been attributed to heat stress (Wetteman and Bazer, 1985) and season of the year with effects on estrus and ovulation (Xue et al., 1994), conception rate, litter size, and litter weights reported (Love et al., 1993). Most modern swine confinement barns are built to operate based on the normal range of outdoor annual temperatures in the United States (4 to 15°C; National Weather Service) and, depending on location, may have to plan for extremes for heat and cold. Because there are considerable differences in building size, design, air flow, and sensing systems, despite the settings in the air control system to provide comfortable conditions for all animals within the breeding barns (18 to 24°C) throughout all weather conditions, it is also true that certain locations within these buildings can differ greatly in temperate as well as in the extremes of outdoor cold or heat. As a result, in any swine confinement building, it should be expected that there will be areas within the building that can be hotter or cooler than the set temperatures for the room. Seasonal infertility in gilts and sows is most often observed in summer and early fall and cannot be attributed to high temperature alone (Hurtgen and Leman, 1980; Prunier et al., 1997; Auvigne et al., 2010). Hormonally, gilts subjected to heat stress (30 to 33°C) exhibit a reduction in FSH and LH during the follicular phase (Flowers and Day, 1990). Others have shown altered concentrations of estrogen prebreeding and reduced concentrations of progesterone postbreeding (Hoagland and Wettemann, 1984). For reproductive performance of gilts, heat stress ranging from 30 to 39°C was reported to reduce expression of estrus, pregnancy rate, numbers of embryos, or embryo survival (Edwards et al., 1968; Teague et al., 1968; Omtvedt et al., 1971). However, not all heat stress effects are similar and d’Arce et al. (1970) noted that for gilts exposed to high temperatures above 28°C, estrus expression was normal but ovulation rate was reduced. This was especially evident as the duration of exposure increased during the

### Table 4

<table>
<thead>
<tr>
<th>Measure</th>
<th>Temperature (temp)</th>
<th>Lux (lx)</th>
<th>$P$-value$_{\text{temp}}$</th>
<th>$P$-value$_{\text{lx}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLD</td>
<td>NEUTRAL</td>
<td>HOT</td>
<td>BRIGHT</td>
</tr>
<tr>
<td>n</td>
<td>24</td>
<td>24</td>
<td>24</td>
<td>36</td>
</tr>
<tr>
<td>No. of position changes$^4$</td>
<td>2.14 ± 0.2$^a$</td>
<td>2.13 ± 0.2$^a$</td>
<td>4.89 ± 0.2$^b$</td>
<td>3.06 ± 0.2</td>
</tr>
<tr>
<td>Sitting position, % of recording time</td>
<td>2.66 ± 0.9</td>
<td>4.42 ± 0.8</td>
<td>4.43 ± 0.9</td>
<td>3.21 ± 0.7</td>
</tr>
<tr>
<td>Standing position, % of recording time</td>
<td>43.1 ± 2.3$^a$</td>
<td>27.1 ± 2.2$^b$</td>
<td>14.1 ± 2.3$^c$</td>
<td>26.8 ± 1.9</td>
</tr>
<tr>
<td>Lying position, % of recording time</td>
<td>54.0 ± 2.6$^a$</td>
<td>68.8 ± 2.5$^b$</td>
<td>81.6 ± 2.6$^c$</td>
<td>70.0 ± 2.1</td>
</tr>
<tr>
<td>Lying position</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventral position, % of lying time</td>
<td>76.7 ± 4.0$^a$</td>
<td>63.0 ± 3.8$^b$</td>
<td>18.0 ± 4.0$^c$</td>
<td>53.4 ± 3.2</td>
</tr>
<tr>
<td>Lateral position, % of lying time</td>
<td>18.7 ± 4.0$^a$</td>
<td>36.9 ± 3.9$^b$</td>
<td>82.0 ± 4.0$^c$</td>
<td>46.6 ± 3.3</td>
</tr>
<tr>
<td>Position within crate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full contact with neighboring gilt,$^5$ % of lying time</td>
<td>3.62 ± 2.2$^a$</td>
<td>10.5 ± 2.2$^b$</td>
<td>8.96 ± 2.2$^c$</td>
<td>5.48 ± 1.8$^a$</td>
</tr>
<tr>
<td>Moderate contact with neighboring gilt,$^5$ % of lying time</td>
<td>14.2 ± 3.1</td>
<td>15.1 ± 2.9</td>
<td>17.6 ± 2.9</td>
<td>18.4 ± 2.4</td>
</tr>
<tr>
<td>No contact with neighboring gilt,$^5$ % of lying time</td>
<td>80.4 ± 3.9</td>
<td>74.8 ± 3.7</td>
<td>73.2 ± 3.8</td>
<td>76.1 ± 3.1</td>
</tr>
</tbody>
</table>

