BODY GROWTH, GROWTH HORMONE, PROLACTIN AND PUBERTY RESPONSE TO PHOTOPERIOD AND PLANE OF NUTRITION IN HOLSTEIN HEIFERS

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Summary

Effects of photoperiod and plane of nutrition on growth, serum concentrations of prolactin (PRL) and growth hormone (GH) and puberty were assessed in Holstein heifers. Sixty prepubertal heifers were assigned to one of four treatment groups arranged in a 2 x 2 factorial. The two main effects were photoperiods of 8 h light:16 h dark (8L:16D) vs 16L:8D, and a low vs high plane of nutrition. Heifers on the low plane of nutrition were fed a diet formulated to achieve a body growth rate of approximately 0.7 kg/d. Daily feed intake was restricted and similar in both groups of low plane heifers subjected to either 8 or 16 h of light daily. Heifers on the high plane of nutrition were fed ad libitum to achieve a growth rate > 1 kg/d. Body weight was recorded every month for 5 mo. The PRL and GH concentrations were measured at d 9, 53 and 132 in serum collected every 30 min for 6 h from five heifers in each treatment group. Progesterone was monitored biweekly in all heifers as an index of puberty (> 1 ng/ml). Heifers subjected to 8L:16D-low plane, 16L:8D-high plane gained .61, .72, .98 and 1.08 kg/d, respectively. In the same treatment order, averaging across all bleedings, concentrations of PRL were 32, 37, 38 and 46 ng/ml serum, and GH averaged 10.9, 9.3, 9.8 and 9.0 ng/ml serum. Similarly, body weight at puberty averaged 268, 257, 278 and 268 kg, respectively. Results suggest that 16L:8D stimulates rate of body weight gain, increases feed efficiency, hastens puberty and increases serum PRL regardless of whether heifers are fed moderately restricted or ad libitum planes of nutrition. We conclude that manipulation of photoperiod may be a useful management practice in cattle production.

(Key Words: Body Growth, Growth Hormone, Prolactin, Puberty, Photoperiod, Nutrition.)

Introduction

A daily photoperiod of 16 h of light (L) and 8 h of dark (D) applied for 4 mo increased body growth of heifers 11 to 17% over that of heifers exposed to natural duration photoperiods of 9 to 12 h daily (Peters et al., 1978), 8L:16D or 24L:0D (Peters et al., 1980). Although heifers exposed to 16L:8D eat more, their efficiency in converting feed into body mass is greater than heifers given less than 12 h of light daily. In these previous experiments, animals were fed ad libitum a high plane of nutrition. However, no information is available concerning the effects of photoperiod on heifers fed a lower plane of nutrition. Thus, our first objective was to determine if 8 or 16 h of light/d affected growth rate of heifers fed high or low planes of nutrition.

Prolactin (PRL) and growth hormone (GH) may control body growth (Bates et al., 1964; Purchas et al., 1970). Serum PRL increases three to seven-fold in calves when duration of light is shifted from 8 to 16 h/d (Bourne and Tucker, 1975; Leining et al., 1979). Furthermore, concentrations of serum PRL increase and GH decrease as energy intake and body growth rate increase (Bassett et al., 1971; Forbes et al., 1979, 1979a; Sejrsen et al., 1983). Therefore, our second objective was to study the effects of photoperiod and plane of nutrition on concentrations of PRL and GH in serum.

Secretion of PRL appears to participate in the maturational process that leads to onset of estrous cyclicity (Ojeda et al., 1980). Hyperprolactinemia (Advis and Ojeda, 1978) or injection

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of prolactin into the median eminence (Clemens et al., 1969) leads to precocious puberty in the female rat. Puberty is also dependent on plane of nutrition. For example, faster growth rates induce earlier onset of estrous cyclicity in cattle (Swanson, 1978). However, a positive relationship exists between average daily gain and body weight at first estrus (Swanson, 1978). Considering the effects of photoperiod on growth rate and prolactin secretion, our last goal was to determine if photoperiod and plane of nutrition affected body weight at puberty.

Materials and Methods

Sixty prepubertal Holstein heifers were assigned on the basis of body weight (average 156 kg at beginning of experiment) to one of four treatment groups arranged as a 2 x 2 factorial. Heifers were housed unrestrained in separate pens and no supplemental heat was provided. Main effects were photoperiod and plane of nutrition. Photoperiods were 8L:16D or 16L:8D. Lights came on at 0700 h each day in all groups.

