Does Feed Restriction Mimic the Effects of Increased Ambient Temperature in Lactating Sows?¹

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ABSTRACT: We evaluated the effects of high ambient temperature and feed restriction in primiparous lactating sows. Females were exposed to either a constant thermoneutral (20°C) or hot environment (30°C). Lactating sows at 30°C were given free access to feed (30AL; n = 12), and sows at 20°C were restricted according to the feed intake recorded at 30°C (20RF; n = 6) or were given free access to feed (20AL; n = 6). Jugular vein catheters were surgically inserted at 100 ± 1 d postcoitum. During lactation, 30AL sows exhibited higher rectal temperatures (P < .05) than 20AL and 20RF sows. Feed intake was reduced by 43% for 30AL compared with 20AL sows. Daily body weight loss was lower (P < .05) in the 30AL than in the 20RF group, and mean litter daily gain over the whole lactation was 18% lower in 30AL than in 20AL sows (P < .05). Plasma concentrations of thyroid hormones (triiodothyronine [T₃] and thyroxine [T₄]) were lower at 30°C than at 20°C at d 4 postpartum and d 8 after weaning for T₄ (P < .001) and at d 4 postpartum (P < .001) and at d 1 and d 8 after weaning for T₃ (P < .01) but were not influenced by feed restriction at 20°C. Mean concentrations of cortisol measured on d 4 and 19 postpartum and on d 1 after weaning were lower in the 30AL than in the 20AL group (P < .05), and neither was different from that in 20RF sows. Ambient temperature and feed intake had no influence on prolactin concentrations on d 19 postpartum and d 1 after weaning. In the 30AL group, concentrations of T₃, cortisol, and prolactin measured at d 19 postpartum were positively correlated with the litter gain observed during the 2nd and 3rd wk of lactation (P < .05). The return to estrus was slightly delayed in 20RF compared with 20AL sows (P < .05) and was quite variable in the 30AL group. These results demonstrate that high ambient temperature has negative consequences on litter growth and return to estrus and induces plasma hormonal variations, that cannot be fully mimicked by feed restriction in primiparous sows.

Key Words: Sows, Temperature, Feed Intake, Lactation, Reproduction


Introduction

Lactating sows are frequently exposed to ambient temperatures higher than the upper critical temperature, which is about 22°C (Black et al., 1993). To avoid excessive increase in body temperature, sows increase heat loss, particularly from the lungs through higher respiratory rate (Black et al., 1993). They also decrease heat production by reducing feed intake and milk production (Schoenherr et al., 1989; Black et al., 1993; Prunier et al., 1997). Another consequence of elevated ambient temperatures is inhibition of reproductive function with delayed puberty attainment (Flowers et al., 1989) and prolonged weaning-to-estrus interval (Prunier et al., 1997). In most of the published data, all sows were fed to appetite, and the effects of hot environment could be explained, at least in part, by the decrease in feed intake (Prunier et al., 1996). The purpose of the present study was to investigate whether the effects of elevated ambient temperatures on reproductive performance of sows are only due to the decrease in voluntary feed intake.

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Materials and Methods

Animals and Experimental Design

A total of 24 Piétrain × Large White females were used for the experiment in two replicates of 12 females. Gilts were inseminated with fresh Large White semen after estrus synchronization with Regumate® (17α-allyl-trenbolone, Roussel-Uclaf, 93235 Romainville, France; a daily dose of 20 mg as a top dressing on the feed for 18 d). Females were allocated to one of three treatment groups (thermoneutral [20°C] with free access to feed, 20AL, n = 6; thermoneutral [20°C] with restricted feed, 20RF, n = 6; or hot environment [30°C] with free access to feed, 30AL, n = 12) when they were moved from the gestation to the farrowing rooms at 84 ± 1 d postcoitum (p.c.) (mean ± SD). Two identical farrowing rooms that accommodated six females each were used. Females remained in these rooms until the end of the experiment at d 12 after weaning. A constant thermoneutral (20°C) or hyperthermal (30°C) environment was maintained. Temperature in the hyperthermal room was initially set at 21°C and was raised daily by 3°C over a 3-d period. Relative humidity was not artificially controlled and was higher at 20°C (replicate 1: 65 ± 9%; replicate 2: 81 ± 10%) than at 30°C (replicate 1: 46 ± 8%; replicate 2: 63 ± 13%) in both replicates (P < .05). Artificial light was provided for 8 h/d throughout the experiment. Females were tethered in farrowing crates measuring 2.1 × 2.2 m. The floor was concrete covered with fresh straw daily.