$^a$For each main effect, means with different superscripts within a row are different ($P < 0.05$).
$^1$COLD = 13.9 ± 0.2°C; NEUTRAL = 20.3 ± 0.2°C; HOT = 29.8 ± 0.1°C.
$^2$DIM = 11 lx; BRIGHT = 433 lx.
$^3$Observation period occurred for approximately 12 h on 2 consecutive d during the 5 wk of the experiment.
$^4$Position changes between sitting, standing, and lying per hour or recording.
$^5$Relative contact with gilts in adjacent crates. Full = all of back/flank; Moderate = some contact of back/flank; No = no back/flank contact.
estrous cycle. Edwards et al. (1968) and Omtvedt et al. (1971) also showed that heat stress before breeding had little effect on estrus or ovulation but when applied after breeding and during the first few weeks of gestation, pregnancy rate and numbers of embryos were reduced. The effect of heat stress was not evident in mid gestation but appeared in late gestation with sows having fewer pigs born alive (Omtvedt et al., 1971). Tast et al. (2002) noted that in cases of seasonal infertility in the form of early pregnancy failure, progesterone concentrations were reduced. Our data would support this observation as we did not observe an effect of treatment on number, formation, or function of corpora lutea and noted no effects on progesterone concentration or pregnancy rate. Collectively the results from all of these experiments would suggest that temperatures below 30°C would not be associated with reproductive failure but that increases above 30°C are often associated with some form of reproductive failure. However, evidence also points to reproductive failure as a result of the type of stress, the level of the stress, its duration of application, and the age and genotype of the animal (Bloemhof et al., 2008) and which could be influenced by the animal housing environment as well as stage of the cycle or reproductive state of the animal at the time of the stress.

We did not observe an effect of light intensity on any measure of gilt reproductive performance but did note a trend for gilts in BRIGHT to have a slightly longer duration of estrus than gilts in DIM. However, because detection occurred only once daily, a difference of 3 h may not be of practical importance. However, considerable variation in light intensity is evident within and among confinement swine breeding barns, despite industry recommendations for a light intensity of 161 to 215 lx (Midwest Plan Service, 2001). Furthermore, seasonal effects on pig reproduction have also been attributed to the photoperiodic changes in animal exposure to light (Love et al., 1993). A review of the effects of light on reproduction in swine suggests minimal effect of light intensity per se but more so as a result of photoperiodicity (Claus and Weiler, 1985) and perhaps from the type of light supplied (Wheelhouse and Hacker, 1982). However there is some evidence to suggest that increasing lux level from 50 to 80 lx improved cyclic activity in prepubertal gilts and that born alive was improved when weaned sows received light intensity above 26 lx (PIGI, 2006). Melatonin is known to be involved in regulating the seasonal reproductive responses in mammals, and evidence from humans shows that melatonin release is responsive to both the intensity and duration of light (Aoki et al., 1998). However, in gilts, the impact of light intensity in the range of 40 to 10,000 lx is reported to have no effect on melatonin release during the scotophase (Tast et al., 2001) or on ACTH or cortisol secretion (Griffith and Minton, 1992). However, Paterson et al. (1992)

Table 5. Least squares means for cortisol, white blood cell measures and immune function assays for mature, synchronized gilts housed in crates and assigned to housing in COLD, 1 NEUTRAL, or HOT rooms, each with DIM 2 or BRIGHT lighting in the period from last feeding of Matrix (Merck Animal Health, Summit, NJ) through breeding and early gestation.

