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The Effect of Lamps with Different Spectral Properties on Prolactin Release in Prepubertal Bulls[1] (41793)

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Abstract. Concentrations of prolactin in serum increased 1.8- to 7.8-fold within 6 weeks after duration of daily light was shifted from 8 to 16 hr. In comparison with cool-white fluorescent light, this increment in concentration of prolactin was similar when a light source that simulates natural sunlight (Vita-Lite), or incandescent, high-pressure sodium, or mercury vapor lamps were used. Regardless of light source, increasing the duration of daily light from 8 to 16 hr during warmer months (Aug) resulted in a greater magnitude of increase in mean prolactin concentrations as compared with increases observed during cooler months (Feb). We conclude that in prepubertal bulls, secretion of prolactin increases similarly when duration of light from lamps with different spectral properties is increased from 8 to 16 hr daily.

Previous studies in calves showed that as daily illumination increased from 8 to 16 hr (8L:16D to 16L:8D), prolactin (PRL) in serum increased about 3-fold (1, 2). Leining *et al.* (3) increased PRL in serum of bull calves using 8 hr of cool-white fluorescent plus 8 hr of red (550–750 nm) or blue (300–425 nm) light (16 hr daily total) in comparison with 8 hr of cool-white fluorescent light per day. Other studies have confirmed the stimulatory effects of long versus short exposures to daily light on PRL in mature rams and ewes (4–7) and lambs (8).

The objective of our study was to examine light sources with different efficiencies and spectral properties for their potential to stimulate PRL release in comparison with cool-white fluorescent light. Efficiencies of the lamps used in these experiments ranged from 20 lumens/W (lpw) for incandescent to 75 lpw for high-pressure sodium lamps.

Materials and Methods. Prepubertal bulls were exposed to an 8L:16D photoperiod (cool-white fluorescent) for 8 weeks, then a 16L:8D photoperiod for 6 additional weeks using Vita-Lite fluorescent (Duro-Test 1157), incandescent (General Electric 200A), high-pressure sodium (General Electric LU70/BU), or mercury vapor (General Electric H175A3922) lamps in comparison with a 16L:8D photoperiod of cool-white fluorescent light (General Electric F40CW/RS/WM). Spectral characteristics of each lamp are shown in Fig. 1 (9–11).

Calves and environmental chambers. The following design was repeated in four separate experiments to test each type of lamp. Eight Holstein bull calves were placed in a light-controlled room at approximately 3 days of age. Ambient temperatures were not controlled. Within the room, calves were individually penned in a 1.1-m wide × 1.8-m long stall. Cool-white fluorescent lamps were located above the calves, and mean light intensity was 212 lx at eye level of the calves. Lights were programmed on at 0700 hr and off at 1500 hr (8L:16D). Thus, calves were raised to weaning in a consistent short-light environment to establish low baseline concentrations of PRL (3). After weaning at about 6 weeks of age, bulls were moved to one of two light–temperature-controlled chambers. Ambient temperatures were maintained at 20 ± 2°C. Four calves were assigned to each light–temperature chamber such that body weights were approximately equal (71 ± 1.8 kg). Animals were housed unrestrained within each chamber and were fed *ad libitum* Calf Starter (Ralston Purina Co., St. Louis, Mo.), alfalfa hay, a mineral supplement block, and water. The photoperiod remained at 8L:16D of cool-white fluorescent light.