When it was not initiated spontaneously, parturition was induced by the injection of 2 mL of Planate® (synthetic prostaglandin, Mallinckrodt VeÂtérinaire S.A., Meaux, France) at 113 d of gestation. Sows of each replicate farrowed within three consecutive days. In the 20°C environment, heater bars were provided for heating young pigs in a corner of the pen. Litters were standardized at 8 to 10 pigs within 48 h after parturition. Conventional pig management was followed, including iron dextran injection at birth and at 10 d of age, tail clipping at birth, and male castration at 10 d of age. During the overall lactation, no creep feed was offered to the pigs; water was freely available from nipple drinkers. Weaning occurred at 20 ± 1 d of age at 1500.

During gestation and after weaning, females were fed 2.5 and 3.0 kg/d, respectively, of a standard diet providing 3.04 Mcal of DE/kg, 12.5% CP, and 51% lysine. During lactation, they were offered a standard diet providing 3.15 Mcal of DE/kg, 17.2% CP, and 85% lysine. All females were fed 1.0 kg of this diet at farrowing and 2.5 by the day after. Thereafter, 20AL and 30AL sows were given free access to feed. Feed refusals were collected daily at 0800 and new feed was distributed at 0800 and 1400. Feed intake was calculated daily and the average intake determined on the six sows maintained at 30°C was given on the following day to the 20RF sows from d 3 postpartum (p.p.). On d 2 p.p., 20RF sows received 3.5 kg of feed. Water was available for ad libitum consumption from nipple drinkers throughout the experiment.

Live pigs were weighed within 14 h after birth and at 1, 2, and 3 wk of age. Daily means of litter weight gain were calculated for statistical analyses. Rectal temperature of the sows was monitored twice weekly at 1400 before the afternoon meal, throughout the experiment. Sows were weighed after farrowing and at weaning. Backfat thickness was ultrasonically measured after farrowing and weaning in three sites (shoulder, back, and loin at 65 mm from the midline), and the mean was calculated for statistical analyses. From the day after weaning, sows were checked twice daily for signs of estrus with a mature boar.

Blood Samples and Hormonal Analyses

At 100 ± 1 d p.c., an indwelling Silastic® (Dow Corning, Midland, MI) catheter was surgically inserted into the right jugular vein under general anesthesia as previously described (Camous et al., 1985). Single blood samples were collected at 1030, via the catheter, at 110 ± 1 d p.c., at 4 ± 1 and 19 ± 1 d p.p., and at d 1, 8, and 12 postweaning (p.w.). Serial blood samples were collected every 20 min from 1100 to 1700 at d 4 and 19 p.p., and at d 1 p.w. Blood samples were collected in tubes containing 100 μL of EDTA (144 mg/mL) and placed immediately on ice. Plasma was obtained by centrifugation and stored at −20°C until assay.

All samples of one replicate were analyzed in duplicate within single assays except for prolactin. For this latter hormone, samples of both replicates were analyzed in only one assay.

Plasma thyroxine (T4) and triiodothyronine (T3) concentrations were quantified on single samples collected at d 110 p.c., d 4 and 19 p.p., and d 1 and 8 p.w. using commercially available RIA kits (ICN Biochemicals, Costa Mesa, CA). For T4, sensitivity was 5 ng/mL and the intra- and interassay CV at 40 ng/mL were 5.3 and 11.3%, respectively. For T3, sensitivity was .2 ng/mL, and the intra- and interassay CV at .83 ng/mL were 3.5 and 12%, respectively.

Plasma cortisol was quantified using a validated RIA (Meunier-SalauÈn et al., 1991) in serial samples collected hourly at d 4 and 19 p.p. and at d 1 p.w. Sensitivity was 2.5 ng/mL, and intra- and interassay CV at 22 ng/mL were 3.3 and 21.1%, respectively. For each profile, mean concentration was calculated and used in subsequent statistical analyses.

