HORMONAL PATTERNS OF BOARS EXPOSED TO NATURAL OR SUPPLEMENTAL LIGHTING DURING PUBERTAL DEVELOPMENT1,2

K. H. Lee3, M. A. Diekman4, K. E. Brandt,
D. M. Grieger and R. D. Allrich

Purdue University5
West Lafayette, IN 47907

ABSTRACT

Thirty-two crossbred boars (Hampshire X Duroc X Yorkshire) were reared under natural lighting (35 lx) or supplemental lighting (1,400 lx) beginning at 4 wk of age. Boars received supplemental lighting from six 40-W fluorescent bulbs between 0530 and 2030 in a nursery unit. From 9 to 32 wk of age, boars received either natural lighting (30 lx) or supplemental lighting (100 lx) in a growing-finishing unit. Blood samples were collected from indwelling cannulae at 20-min intervals for 6 h every 2 wk from 2.5 to 7 mo of age. Libido scores were evaluated during alternate weeks when intensive blood samples were not taken. Libido scores were not different between natural and supplemental lighting treatments (P > .30). However, at 122 d of age, libido scores of boars exposed to supplemental lighting tended to be higher (P = .10) than those exposed to natural lighting. Although mean serum concentrations of luteinizing hormone (LH) were higher (P < .05) in boars at 75, 89, 103 and 131 d of age reared under supplemental lighting than boars of the same age reared under natural lighting, the number of LH secretory spikes was similar between the treatment groups (P = .39). Serum concentrations of LH decreased in both treatment groups as boars became older (P < .05). However, the incidence of LH spikes was similar across ages and between treatment groups from 2.5 to 7 mo of age. Mean serum concentrations of follicle stimulating hormone and testosterone were similar between treatments (P > .75).

(Key Words: Boar, Puberty, Supplementary Light, LH, FSH, Testosterone.)

Introduction

The onset of mating behavior and the minimum age for successful collection of semen in boars has been shown to be accelerated by exposure to extended photoperiods (Mahone et al., 1979; Berger et al., 1980; Hoagland and Diekman, 1982). These data indicated that supplemental lighting had some accelerating effects on puberty in boars. However, serum concentrations of luteinizing hormone (LH), follicle stimulating hormone (FSH) and testosterone were not affected by supplemental lighting when measured in blood samples collected biweekly (Hoagland and Diekman, 1982; Brandt and Diekman, 1985).

Gilts, exposed to boars and supplemental lighting during periods of decreasing daylength, attained puberty an average of 20 d earlier than gilts that received boar exposure alone (Diekman and Hoagland, 1983). The effectiveness of supplemental lighting on decreasing the age of puberty in gilts appears to be dependent upon season since exposure of gilts to supplemental lighting during periods of increasing daylength had no effect on age of puberty. Supplemental lighting did not alter serum concentrations of LH, FSH or prolactin in either experiment (Diekman and Hoagland, 1983), but frequent blood samples (20-min intervals for 4 h) were not drawn until gilts were 6 mo of age. Therefore, the objectives of the present investigation were to determine average serum concentrations of LH, FSH and testosterone in boars exposed to natural or supplemental lighting during pubertal development.
concentrations of LH, FSH and testosterone and the secretory pattern of serum LH when frequent blood samples were drawn every 20 min for 6 h from prepubertal boars exposed to natural or supplemental lighting beginning at 2.5 mo of age.

**Materials and Methods**

**Animals.** Sixteen crossbred boars (Hampshire × Duroc × Yorkshire) at the Baker-Purdue Swine Center were placed in two pens of the upper deck of the nursery unit (1.6 m²/pen) following weaning at 4 wk of age and received natural daylight through windows with light intensity of 35 lx. Sixteen boars were randomly assigned to supplemental-lighted treatment group and received illuminance of 1,400 lx from six 40-W cool fluorescent bulbs from 0530 to 2030 each day. At 9 wk of age, boars from both treatment groups were moved into four slatted, reinforced-concrete floor pens (7.2 m²/pen) of a growing and finishing environmentally regulated building. Both treatment groups received natural lighting through the windows (.3 m³) of the building, which were located 1.7 m above the pen floor. Light intensity of 30 lx was measured .5 m above the floor. A solid partition prevented the supplemental lighting from reaching the boars in the natural-lighted treatment group. Boars were exposed to natural or supplemental lighting from August 9, 1982 through March 3, 1983. Lights were regulated by an automatic timer to be on continuously from 0530 to 2030 each day.