Blood sampling. Approximately 1.5 to 2.5 weeks after exposure to 8L:16D in the light–temperature-controlled chambers (364 lx for all experiments), calves (approximately 8 weeks of age) were fitted with an indwelling

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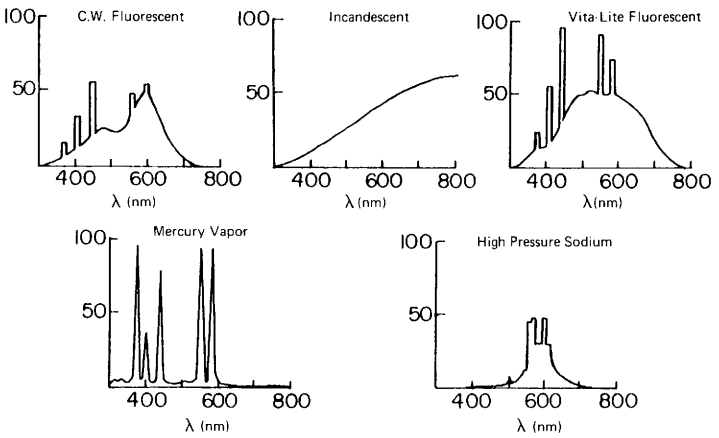

FIG. 1. Spectral characteristics of five different lamp types. Panels show the relative power (ordinate) between the spectral range (abscissa) of ultraviolet (300 nm) to infrared (800 nm).

jugular cannula (Ico-Rally Corp. SLV 105 18 clr.) and bled the following day. At 0700 hr on the day of sampling, the animals were restrained with halters and blood was sampled and discarded at 15-min intervals for 1 hr to accustom animals to the sampling procedure. After the presampling period, blood was collected for 6 hr at 30-min intervals. Cannulae were filled with 3.5% sodium citrate between samplings to prevent coagulation. Blood samples were allowed to clot for 6 to 8 hr at room temperature and stored for 24 hr at 5°C, then centrifuged at approximately 1000*g* for 20 min. Serum was decanted and frozen at −20°C until assayed for PRL (12).

After these initial blood samples were collected during exposure to 8L:16D, photoperiod was shifted to 16L:8D (0300–1900 hr) for an additional 6 weeks. Four calves in one chamber were exposed to Vita-Lite fluorescent (Experiment 1), incandescent (Experiment 2), high-pressure sodium (Experiment 3), or mercury vapor (Experiment 4) light sources in four separate trials. A 16L:8D photoperiod of cool-white fluorescent light was used as the control treatment for the second group of four calves in each trial. Light intensities were equalized between chambers within each trial. The following are intensities (lx) for each lamp type and its cool-white fluorescent control: Vita-Lite (554, 622), incandescent (367, 365), high-pressure sodium (151, 121), mercury vapor (232, 236). Venipuncture samples were collected twice weekly during the 6 weeks of 16L:8D. At the end of the 6-week exposure to 16L:8D from each light source, calves (approximately 14 weeks of age) were cannulated and blood was collected for 6 hr at 30-min intervals. Ambient temperatures were recorded in each chamber at the time each blood sample was collected. Feed and water were available throughout blood sampling periods.

Hormone assay. Concentrations of PRL in serum were quantified by double antibody radioimmunoassay as previously described (12).

Statistical analyses. A mean concentration of PRL was calculated for each animal at the 6-hr bleeding times at Weeks 8 and 14. Data from each experiment were analyzed using split-plot analysis of variance to test for PRL differences between bleeding periods. In addition to the model analysis, mean PRL concentrations of bleedings within each treatment were compared using Student's *t* test, where the first bleeding mean was compared with the last bleeding mean. Split-plot analysis of variance was also used to test for differences in concentrations of PRL in samples collected by venipuncture at 3-day intervals during the experiments.

Results. *Experiment 1.* After 8 weeks exposure to 8 hr of cool-white fluorescent light per day prolactin averaged 32.7 and 35.6 (±4.7) ng/ml ($P > 0.05$) of serum collected at 30-min intervals for 6 hr for both groups of four animals (Fig. 2A). Six weeks after bulls were switched to 16 L from cool-white and Vita-Lite fluorescent lamps PRL increased (*P*