<table>
<thead>
<tr>
<th>Measure 3</th>
<th>Temperature (temp)</th>
<th>Lux (lx)</th>
<th>P-value temp</th>
<th>P-value lx</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLD 24</td>
<td>NEUTRAL 24</td>
<td>HOT 24</td>
<td>BRIGHT 36</td>
</tr>
<tr>
<td>Plasma cortisol, 3 ng/mL</td>
<td>25.9 ± 1.8 a</td>
<td>22.3 ± 1.9 b</td>
<td>20.9 ± 1.8 b</td>
<td>23.8 ± 1.5</td>
</tr>
<tr>
<td>White blood cells × 107 cells/mL</td>
<td>3.3 ± 0.1 a</td>
<td>3.5 ± 0.1 a</td>
<td>3.1 ± 0.1 b</td>
<td>3.2 ± 0.1</td>
</tr>
<tr>
<td>Neutrophils × 107 cells/mL</td>
<td>4.4 ± 0.2</td>
<td>3.79 ± 0.2</td>
<td>3.97 ± 0.2</td>
<td>3.89 ± 0.2</td>
</tr>
<tr>
<td>Lymphocytes × 107 cells/mL</td>
<td>3.9 ± 0.2</td>
<td>4.3 ± 0.2</td>
<td>4.5 ± 0.2</td>
<td>4.2 ± 0.2</td>
</tr>
<tr>
<td>Neutrophils, %</td>
<td>30.0 ± 1.2 a</td>
<td>24.4 ± 1.2b</td>
<td>25.2 ± 1.2 b</td>
<td>27.0 ± 0.97</td>
</tr>
<tr>
<td>Lymphocytes, %</td>
<td>64.0 ± 4.1</td>
<td>75.4 ± 4.2</td>
<td>68.1 ± 4.2</td>
<td>66.8 ± 3.4</td>
</tr>
<tr>
<td>Neutrophil/lymphocyte ratio</td>
<td>0.52 ± 0.04 a</td>
<td>0.40 ± 0.04 b</td>
<td>0.41 ± 0.04 b</td>
<td>0.45 ± 0.03</td>
</tr>
<tr>
<td>Monocytes, %</td>
<td>1.3 ± 0.2</td>
<td>1.5 ± 0.2</td>
<td>1.4 ± 0.2</td>
<td>1.3 ± 0.1</td>
</tr>
<tr>
<td>Eosinophils, %</td>
<td>3.3 ± 0.4</td>
<td>4.0 ± 0.4</td>
<td>4.3 ± 0.4</td>
<td>3.4 ± 0.3 a</td>
</tr>
<tr>
<td>C5a chemotaxis, cells/4 fields</td>
<td>51.9 ± 3.3</td>
<td>51.0 ± 3.5</td>
<td>50.8 ± 4.7</td>
<td>51.3 ± 3.0</td>
</tr>
<tr>
<td>IL-8 chemotaxis, cells/4 fields</td>
<td>72.7 ± 3.7</td>
<td>62.3 ± 4.0</td>
<td>74.8 ± 4.3</td>
<td>69.1 ± 3.2</td>
</tr>
<tr>
<td>Neutrophil phagocytosis, %</td>
<td>61.0 ± 1.7</td>
<td>58.4 ± 1.7</td>
<td>56.9 ± 1.7</td>
<td>58.5 ± 1.3</td>
</tr>
<tr>
<td>ConA proliferation index</td>
<td>1.3 ± 0.4</td>
<td>1.1 ± 0.4</td>
<td>2.0 ± 0.4</td>
<td>1.4 ± 0.3</td>
</tr>
<tr>
<td>LPS proliferation index</td>
<td>1.7 ± 0.2</td>
<td>1.7 ± 0.2</td>
<td>1.2 ± 0.2</td>
<td>1.5 ± 0.2</td>
</tr>
</tbody>
</table>

3For each main effect, means with different superscripts within a row are different (P < 0.05).
1COLD = 13.9 ± 0.2°C; NEUTRAL = 20.3 ± 0.2°C; HOT = 29.8 ± 0.1°C.
2DIM = 11 lx; BRIGHT = 433 lx.
3N:L = neutrophil-to-lymphocyte ratio; C5a = complement-5a; IL-8 = interleukin-8; ConA = concanavalin A; LPS = lipopolysaccharide.
4Proliferation index = optical density of stimulated cells divided by optical density of unstimulated cells; mitogen concentration 20 nM.
noted that the weak seasonal responses in the pig have made association of melatonin with fertility difficult even though clear diurnal effects in response to light are evident. Although the lighting effect and melatonin relationship remains unclear in the pig, an intriguing study recently revealed that the gene for the melatonin receptor in swine is located on the same chromosome as the genes controlling ovulation rate and litter size (Ramírez et al., 2009). Diurnal effects in the pig have been shown as exposure of pigs to approximately 250 lx during either their natural daytime or nighttime phases results in changes in the pulse frequency of LH in response to estradiol (Evans et al., 1994). In late gestation, exposure to short or long photoperiod in the range of 32 to 266 lx was observed to improve the synchrony (Stevenson et al., 1983) and proportion of sows expressing estrus after weaning (Tast et al., 2005) in response to season of year (Prunier et al., 1994).