A 16% crude protein corn-soybean diet supplemented with minerals and vitamins was fed to the boars until they weighed 55 kg, and then a 14% crude protein diet was used through the end of the experiment. Boars were fed ad libitum until 185 d of age when body weight averaged 110 kg. Subsequent daily dietary intake was limited to an average of 1.1 kg/boar.

Sexual behavior of boars was evaluated biweekly from 122 to 220 d of age. Libido was assessed by observation of the boar's behavior during a 20-min exposure to an ovariectomized gilt in estrus. Estrus was induced in gilts by injection of 1 mg estradiol cypionate 3 d before behavior was evaluated. Libido scores were assigned as follows: 1, no sexual interest; 2, minimal sexual interest but no attempts at mounting; 3, mounting with incorrect orientation for semen collection; 4, a single mount with proper orientation, but no semen collection; 5, several mounts with proper orientation, but no semen collection and 6, successful mounting and collection of semen.

From 75 to 215 d of age, blood samples were taken from indwelling jugular cannulae (Diekman and Hoagland, 1983) from eight boars in each treatment group every 2 wk. Intensive blood sampling periods occurred on alternate weeks when libido scores were not measured. Blood samples were collected from each cannulated boar at 20-min intervals for 6 h (19 samples/boar). After blood samples were allowed to clot overnight at 4 C, serum was separated by centrifugation at 2,500 x g for 30 min and then stored at −20 C until assayed.

**Measure of Serum Hormones.** A previously reported and validated radioimmunoassay (RIA) was used to quantify plasma concentrations of testosterone (Gay and Kerlan, 1978; Brandt and Diekman, 1985). Of 21 different steroids tested, only dihydrotestosterone (DHT) significantly cross-reacted (69%) with the antiserum used (S250, sheep anti-testosterone-11-bovine serum albumin). Because serum DHT concentrations have been reported to be .7 ng/ml in mature boars (Schanbacher, 1976), the reported levels of testosterone may represent a combination of testosterone and DHT. One-half milliliter of serum from each of the 19 blood samples per boar was pooled and all pooled samples from the 11 age periods were analyzed in a single assay. Recovery of 3H-testosterone added to plasma before extraction averaged 87.8 ± 2%. Sensitivity of the assays was 20 pg/tube (100 pg/ml). Intra-assay and inter-assay coefficients of variation were 9.3 and 11.8%, respectively.

Serum LH was quantified by RIA (Niswender et al., 1970; Diekman and Hoagland, 1983) with porcine LH (LER-786-3) used as the radioiodinated antigen and standard. Sensitivity of the assays was .04 ng/tube (.13 ng/ml). Recovery of six quantities of pLH (.1 to 2.5 ng) added to 300 μl of serum containing .1 ng LH/ml was 104.4 ± 4.6%. When serum samples were measured at volumes ranging from 100 to 300 μl, curves were parallel to standard curves. Intra-assay and inter-assay coefficients of variation were 9.6 and 10.8%, respectively.

---

*General Electric Light Meter, type 214, Cleveland, OH.*
Concentrations of serum FSH were quantified by RIA (Van de Wiel et al., 1981) using porcine FSH (Ryan, II A3-Cs) as the radioiodinated antigen and standard. Sensitivity of the assay was .2 ng/tube (1 ng/ml). Recovery of six quantities of porcine FSH (0.8 to 12.5 ng) added to 100 μl of serum containing 0.5 ng FSH/ml was 110 ± 6.3%. When serum samples were measured at volumes ranging from 50 to 300 μl, curves were parallel to standard curves. Intra-assay and inter-assay coefficients of variation for serum FSH were 11.6 and 14.8%, respectively. When pituitary extracts were measured at volumes ranging from 50 to 200 μl, curves were parallel to standard curves.

**Statistical Analyses.** To determine the number of secretory spikes of serum LH per sampling period for each boar, the following procedure was used. A baseline was established by averaging all values from 19 blood samples at the same bleeding period and removing any values that were greater than 2 SD from this baseline. This process was repeated until all the values forming the baseline were within 2 SD of each other. Any value from the 19 samples was then classified as a peak if it was greater than 2 SD from the final calculated baseline, and was immediately followed by a value that was at least 1 SD higher than the final baseline. A nonparametric statistic, the Kruskal-Wallis rank test (Hollander and Wolfe, 1973), was used to test for differences in frequency of LH peaks among different ages and treatments, and differences in libido scores between treatment groups. For FSH, 19 blood samples from a 6-h intensive sampling period were collected from each boar from each age period. These samples were pooled and analyzed in duplicate.

