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Long-Day Photoperiod that Enhances Puberty Does Not Limit Body Growth in Holstein Heifers*,†

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ABSTRACT

Previous research has demonstrated that extended photoperiod accelerates pubescence in dairy heifers thereby limiting time for mammary development, which could be detrimental to future milk yield. We hypothesized that the potential negative effects of rapid growth and puberty through long-day photoperiod (LDPP) exposure could be overcome with a greater supply of metabolizable protein in dairy heifers fed rumen-undegradable protein (RUP). In an initial slaughter study, we compared deuterium oxide (D_2O) and direct chemical analysis to assess body composition at 5 and 7 mo of age in heifers (n = 20) exposed to LDPP or short-day photoperiod (SDPP). Before slaughter, D_2O dilution was used to estimate body composition and results were compared with actual values determined by direct chemical analysis of body tissue. In 5-mo-old heifers, the correlations between estimates of body protein, water, and mineral contents as determined by D_2O dilution and direct chemical analysis of body tissue were 0.86, 0.85, and 0.76, respectively; however, fat content values were not correlated (r = –0.068). In 7-mo-old heifers, we were unable to accurately estimate body composition using the D_2O dilution method. A second study was conducted to determine if LDPP, which has previously been shown to hasten puberty, could be combined with RUP to promote lean growth without limiting body stature in prepubertal heifers. Thirty-two weaned heifers (86 ± 2 d old; 106.2 ± 17.3 kg of body weight) were assigned to LDPP or SDPP and RUP or control diet in a 2 × 2 factorial arrangement until the onset of puberty. Relative to SDPP, LDPP increased prolactin secretion and promoted lean growth. Exposure to LDPP also enhanced body weight, withers height, and heart girth. Furthermore, RUP supplementation increased withers height and heart girth. There was a significant interaction between LDPP and RUP for hip height. Moreover, LDPP hastened the onset of puberty. In summary, D_2O was a feasible method to estimate lean composition in heifers at younger ages; however, it failed to accurately estimate body composition in heifers around puberty. Long-day photoperiod hastened puberty and accelerated lean growth without limiting skeletal growth in dairy heifers.
(**Key words:** photoperiod, protein, heifer, growth)

Abbreviation key: EBF = empty body fat, **EBM** = empty body mineral, **EBP** = empty body protein, **EBW** = empty body water, **EBWT** = empty body weight, **HG** = heart girth, **HH** = hip height, **LDPP** = long-day photoperiod, **PRL** = prolactin, **SDPP** = short-day photoperiod, **WH** = withers height.

INTRODUCTION

Dairy producers strive to adopt management techniques that reduce age at first parturition without impairing milk production potential. The use of long-day photoperiod (**LDPP**) to hasten the onset of puberty (Peters et al., 1980; Schillo et al., 1983) could potentially reduce the age of heifers at first parturition. However, accelerating puberty may have negative consequences in dairy heifers. Decreasing age at puberty may reduce prepubertal mammary gland development by reducing the length of the allometric phase of mammary gland growth (Meyer et al., 2004a,b). Although estrogen is the dominant gonadal steroid circulating before puberty, the concentrations are relatively low (Rodrigues et al., 2002). At puberty, the relatively high circulating concentrations of estrogen may reduce bone growth, particularly that of the long bones (Chagin et al., 2004). Thus, decreasing the duration of the prepubertal growth phase may slow or limit skeletal growth. The correlation of body size to milk production at first lactation is greater than the correlation of BW to milk pro-

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duction at first lactation (Heinrichs and Hargrove, 1987). Therefore, limiting skeletal growth of dairy heifers may reduce subsequent milk yields. In addition to limiting mature body size, rapid growth may affect body composition and negatively influence subsequent lactations. Accelerating body growth by feeding diets that are high in energy promotes fat accumulation, which impairs mammary growth in the prepubertal dairy heifer (Capuco et al., 1995, 2003; Sejrsen and Purup, 1997, Sejrsen et al., 2000). Promoting lean growth may overcome the negative influence of accelerating growth through dietary manipulation. Moallem et al. (2004a,b) showed that administration of bST to growing dairy heifers promotes lean growth, and RUP feeding in combination with bST accelerates lean skeletal growth in prepubertal dairy heifers. The effect of additional dietary RUP on skeletal growth rates was greatest from 90 to 150 d of age and diminished thereafter, suggesting that metabolizable protein was limiting in early life. In contrast, the effect of bST tended to be greater around puberty, but only in the presence of supplemental RUP. Therefore, additional metabolizable protein may improve the response of heifers exposed to LDPP.