We measured gilt body temperature and performance in response to temperature and light intensity with body temperature and weight gain being affected. Changes in pig body temperature in response to their environment have been previously reported (Edwards et al., 1968; d’Arce et al., 1970; Ømtvedt et al., 1971). In our study, gilts were restricted fed, and we noted no effects of room temperature on intake but did record changes in BW gain and body temperature. Gilts in HOT rooms had the greatest body temperatures and BW gains whereas gilts in COLD rooms had the least. These data indicate that for these individually housed gilts, room temperature evoked thermoregulatory responses in their attempt to maintain a thermoneutral state. Based on lack of BW gain among gilts in COLD it appears that more energy was needed for heat generation to maintain body temperature instead of growth. This effect of decrease in BW gain has been observed previously among gilts exposed to cold temperatures, but reproductive measures were not assessed (Verstegen and Curtis, 1988). For sows housed at temperatures above their thermal comfort zone, it has been shown that these animals have a decreased feed intake, increased water consumption, increased respiration rate (Brown-Brandl et al., 1998), and as gestation progresses may show increased weight loss (Heitman et al., 1951). Animal behavior is an important assessment as an indicator of adaptation to environmental challenges. Although no changes in behavior were noted in response to light intensity, room temperature evoked various thermoregulatory behaviors for gilts kept in either COLD or HOT environments. Postural changes have been noted in periparturient sows in response to thermal environment (Malmkvist et al., 2009). In the present study, gilts changed postural positions between standing and lying and spent more time in a particular lying position in response to room temperature in attempt to increase (HOT) or decrease (COLD) body surface area. Gilts changed positions more often from a standing to lying position in the HOT room and spent more of their time lying in a lateral position. The greater frequency of position changes and more time in the lateral lying position is likely a behavioral thermoregulatory process used to maximize heat dissipation via surface conduction to the concrete floor. Conversely, gilts in the COLD spent the least amount of time in the lying position and when lying spent the most amount of time in the ventral position to minimize heat loss by body surface contact with the concrete floor. Collectively, these behavioral changes suggest that gilts in each of the environments were behaviorally adapting to certain levels of thermal stress. Moreover, it appears that the gilts in HOT environment were better able to behaviorally regulate the loss of heat to their environment without compromising BW gain. However, gilts in COLD may have had some difficulty coping as indicated by their reduced BW gain, which could be related to energy expenditure associated with standing to avoid contact with the cold concrete floor. Another concern is that increased duration of COLD exposure beyond d 30 of gestation would prolong the physiological stress resulting in increased cortisol to aid in mobilizing body energy reserves away from growth and BW gain to sustain pregnancy and fetal growth. It was also evident that the exposure to COLD altered some of the immune cell measures and functional tests, which could also explain a diversion of energy from away from BW gain.

The effects of temperature were evident on cortisol concentration and a few measures of immune response whereas light intensity affected only 1 measure of immune function. Cortisol can be used as an indicator of stress in pigs (Becker et al., 1985), but much of the data suggests limited involvement of acute stress and cortisol on reproductive failure (Turner et al., 2005). However, in the present study, gilts in the COLD temperature showed the greatest cortisol concentrations and without any detrimental effect on reproduction. Temperatures higher or lower than the thermal comfort zone of an animal can cause stress and, if animals are unable to adapt, can eventually be challenging to health and well-being (Webster et al., 1993). Data from the present experiment indicated that gilts in the COLD temperature were most likely stressed. Hyun et al. (2005) reported that an increased neutrophil:lymphocyte (N:L) ratio is an indicator of a stress response. Based on the behavioral changes, cortisol, and N:L ratio it is plausible that those gilts kept in COLD rooms were experiencing stress and were having difficulty coping with their environment, which resulted in reduced BW gain. Furthermore, the gilts in the HOT room, although also under some stress,
were able to make postural changes to adapt without evoking changes in cortisol or immune status.

The results of the present study indicate that variation in air temperature in the range of 15 to 30°C and light intensity variation from 11 to 433 lx would not be expected to be associated with failure in estrus expression, ovulation, embryo, or pregnancy loss for breeding females housed in crates. However, it would appear that if breeding swine are exposed to cold temperatures for an extended duration during housing in confinement, the stress response could alter use of body reserves and energy intake for thermoregulatory rather than growth processes. As a result, this could ultimately lead to physiological changes that could affect well-being, productivity, and longevity. With considerable differences among farms in building temperature regulation, herd genotype, and within-farm variation in herd parity structure, there would seem to be great potential for effects of animal microenvironment on individual health status and well-being. Therefore, to minimize potential problems in animal health and well-being, evaluation of different locations within barns for temperature variation, especially in seasonal extremes, could prove helpful for managing at risk animals. Furthermore, in certain locations within barns, there may be some advantages in providing supplemental heat, cooling, or provision of additional feed where problems occur. Producers may be able to place less mature, lighter, or leaner animals into warmer areas and leave cooler areas for older, larger sows. Lastly, because there was no impact of light intensity on any measures of reproduction and limited effect on well-being, producers may be able to reduce lighting level to reduce energy needs without effects on reproductive performance.

**LITERATURE CITED**