Serum concentration of LH, FSH and testosterone were subjected to a univariate analysis of repeated measures designed by BMDP2V (BMDP, 1977), with treatment and age as fixed factors. Differences among means were tested by Newman-Keuls' sequential range test (Steel and Torrie, 1980).

**Results**

**Libido Scores.** Because libido scores were similar (P>.05) in boars that were cannulated biweekly and those that were not, the data were combined and presented in table 1. In both treatment groups, libido scores increased as boars became older (P<.01). No differences in libido scores were detected between natural- and supplemental-lighted boars (P>.30). However, at 122 d of age, libido scores of boars exposed to supplemental lighting tended to be higher (P=.10) than those reared in natural light.

**LH.** Mean serum concentrations of LH in boars exposed to natural or supplemental lighting are presented in table 2. Average serum concentrations of LH among the age x treatment subgroups ranged from .92 to .17 ng/ml. Mean serum concentrations of LH decreased with age except for a peak observed at 117 d of age. Average serum concentrations of LH in supplemental-lighted boars were higher (P<.05) than natural-lighted boars at 75, 89, 103 and 131 d of age.

**LH Secretory Spikes.** Incidence of identified spikes of serum LH in boars exposed to natural or supplemental lighting from 75 to 215 d of age are presented in table 3. Number of LH spikes ranged from 0.38 to 1.75 during the 6-h intensive sampling period (19 samples). Frequency of secretory spikes of LH was similar between treatments (P=.39). In addition, the frequency of LH spikes did not change in either treatment between 75 to 215 d of age (P=.14).

**FSH.** Concentrations of serum FSH varied from 44 to 113 ng/ml from 75 to 173 d of age. No differences in serum concentrations of FSH were found (P=.75) between natural and supplemental lighting treatment groups. When data from both treatments were combined, no

### Table 1. Libido Scores of Boars Exposed to Natural or Supplemental Lighting

<table>
<thead>
<tr>
<th>Age, d</th>
<th>Natural</th>
<th>Lighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>122b</td>
<td>1.4 ± .3</td>
<td>2.5 ± .5</td>
</tr>
<tr>
<td>136</td>
<td>1.6 ± .3</td>
<td>2.1 ± .5</td>
</tr>
<tr>
<td>150</td>
<td>2.9 ± .5</td>
<td>2.7 ± .5</td>
</tr>
<tr>
<td>164</td>
<td>2.2 ± .4</td>
<td>2.7 ± .5</td>
</tr>
<tr>
<td>178</td>
<td>2.6 ± .4</td>
<td>2.6 ± .5</td>
</tr>
<tr>
<td>192</td>
<td>2.9 ± .5</td>
<td>2.7 ± .5</td>
</tr>
<tr>
<td>206</td>
<td>2.9 ± .4</td>
<td>3.1 ± .5</td>
</tr>
<tr>
<td>220</td>
<td>2.6 ± .5</td>
<td>3.5 ± .5</td>
</tr>
</tbody>
</table>

aMean ± SE. No difference between treatment group (P>.30).

bAge effect for both treatment groups (P<.01).

cFourteen boars were tested at each age.

dFifteen boars were tested at each age.
TABLE 2. MEAN SERUM CONCENTRATIONS OF LUTEINIZING HORMONE (LH) IN BOARS EXPOSED TO NATURAL OR SUPPLEMENTAL LIGHTING

<table>
<thead>
<tr>
<th>Age, d</th>
<th>Natural</th>
<th>Lighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 b</td>
<td>.61 ± .14 ch (7)</td>
<td>.92 ± .15 g (6)</td>
</tr>
<tr>
<td>89</td>
<td>.35 ± .07 d,h (8)</td>
<td>.67 ± .09 f (8)</td>
</tr>
<tr>
<td>103</td>
<td>.25 ± .03 d,h (8)</td>
<td>.46 ± .11 e (8)</td>
</tr>
<tr>
<td>117</td>
<td>.56 ± .10 c,dh (8)</td>
<td>.65 ± .15 f (7)</td>
</tr>
<tr>
<td>131</td>
<td>.28 ± .03 d,h (8)</td>
<td>.39 ± .06 d,e (8)</td>
</tr>
<tr>
<td>145</td>
<td>.26 ± .04 d,h (8)</td>
<td>.30 ± .05 d (8)</td>
</tr>
<tr>
<td>159</td>
<td>.20 ± .02 c,dh (8)</td>
<td>.23 ± .02 c,h (8)</td>
</tr>
<tr>
<td>173</td>
<td>.17 ± .03 d (7)</td>
<td>.18 ± .02 c,h (8)</td>
</tr>
<tr>
<td>187</td>
<td>.19 ± .02 c,dh (8)</td>
<td>.24 ± .04 d (8)</td>
</tr>
<tr>
<td>201</td>
<td>.19 ± .03 c,dh (7)</td>
<td>.25 ± .03 c,dh (7)</td>
</tr>
<tr>
<td>215</td>
<td>.20 ± .03 c,dh (8)</td>
<td>.25 ± .07 c,dh (4)</td>
</tr>
</tbody>
</table>