Concentrations of prolactin (PRL) were determined by RIA in serial samples collected every 20 min at d 19 p.p. and every 60 min at d 1 p.w. Validated assay reagents were provided by A. F. Parlow (Pituitary Hormones and Antisera Center, Harbor-UCLA Medical Center). Iodination was performed with chloramine T. Purified pPRL (AFP-9764B) was
used for iodination and as the reference preparation. Rabbit anti-pPRL (AFP-084255) was used at a final dilution of 1:200,000. Cross-reactions with pGH (AFP-10864B), pFSH (AFP-10640B), pLH (AFP-49328), and pTSH (AFP-10704B) were less than .1%. Serial dilutions of plasma from one lactating sow were parallel to the standard curve. Recovery of different amounts of exogenous pPRL (50 to 5,000 pg/tube) added to 50 μL of plasma containing 1 ng PRL/mL was 1.09 ± .02% (mean ± SE, n=12). Sensitivity was 1 ng/mL, and the intra-assay CV was 6.6% at 8.6 ng/mL. For each profile, mean concentration was calculated and used in subsequent statistical analyses.

A direct RIA (Terqui and Thimonier, 1974) was performed at d 12 p.w. to determine whether progesterone (P4) concentration was higher than 5 ng/mL, which indicates that ovulation had occurred.

**Statistical Analyses**

Percentages of cyclic females after weaning were compared by chi-squared analysis. Other comparisons were performed by analysis of variance using the GLM procedure of SAS (1989) with replicate and treatment as main effects and the interaction between these two factors. For rectal temperatures and hormonal concentrations, split-plot models were used that included sow nested within treatment × replicate, day of sampling, and treatment × day as sources of variation. The effects of replicate, treatment, and treatment × replicate were tested using sow within treatment × replicate as the error term. The effects of day of sampling and treatment × day were tested using the residual error term. For characteristics of sows at weaning and variations during lactation, a covariate (body weight or backfat at farrowing) was included in the statistical model. For live weight at birth and at weaning, number of pigs at birth and at weaning, respectively, was included as a covariate. Similarly, for daily litter weight gain per week, live weight of the litter at the beginning of each week was included as a covariate. In the event of a significant treatment × day interaction, differences between days were determined within treatments, and differences among treatments were determined within days. Treatment means were separated using the Bonferroni t-test. Within the 30AL group (n = 12), Pearson correlations were calculated to check that hormone levels and litter growth were significantly correlated.

**Results**

There was a treatment × day interaction for rectal temperature (P < .001). At the end of gestation, rectal temperature was similar in 20AL and 20RF sows (P > .1) and was lower than in 30°C sows (P < .05) (Figure 1). During lactation, 30AL sows exhibited higher rectal temperatures than 20AL and 20RF sows (P < .05). The difference between 30AL and 20RF sows was always significant, except at d 12 p.p. At the end of lactation (d 19 and 21 p.p.), rectal temperature was lower in the 20RF than in the 20AL group (P < .05). In the three groups, rectal temperature was higher during lactation than before farrowing and after weaning (P < .05).

For ad libitum sows, average daily feed intake calculated for the overall period of lactation was 43% lower at 30 than at 20°C (P < .05) (Table 1). Feed consumption of 20RF and 30AL sows was similar.

Body weight and backfat thickness at farrowing were similar in the three groups of sows (Table 1). Live weight losses during lactation were lower in 20AL than in 30AL sows (P < .05) and in 30AL than in 20RF sows (P < .05). Daily backfat loss was lower in 20AL than in 30AL and 20RF females (P < .05), but the difference between 20RF and 30AL sows was not significant.

Total number of pigs at birth (10.2 ± .6 pigs), number born alive (9.8 ± .5 pigs), number present at d 2 p.p. (8.6 ± .1 pigs), and number dead (.3 ± .1 pigs) during lactation were similar in the three groups (P > .10). There was no significant effect of treatment on live weight of pigs at birth (1,290 ± 33 g) and at weaning (6,082 ± 150 g). However, mean litter daily gain over the whole lactation was lower in the 30AL than in the 20AL group (20AL: 2,048 ± 104 g/d; 20RF: 1,965 ± 83 g/d; 30AL: 1,618 ± 88 g/d; P < .05). During the 1st wk of lactation, treatment had no influence (P > .10) on the litter daily gain (Figure 2). During the 2nd wk of lactation, litter daily gain was lower in 30AL than in 20AL sows (P < .05), and neither was
Table 1. Body weight and backfat depth changes during lactation for first-litter sows (mean ± SE)