We hypothesized that the potential negative effects of accelerating growth and hastening puberty of dairy heifers through exposure to LDPP could be overcome by providing greater supply of metabolizable protein through RUP feeding. The objectives of the slaughter study were to determine the influence of photoperiod on mammary growth and to compare the slaughter (i.e., direct chemical analysis of tissue composition) and deuterium oxide (D_2O) dilution methods for assessment of body composition in prepubertal heifers exposed to LDPP or short-day photoperiod (**SDPP**). A second growth study was conducted to determine whether LDPP in combination with RUP could promote lean growth without limiting body size in the prepubertal heifer.

MATERIALS AND METHODS

Experimental Design

For the slaughter study, 20 weaned Holstein heifers (84 ± 15 d of age), were purchased from a commercial producer, and maintained in natural photoperiod conditions for 7 d as a pretreatment period to acclimate to a new diet. All animals were in good health and vaccinated according to general management procedures of the University of Illinois Dairy Center. The diet was a TMR formulated as the control diet presented in Table 1. Animals were fed to ad libitum intake at 1000 h each day. Calves were housed in identical pens within the Photoperiod Research Barn at the University of Illinois Dairy Center. Each pen was lit by metal halide bulbs to an average illumination intensity of 450 lx at a height of 1 m above the stall floor. Although only 2 pens were used for this initial study, heifer was used as the experimental unit, as each animal received light individually, albeit from the same overall source. It can be argued that pen per se may influence the response, and photoperiod and pen are confounded, yet in previous studies we have not observed an effect of pen on photoperiodic responses in this (Auchtung et al., 2004, 2005) or other facilities (Auchtung et al., 2003; Kendall et al., 2003).

Table 1. Chemical analysis and composition of diet fed to heifers exposed to long-day photoperiod or short-day photoperiod from 3 mo of age until the onset of puberty.

Nutrient composition (DM basis)	Control diet	RUP diet
CP, %	16.9	16.7
ADF, %	23.3	23.6
NDF, %	32.4	35.4
NE_M,[1] Mcal/kg	1.69	1.65
NE_G,[1] Mcal/kg	1.08	1.04
Ingredient, %		
Corn silage	51.9	51.9
Alfalfa silage	23.3	23.3
Corn grain, ground	14.1	11.9
Soybean meal, 48% CP	9.5	7.9
Fish meal	—	4.0
Limestone	0.17	0.17
Dicalcium phosphate	0.17	0.17
Salt, white	0.35	0.35
Mineral-vitamin mix[2]	0.17	0.17

[1] NE_M = Net energy for maintenance; NE_G = net energy for gain.

[2] Vitamin A, 2,200,000 IU/kg; vitamin D, 660,000 IU/kg; vitamin E, 22,000 IU/kg; K, 7.5%; Fe, 2.0%; Zn, 3.0%; Mn, 3.0%; Cu, 5,000 ppm; Co, 40 ppm; I, 250 ppm; Se,150 ppm.

After the acclimation period, all calves were allocated to individual pens and then subjected to a study of body composition using D_2O dilution methodology (Andrew et al., 1995; Auchtung et al., 2002) to determine total body water. On d 6, 4 animals were slaughtered (62.5 ± 42 d old, BW = 83.1 ± 33.3 kg) and subjected to a chemical analysis to provide a baseline of body composition. The remaining 16 calves (BW = 94.3 ± 6.8 kg) were randomly allotted to 1 of 2 photoperiod treatment groups [LDPP (16 light:8 dark) or SDPP (8 light:16 dark)] until slaughter on experimental d 70 or 140. The D_2O dilution methodology was conducted before each slaughter. Four animals per treatment were slaughtered at approximately 5 and 7 mo of age to determine the effect of LDPP and SDPP on composition and to allow for comparison of the D_2O and direct chemical estimations of body composition. Mammary glands were also collected for determination of photoperiod treatment on measures of mammary growth and composition.

For the main growth experiment, an additional 32 weaned heifers (86 ± 2 d old; BW = 106.2 ± 17.3 kg)