aMean ± SE of 19 samples from each sampling period for each boar.
bAge effect for both treatment groups (P<.05).
c,d,e,f,g Means within a column that do not have a common superscript differ (P<.05).
h,i Means within the same row that do not have a common superscript differ (P<.05).
jNumber in parentheses denotes number of boars.

differences in serum concentrations of FSH were found from 75 to 215 d of age (figure 1).

**Testosterone.** Average serum concentrations of testosterone ranged from .96 to 4.47 ng/ml from 75 to 215 d of age. Serum testosterone concentrations increased rapidly between 131 and 201 d of age (P<.001) and dropped sharply between 201 and 215 d of age in both treatment groups. Because differences between treatment groups were not observed (P=.93), data were combined for presentation in figure 1.

TABLE 3. FREQUENCY OF LUTEINIZING HORMONE (LH) SECRETORY SPIKES IN BOARS EXPOSED TO NATURAL OR SUPPLEMENTAL LIGHTING

<table>
<thead>
<tr>
<th>Age, d</th>
<th>No. of LH spikes·boar−1·6 h−1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural</td>
</tr>
<tr>
<td>75 b</td>
<td>1.3 ± .2 (7)</td>
</tr>
<tr>
<td>89</td>
<td>1.1 ± .2 (8)</td>
</tr>
<tr>
<td>103</td>
<td>1.4 ± .3 (8)</td>
</tr>
<tr>
<td>117</td>
<td>1.8 ± .3 (8)</td>
</tr>
<tr>
<td>131</td>
<td>1.2 ± .4 (8)</td>
</tr>
<tr>
<td>145</td>
<td>1.1 ± .4 (8)</td>
</tr>
<tr>
<td>159</td>
<td>.8 ± .3 (8)</td>
</tr>
<tr>
<td>173</td>
<td>.6 ± .4 (7)</td>
</tr>
<tr>
<td>187</td>
<td>.4 ± .3 (8)</td>
</tr>
<tr>
<td>201</td>
<td>.4 ± .3 (7)</td>
</tr>
<tr>
<td>215</td>
<td>.4 ± .3 (8)</td>
</tr>
</tbody>
</table>

aMean ± SE. No difference between natural and supplemental-lighted boars (P=.39).
bNo age effect (P=.39).
cNumber in parentheses denotes number of boars.

Figure 1. Profiles of combined average serum concentrations of luteinizing hormone (LH), follicle stimulating hormone (FSH) and testosterone in boars exposed to natural and supplemental lighting. Standard errors proportional to their means in each of the treatment groups.


Discussion

Data in this study agree with an earlier one in that supplemental lighting did not alter serum concentrations of testosterone during pubertal development of boars (Hoagland and Diekman, 1982). In contrast, Minton et al., (1980) observed that boars exposed to 16 h of fluorescent light daily tended to have higher serum concentrations of testosterone. After data were combined from natural- and supplemental-lighted treatment groups (figure 1), the secretory pattern of serum testosterone was similar to previous reports (FlorCruz and Lapwood, 1978; Allrich et al., 1982; Hoagland and Diekman, 1982).

During pubertal development in boars, changes in metabolic clearance rate (MCR) of testosterone in blood may influence circulating concentrations of the hormone (Allrich et al., 1982). Recently, Christenson et al., (1984) determined that the MCR for blood testosterone was greater for prepubertal boars at 80 than 160 d of age. Because serum concentrations of testosterone remained constant regardless of whether boars were reared under natural or supplemental lighting, it is possible that supplemental lighting increased secretion of testosterone into the blood but concentrations remained the same because MCR was also elevated.