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatmenta</th>
<th>Statistical significanceb</th>
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<tbody>
<tr>
<td></td>
<td>20AL (n = 6)</td>
<td>20RF (n = 6)</td>
</tr>
<tr>
<td>Feed intake, kg/d</td>
<td>4.9 ± .10c</td>
<td>3.1 ± .02d</td>
</tr>
<tr>
<td>Sow body weight, kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farrowing</td>
<td>179 ± 3</td>
<td>190 ± 6</td>
</tr>
<tr>
<td>Weaningc</td>
<td>171 ± 1c</td>
<td>159 ± 4d</td>
</tr>
<tr>
<td>Daily change</td>
<td>−.39 ± .19c</td>
<td>−1.50 ± .23c</td>
</tr>
<tr>
<td>Backfat thickness, mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farrowing</td>
<td>15.5 ± 31</td>
<td>16.1 ± .37</td>
</tr>
<tr>
<td>Weaningd</td>
<td>14.6 ± .57</td>
<td>12.6 ± .22</td>
</tr>
<tr>
<td>Daily change</td>
<td>−.04 ± .03c</td>
<td>−.17 ± .02d</td>
</tr>
</tbody>
</table>

a20AL = sows fed to appetite during lactation and maintained at 20°C. 20RF = sows feed-restricted during lactation and maintained at 20°C. 30AL = sows fed to appetite during lactation and maintained at 30°C.
bStatistical significance of treatment indicated by **P < .01 and ***P < .001.
c,d,eMeans within a row lacking a common superscript letter differ (P < .05).
gEffect of body weight at farrowing as covariate, P < .001.
hEffect of backfat thickness at farrowing as covariate, P < .001.

...differ from that in 20RF sows. During the 2nd wk of lactation, litter gain differed between the three groups (P < .05).

The treatment × day interaction was significant for T4 (P < .01) and T3 (P = .06). Therefore, comparisons were made within each series of blood samplings (Figures 3 and 4). Plasma concentrations were lower at 30°C than at 20°C at d 4 p.p. and at d 8 p.w. (P < .001) for T4 and at d 4 p.p. (P < .001) and at d 1 (P < .01) and d 8 p.w. (P < .001) for T3. However, no effect of feed restriction on thyroid hormones was observed in sows maintained at 20°C. Within each stage of sampling, plasma T4 and T3 concentrations were positively correlated (P < .01). In the 30AL group, concentration of T3 measured at d 19 p.p. was positively correlated with the litter daily gain ob-

Figure 2. Effect of high ambient temperature and feeding regimen on daily litter gain. Values are means ± SE. Within week of measurement, means lacking a common letter differ (P < .05). Effect of live weight of litters at birth and d 7 and 14 postpartum as a covariate was significant (P < .05) for litter weight gain during wk 1, 2, and 3, respectively. 20AL = sows fed to appetite during lactation and maintained at 20°C. 20RF = sows feed-restricted during lactation and maintained at 20°C. 30AL = sows fed to appetite during lactation and maintained at 30°C.

Figure 3. Effect of high ambient temperature and feeding regimen on plasma thyroxine. Values are means ± SE. Analysis of the data revealed a significant treatment × day interaction (P < .01). Within day of sampling, means lacking a common letter differ (P < .05). 20AL = sows fed to appetite during lactation and maintained at 20°C. 20RF = sows feed-restricted during lactation and maintained at 20°C. 30AL = sows fed to appetite during lactation and maintained at 30°C. p.c. = postcoitum, p.p. = postpartum, p.w. = postweaning.
Figure 4. Effect of high ambient temperature and feeding regimen on plasma triiodothyronine. Values are means ± SE. Analysis of the data revealed a close to significance treatment × day interaction ($P = .06$). Within day of sampling, means lacking a common letter differ ($P < .05$). 20AL = sows fed to appetite during lactation and maintained at 20°C. 20RF = sows feed-restricted during lactation and maintained at 20°C. 30AL = sows fed to appetite during lactation and maintained at 30°C. p.c. = postcoitum, p.p. = postpartum, p.w. = postweaning.

Figure 5. Effect of high ambient temperature and feeding regimen on plasma cortisol. Values are means ± SE. Analysis of the data showed no treatment × day interaction ($P > .1$) but a significant effect of temperature ($P < .05$). 20AL = sows fed to appetite during lactation and maintained at 20°C. 20RF = sows feed-restricted during lactation and maintained at 20°C. 30AL = sows fed to appetite during lactation and maintained at 30°C. p.p. = postpartum, p.w. = postweaning.