Planes of nutrition were designed to produce average body weight gains of approximately 0.7 (Low) or >1 kg/d (High). Diets for both planes of nutrition contained the same ingredients, but differed in composition (table 1). Each diet was fed as a complete mix once a day at 1300 h. Groups of heifers on the High plane were fed ad libitum a diet greater in protein and energy content than heifers on the Low plane. Total ors/group for heifers on the High plane of nutrition were weighed daily. Daily feed intake/group of Low heifers was restricted with no ors and was similar for heifers subjected to either 8 or 16 h of light daily; average dry matter intake/heifer ranged from 3.99 to 4.73 kg/d during the experiment. The experiment started on January 25 and the first month of the trial was used to adjust feed intake to the desired growth rate for Low heifers. Water was freely available.

Approximately every month, heifers were deprived of water for 16 h, then body weight was measured between 0800 and 1000 h. The last body weight for the growth trial was measured for all heifers on June 12 after 138 d.

On February 2, March 18 and June 5, an indwelling cannula was inserted into a jugular vein of five heifers initially selected at random from each treatment group. The same heifers were bled each time. The following day, starting at 0700 h, blood samples were collected at 30-min intervals and discarded until 1000 h to condition animals to the sampling procedure. Thereafter, 10 ml of blood were collected at 30-min intervals for 6 consecutive hours. Sufficient feed was provided to all groups on the day before collection of blood, so that feed was continuously present during collection. On the day of blood collection, feeding was delayed until after all blood samples were collected. Average ambient temperatures during collection of blood in February, March and June were 4.3, 8.6 and 22.3 °C, respectively. Blood samples were allowed to clot for 2 to 6 h at 20 °C, then stored overnight at 4 °C. The following day, sera

| TABLE 1. FEED COMPOSITION AND INGREDIENTS IN THE DIET FOR EACH PLANE OF NUTRITION |
|-----------------------------------|----------------|----------------|
| Item                              | Low            | High           |
| Composition                       |                |                |
| Dry matter, %                     | 32.5           | 40.3           |
| Protein, %                        | 12.5           | 13.5           |
| Energy, Mcal ME/kg\(^a\)          | 2.59           | 2.80           |
| Ingredients\(^b\), %              |                |                |
| Alfalfa-brome haylage (IFN 3-08-147) | 9.7        | 9.7            |
| Corn silage (IFN 3-28-250)         | 73.8           | 44.9           |
| High moisture corn (IFN 4-20-770)  | 6.9            | 33.9           |
| Supplement (42% crude protein)     | 9.7            | 11.6           |

\(^a\)ME = metabolizable energy.

\(^b\)Dry matter basis.
were obtained by centrifugation at 2,000 $\times$ g for 30 min. Sera were decanted and stored at $-20^\circ$C until assayed for PRL (Koprowski and Tucker, 1971) and GH (Purchas et al., 1970).

Starting at 205 kg body weight, progesterone concentration in serum from a single sample of blood from the tail vessel was monitored biweekly as an index of onset of estrous cyclicity (puberty) in all heifers. Concentrations of progesterone greater than 1 ng/ml indicated the existence of a functional corpus luteum. Body weight at puberty was extrapolated from the regression of the body growth curve of each animal. Animals (26 of 60) that had not reached puberty by the end of growth trial (d 138) were maintained under photoperiod and nutritional treatments until detection of puberty in all heifers. Measurements of body weights of these prepubertal heifers were continued at monthly intervals until detection of puberty.

Body weight, serum PRL and GH changes were analyzed by split-plot analyses of variance (Gill and Hafs, 1971). Body weight on d 28 was used as a covariate in the analysis of body weight changes during the remainder of the experiment. To minimize heterogeneity of variance of PRL and GH means, statistical analyses were conducted on data transformed to natural logarithm. Least-square means were tested by Bonferroni procedure (Gill, 1978).

Body weight at puberty and days on experiment to reach puberty were subjected to analyses of variance.

**Results**

**Weight Gain.** Body weight of all heifers averaged 186 kg after 28 d on the experiment (February 22). Body weights increased to 252, 268, 296 and 308 kg on d 138 (June 12) for 8L:16D, Low; 16L:8D, Low; 8L:16D, High and 16L:8D, High heifers, respectively (figure 1). Average daily gains (ADG) of heifers subjected to 16L:8D were 18 and 10% greater ($P<.001$) than those of heifers exposed to 8L:16D in the Low and High groups, respectively. There was no photoperiod by plane of nutrition interaction ($P>.10$).