Serum concentrations of testosterone in boars between 187 and 201 d of age had a noticeable peak (figure 1), as reported previously (FlorCruz and Lapwood, 1978; Allrich et al., 1982; Hoagland and Diekman, 1982; Lee, 1982; Brandt and Diekman, 1985). This testosterone peak corresponds with morphological maturation of boar testes (Straaten and Wensing, 1978) and aggressive sexual behavior at 25 wk of age (FlorCruz and Lapwood, 1978). Therefore, this testosterone peak may correlate with triggering the first spontaneous ejaculation and aggressive sexual behavior. When maximum growth of testes components and accessory sex organs are obtained, testosterone may no longer be required in high concentrations. With a new set-point being established, lower testosterone concentrations may be sufficient to maintain normal reproductive functions (Allrich et al., 1982).

Libido score patterns obtained in this experiment were similar to patterns obtained when boars were subjected to supplemental lighting during periods of short daylength (Mahone et al., 1979; Hoagland and Diekman, 1982) or decreasing daylength (Berger et al., 1980). Although there were no differences in libido scores between natural and supplemental lighting from 122 to 220 d of age, boars at 122 d of age exposed to supplemental lighting tended to have higher libido scores than natural-lighted boars. Hoagland and Diekman (1982) observed that libido scores of supplemental-lighted boars at 23 wk of age were higher than natural-lighted boars. These experiments imply that supplemental lighting has its accelerative effects on puberty at very young ages.

Hoagland and Diekman (1982) observed that serum concentrations of LH were similar for natural- and supplemental-lighted boars from 15 to 31 wk of age, with one exception; boars that received supplemental lighting had higher concentrations at 17 wk of age. Furthermore, Brandt and Diekman (1985) reported that serum concentrations of LH in boars exposed to supplemental lighting from 75 to 131 d of age. Characterization of serum LH was more complete in this study because blood samples were taken every 20 min for 6 h; only one blood sample per bleeding period was taken in earlier studies (Hoagland and Diekman, 1982; Brandt and Diekman, 1985).

Blood profiles of LH averaged over both treatment groups were similar to those reported previously (FlorCruz and Lapwood, 1978; Hoagland and Diekman, 1982; Schinckel et al., 1984; Brandt and Diekman, 1985). These studies indicate that higher concentrations of LH appear around 120 d of age and then decreased steadily afterwards. Fluctuations in mean serum concentrations of LH were reflected by changes in the frequency of identified LH spikes (table 3). No differences in number of LH spikes were observed between natural- and supplemental-lighted boars (P=.39) or between boars 75 to 215 d of age (P=.14).

In the present study, incidence of LH secretory spikes averaged overall age groups was 1.0 per 6 h. Previous investigators have determined that frequency of LH spikes ranged from .9 to 2 spikes for a 4- or 5-h sampling period (Kittok et al., 1984; Schinckel et al., 1984). Even though there was considerable variation in the methods used to define a secretory spike in these studies, the number of LH spikes were remarkably similar. In most cases, LH secretory spikes in boars were easily identifiable because
basal concentrations remain very low and stable between infrequent episodic releases of hormone.

According to the gonadostat hypothesis (Ramirez and McCann, 1963; Foster and Ryan, 1979), blood concentrations of LH should increase before puberty due to a decreased potency of steroid inhibitory feedback. In boars, however, serum concentrations of LH are reduced as they approach puberty, while serum concentrations of testosterone increase as boars become older. Even though mean serum concentrations of LH were higher from 75 to 131 d of age in boars reared under supplemental lighting, a hormonal correlate of light-stimulated libido has not been identified. Perhaps neurotransmitters are important in mediating development of libido in boars. In adult male rats, increases in dopamine and decreases in serotonin at central nervous system synapses facilitate libido (Malmnas, 1973). Alternatively, melatonin has been shown to be a key hormone by which sheep measure daylength (Karsch et al., 1984). Data on serum concentrations of melatonin in boars exposed to various lighting conditions have not been reported.

Because the biological activity (Lucky et al., 1980; Buckingham and Wilson, 1985; Burstein et al., 1985), half-life (Weick, 1977) and isoelectric focusing profile (Robertson et al., 1982; Chappel and Ramaley, 1985) of gonadotropins differ between reproductive states, circulating concentrations of gonadotropins as measured by radioimmunoassay may be inadequate as a predictor of pubertal development in the boar. Use of porcine Leydig cells in a radioreceptor assay to measure biological activity of gonadotropins during prepubertal development of boars may prove to be a more accurate indicator of sexual maturity of the boar.

Literature Cited