Discussion

The present data demonstrate that the effects of elevated ambient temperature on sow and litter performance as well as on endocrine data of sows could not be fully mimicked by feed restriction. One of the most obvious consequences of elevated temperature is an increase in the rectal temperature, in agreement with previous studies (Lynch, 1977; Hoagland and Wetteman, 1984; Schoenherr et al., 1989). This suggests that evaporative and non-evaporative heat losses were not sufficient to dissipate metabolic heat production in sows maintained in a hot environment. Mechanisms of heat dissipation are less efficient in pigs than in other animals, such as cattle and sheep, probably because of the relatively low density of functional sweat glands (Mount, 1968).

Lower relative humidity at 30°C than at 20°C may have increased heat losses by evaporation and attenuated the potential effects of elevated ambient temperature (Morrison et al., 1969). Although mean rectal temperature during lactation increased to 40.3 ± 1°C in the 30AL group, none of the sows reached the upper lethal body temperature, which has been reported to be 42°C (Pullar, 1949; Curtis, 1983).

Other important consequences of elevated ambient temperature are lower voluntary feed intake, which is in agreement with previous studies (Lynch, 1977; Barb et al., 1991; Black et al., 1993), and decreased body reserve mobilization, as already observed by Prunier et al. (1997). These reductions represent metabolic adaptations to reduce the amount of heat produced via digestive and metabolic processes and hence to limit the increase in body temperature. The
Thyroid hormones are considered to be key hormones in controlling heat production in homeothermic animals (McNabb, 1995) and to play an important role in mammary gland development and function (Vonderhaar and Greco, 1979; Bhattacharjee and Vonderhaar, 1984). They stimulate oxygen consumption and protein synthesis by the mammary gland (Cabell and Esbenshade, 1990). Significant decreases in plasma T4 and T3 associated with increased ambient temperature are consistent with previous studies in growing pigs (Ingram and Slebodzinski, 1965; Evans and Ingram, 1977; Macari et al., 1986) and in lactating sows (Prunier et al., 1997). Similarly, plasma levels of thyroid hormones were depressed in lactating cows (Johnson and Vanjonack, 1975; Johnson et al., 1991) and in mares (Katoch et al., 1974) under elevated temperature. Decrease in plasma concentrations of T4 and T3 in 30AL sows can be regarded as an adaptive mechanism to reduce heat production. Feed restriction during lactation had no clear influence on plasma thyroid hormones in our experiment, in agreement with Brendemuhl et al. (1987) and Giesemann et al. (1989), who showed no influence of energy intake in lactating sows. Studies conducted with rats (Glass et al., 1978), growing pigs (Grigio and Ingram, 1985), and lactating sows (Giesemann et al., 1989) suggest that energy status has only marginal effects on circulating levels of T4. At 20 and 30°C, plasma T4 increased after weaning, in agreement with previous results in sows (Brendemuhl et al., 1987) and other animals (Lorscheider and Reineke, 1971; Katoch et al., 1974; Johnson et al., 1991).

Corticosteroids seem to play a positive role in maintenance of lactation (Hansel, 1985) and favor mobilization of body energy reserves and heat production (Baxter and Forsham, 1972). Therefore, lower cortisol concentrations in sows exposed to 30°C probably contribute to decreased heat production. Similar chronic effects of elevated temperature on corticoid levels were previously observed in lactating sows maintained under a controlled environment (Barb et al., 1991; Prunier et al., 1997) or sampled during summer (Marple et al., 1972; Wrathall, 1987) as well as in other ungulates in controlled environments (Stott and Robinson, 1970; Olsson et al., 1995). Feed restriction has no clear effect on plasma cortisol concentrations in lactating sows maintained at 20°C. This is in agreement with previous results obtained in feed-restricted (Prunier et al., 1993b) and feed-deprived peripubertal gilts (Barb et al., 1997). In contrast, Baidoo et al. (1992) observed higher cortisol levels in feed-restricted lactating sows.

Because thyroid hormones and cortisol are catabolic and modulate nutrient partitioning toward milk production (Motil et al., 1994), the decrease in plasma concentrations of these hormones during thermal stress contributes to limit body reserve mobilization and to decreased milk production. The lack of an influence of chronic heat exposure on plasma prolactin is consistent with previous observations in growing pigs (Matteri and Becker, 1996), cyclic gilts (Kraeling et al., 1987), and lactating sows (Barb et al., 1991). In contrast, in heifers and cows, plasma prolactin is increased under elevated temperatures (Thatcher, 1974; Wettemann and Tucker, 1974; Stephenson et al., 1980). Reduction in feed intake at 20°C had no effect on plasma prolactin in lactating sows, in accordance with Baidoo et al. (1992). The dramatic decrease of plasma prolactin after removal of the pigs to about 15% of the levels measured before weaning is in agreement with previous reports (Bevers et al., 1978; Stevenson et al., 1981; Edwards and Foxcroft, 1983).