**TABLE 2. AVERAGE DAILY DRY MATTER INTAKE EXPRESSED AS PERCENTAGE OF BODY WEIGHT**

<table>
<thead>
<tr>
<th>Plane of nutrition</th>
<th>Low$^a$</th>
<th>High$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>8L:16D</td>
<td>16L:8D</td>
</tr>
<tr>
<td>0 to 28</td>
<td>3.33</td>
<td>3.34</td>
</tr>
<tr>
<td>29 to 59</td>
<td>2.07</td>
<td>2.01</td>
</tr>
<tr>
<td>60 to 83</td>
<td>2.09</td>
<td>2.01</td>
</tr>
<tr>
<td>84 to 111</td>
<td>1.93</td>
<td>1.86</td>
</tr>
<tr>
<td>112 to 138</td>
<td>1.95</td>
<td>1.85</td>
</tr>
<tr>
<td>0 to 138</td>
<td>1.94</td>
<td>1.86</td>
</tr>
</tbody>
</table>

$^a$Dry matter intake for both groups was restricted to a similar amount daily and ranged from 3.99 to 4.73 kg of dry matter·d$^{-1}$·heifer$^{-1}$ throughout the experiment.

$^b$Dry matter intake was provided ad libitum.
**Photoperiod and Nutrition Effects in Cattle**

**Dry Matter Intake.** Statistical comparisons of dry matter intake between photoperiod or nutritional treatments were not possible because animals were fed in groups, not individually. Average daily dry matter intakes throughout the experiment, expressed in percentage of body weight for heifers exposed to either 8L:16D or 16L:8D, were 1.94 and 1.86% for Low heifers, and 2.76 and 2.85% for High heifers (table 2). During the last 3 mo of the experiment, animals exposed to 16L:8D and on High nutrition consumed 6.7% more dry matter/d than High heifers given 8L:16D. Nevertheless, feed to gain ratio during the trial remained in favor of High animals exposed to 16L:8D (5.97) as compared with High animals given 8L:16D (6.07).

Dry matter intake·d⁻¹·heifer⁻¹ on Low nutrition was similar in both photoperiod groups and ranged from 3.99 to 4.73 kg/d throughout the trial. Yet, feed to gain ratio in these heifers was smaller for those exposed to 16L:8D (6.79) than for those subjected to 8L:16D (6.95).

**Serum GH and PRL.** Days of bleeding did not influence (P>.10) concentrations of GH in serum (figure 2). Photoperiod neither affected nor interacted with days of bleeding to change concentrations of GH in serum (P>.10). Nevertheless, averaging across all days of bleeding, there was a tendency (P<.10) for GH to be higher in animals given 8L:16D (10.3 ng/ml) in comparison with 16L:8D (9.2 ng/ml). On the other hand, there was a significant interaction between planes of nutrition and days of bleeding (P<.05). During the last bleeding (d 133), greater (P<.05) concentrations (ng/ml) of GH were found in animals on the Low nutrition (10.9) compared with the High nutrition treatment (8.5).

Days of bleeding significantly affected (P<.001) serum PRL (figure 3) with greater concentrations (ng/ml) at the end of the experiment (80.1) than on d 9 (22.7) or d 53 (29.9). Averaging across all days of bleeding, prolactin in serum was greater (P<.001) under 16L:8D (41.2 ng/ml) than 8L:16D (34.9 ng/ml). However, there was a significant interaction between photoperiod and days of bleeding (P<.01). Plane of nutrition affected (P<.001) PRL concentration in serum. Averaging across the three sampling times, PRL was greater (P<.001) for animals on High nutrition (42.0 ng/ml) than for animals on Low nutrition (34.4 ng/ml). There was no interaction between plane of nutrition and days of bleeding (P>.05) even though greater (P<.05) concentrations (ng/ml) of PRL were found in animals on the High nutrition (93.6) when compared with animals on the Low nutrition (68.6) on d 133.
Figure 4. Effects of photoperiod and plane of nutrition on body weight at puberty (pooled SE = 17.7 kg) and interval from start of experiment to puberty (pooled SE = 1.3 wk). Each bar represents the mean of 14 or 15 animals.

Puberty. Heifers tended to reach puberty at a smaller weight when exposed to 16L:8D (P<.19) or to the Low plane of nutrition (P<.19) in comparison with 8L:16D or High nutrition, respectively (figure 4). Nevertheless, the interval from the start of the experiment to puberty was shortened for animals on High nutrition (P<.01) or under 16L:8D photoperiod (P<.07).

Discussion

Our results confirm previous findings (Peters et al., 1980) that a photoperiod of 16L:8D increases growth rate of Holstein heifers over that of heifers exposed to 8L:16D when they are fed ad libitum a high plane of nutrition. Furthermore, for the first time in cattle, we have demonstrated that the 16L:8D photoperiod will stimulate body growth rates when animals are fed a relatively lower plane of nutrition. Similar observations have been reported by Forbes et al. (1975, 1979b) in studies with lambs. Therefore, stimulation of body growth by manipulating photoperiod could prove to be a useful management tool in cattle production.

Also, in the present study, we have confirmed previous investigations in cattle (Peters et al., 1980) that the increased growth rate in heifers exposed to 16L:8D and fed ad libitum a high plane of nutrition was associated with greater feed consumption. Increased intakes commenced approximately 8 wk after initiation of 16L:8D photoperiod. Nevertheless, in both studies, feed to gain ratios were lowest for heifers given 16 h of light daily, suggesting greater efficiency in converting feed into body weight gain. This premise is further strengthened by data from the animals fed the Low plane of nutrition where both photoperiod groups were given identical amounts of feed daily; nevertheless, Low heifers on 16L:8D grew faster than Low heifers exposed to 8L:16D. This latter observation does not support the hypothesis that increased body growth rate associated with 16L:8D was due to increased gut fill. Similar observations on feed consumption and feed efficiency were made by Forbes et al. (1975, 1979b) and Schanbacher and Crouse (1980) in studies with lambs. Thus, a 16L:8D photoperiod may stimulate growth rate by increasing feed intake and efficiency.

Homeorhesis is defined as the coordination of metabolism of body tissues in support of a dominant developmental or physiological process (Bauman and Currie, 1980; Bauman et al., 1981). Bauman et al. (1981) advanced the hypothesis that GH and PRL serve as chronic coordinators of nutrient partitioning among tissues. In the present study, we observed discernable effects of plane of nutrition and photoperiod on GH and PRL concentrations in serum. By the end of the experiment, animals on High nutrition had greater concentrations of PRL and less GH in comparison with animals on Low nutrition. Thus, high concentrations of PRL and low GH were associated with faster growth rates. When animals were exposed to 16L:8D, levels of PRL were increased without significant change in GH. Yet, these animals grew faster than animals under 8L:16D. In this physiological comparison, fast growth rates were associated with high levels of PRL. Similar observations have been made in lambs (Forbes et al., 1979b). Collectively, it suggests a possible role of PRL as a homeorhetic factor involved in the photoperiodic regulation of growth. In fact, active immunization against PRL (Ohlson et al., 1981) or inhibition of PRL secretion with 2-Br-α-ergocryptine (Eisemann et al., 1981) decreased body weight gain and feed intake in sheep.

A negative relationship exists between concentrations of GH and rate of body growth (Purchas et al., 1970). Our data support these observations. For example, heifers on High nutrition were the fastest growing heifers, but
they had smaller concentrations of GH than Low plane heifers.

The concentration of PRL varies with seasons in cattle (Koprowski and Tucker, 1973). In the present experiment, days of bleeding variations in concentrations of PRL were observed in the face of constant photoperiod. The concentrations of PRL increased from a minimal value in February to a maximum in June. On the other hand, there was no days of bleeding variation in GH concentrations. Similar observations have been reported by Peters et al. (1978). Based on previous observations (Peters et al., 1978), we believe that the major part of the days of bleeding variation in PRL may have been due to the temperature increment among bleeding days.

Swanson (1978) showed a positive relationship between average daily gain and body weight at first estrus. These results were confirmed in the present experiment. Compared with the Low plane of nutrition, animals on the High plane of nutrition reached puberty at a heavier weight. However, this relationship is not always maintained. For example, within each plane of nutrition, heifers under 16L:8D grew faster, but reached puberty at a smaller weight than heifers exposed to 8L:16D. This confirms previous observations that 16L:8D may accelerate onset of puberty (Peters et al., 1978). The PRL changes associated with photoperiod might be involved in hastening onset of puberty in cattle. Nevertheless, no cause and effect relationship can be established at this time.

In conclusion, photoperiod may prove to be a useful management tool in cattle production. Growth rate and feed efficiency are increased when animals are exposed to 16 h of light daily. Furthermore, these animals may reach puberty at an earlier age and lighter weight. Further data will be needed to establish a role for PRL and GH in mediating these effects of photoperiod.

**Literature Cited**


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