In agreement with studies comparing females maintained under controlled temperature (Schoenherr et al., 1989; Black et al., 1993) or submitted to seasonal variations (Xue et al., 1994; Azain et al., 1996), our results show a significant depressant effect of elevated ambient temperature on litter growth. Contrarily, reduction of feed intake at 20°C had no clear effect on litter growth in accordance with previous studies (Noblet and Etienne, 1986; Prunier et al., 1993a). Assuming that litter weight gain is indicative of milk production (Lewis et al., 1978; Noblet and Etienne, 1989), the temperature-related decrease probably reflects a decline in milk production. This hypothesis is in accordance with the observations of Schoenherr et al. (1989) showing a nonsignificant decrease of 10% in daily milk production over a 22-d lactation and those of Barb et al. (1991) recording a significant decline of 25% on d 21 of lactation in sows maintained at 32°C compared with 20°C. Mechanisms explaining the direct influence of

<table>
<thead>
<tr>
<th>Weaning-to-estrus interval, d</th>
<th>20AL (n = 6)</th>
<th>20RF (n = 6)</th>
<th>30AL (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 6</td>
<td>5</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>7 to 11</td>
<td>1</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>&gt; 11</td>
<td>0</td>
<td>1</td>
<td>4</td>
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*20AL = sows fed to appetite during lactation and maintained at 20°C. 20RF = sows feed-restricted during lactation and maintained at 20°C. 30AL = sows fed to appetite during lactation and maintained at 30°C.
elevated ambient temperature on milk yield are not known. It can be hypothesized that nutrient supply to the mammary gland is not sufficient to support normal milk synthesis because feed intake and mobilization of body reserves are depressed at 30°C. Thus, in contrast to sows maintained within the zone of thermoneutrality, which are able to compensate for feed restriction by mobilizing more body reserves, sows at 30°C lose this capability. Second, a deficiency in nutrient supply to the mammary gland may be related to a redistribution of blood flow to the skin in order to increase heat losses (Black et al., 1993). Third, the reduction in milk production may be related to a lower influence of T₄, T₃, and cortisol on the mammary gland. This hypothesis is supported by the decrease in plasma concentrations of these hormones at 30°C and by the existence of positive correlations between hormone concentrations and litter weight gain in the 30AL group.

Present results showing that feed restriction under thermoneutrality increases the weaning-to-estrus interval are in accordance with Aherne and Kirkwood (1985) and Dourmad et al. (1994). The weaning-to-estrus interval was quite variable in sows maintained at 30°C. One-third of 30AL sows came into estrus 5 to 6 d after weaning, similarly to full-fed sows, one-third had a slightly delayed weaning-to-estrus interval, similarly to restricted sows maintained at 20°C and one-third had a strongly delayed interval. Delayed return to estrus after weaning was already observed in summer compared with winter (Clark et al., 1986; Prunier et al., 1994; Azain et al., 1996) or in females maintained under controlled high ambient temperature (Prunier et al., 1997). This influence of ambient temperature on the return to estrus after weaning is mediated, at least in part, by its effect on the mammary gland is not fully mimicked by feed restriction, other endocrine mechanisms of adaptation to heat stress may be occurring. It has been observed that LH secretion is decreased under elevated ambient temperature in lactating dairy cows (Wise et al., 1988), prepubertal gilts (Flowers and Day, 1990), and lactating sows (Barb et al., 1991). Therefore, inhibition of LH secretion may have occurred in our sows and contributed to delay the return to estrus after weaning.

### Implications

Present data show that constant elevated ambient temperature has negative consequences on litter growth and return to estrus of sows after weaning. These effects are probably due to metabolic and endocrine adaptations to avoid hyperthermia. Sows reduce feed intake to reduce heat production, but the reduction in feed intake alone has only minor effects on sow performance and on secretion of thyroid hormones, cortisol, and prolactin. Additional research is necessary to quantify and understand these effects.

### Literature Cited