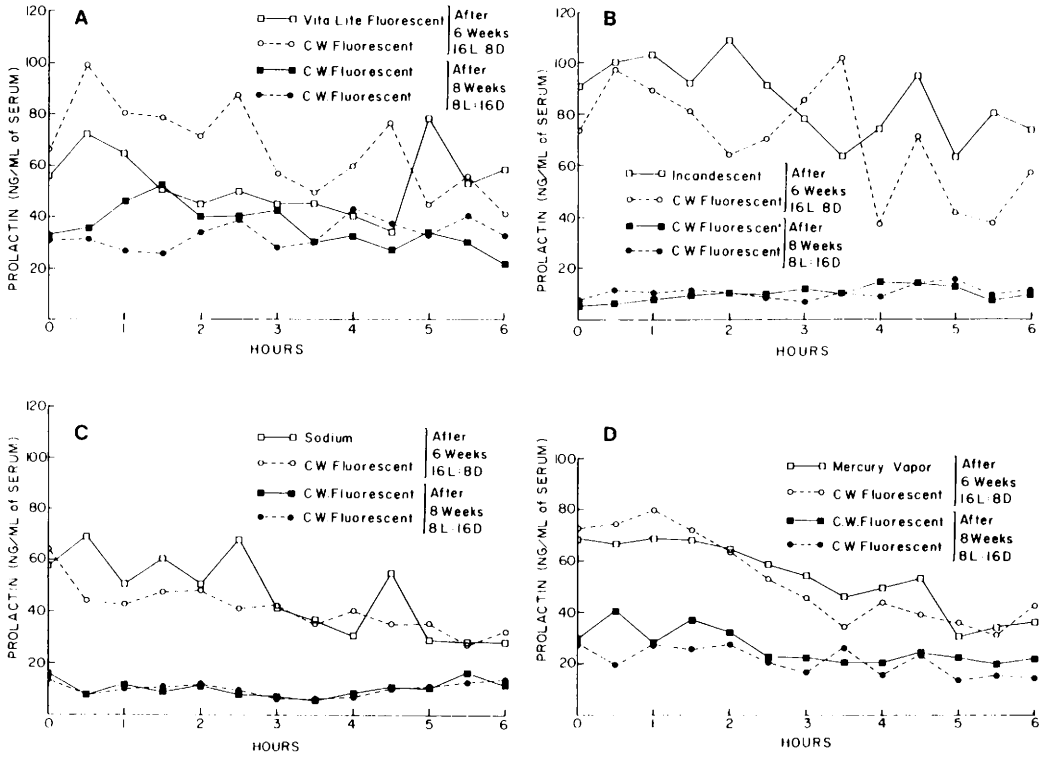

FIG. 2. Six-hour profiles of the effect of 8 hr of light per day (cool-white fluorescent) or 16 hr of light per day from cool-white fluorescent, Vita-Lite fluorescent (A), incandescent (B), high-pressure sodium (C), or mercury vapor (D) lamps on concentrations of prolactin in serum of prepubertal bulls. Samples were collected by jugular cannula. There were four bulls per observation.

< 0.01) to an average of 66.8 and 53.2 (±6.1) ng/ml, respectively (Fig. 2A). The PRL response to these light source treatments did not differ ($P > 0.05$). However there was an interaction ($P < 0.01$) between light source and time within the 6-hr sampling period. A linear increase ($P < 0.05$) in PRL was observed over the 6 weeks of the experiment in both groups after the 16L:8D photoperiod was begun; however, concentrations of PRL in response to increased photoperiod were not different ($P > 0.05$; Fig. 3A) between light sources. Within comparable time frames, PRL concentrations tended to be higher in serum of samples collected by venipuncture versus those collected by cannulation.

Experiment 2. PRL averaged 10.6 and 9.5 (±1.9) ng/ml ($P > 0.05$; Fig. 2B) after 8 weeks of 8 hr of fluorescent light each day. Six weeks after photoperiod was shifted to 16L:8D of cool-white fluorescent or incandescent lamps PRL increased ($P < 0.01$) to an average of 71.0 and 85.4 (±15.1) ng/ml (Fig. 2B). The incandescent light source did not differ ($P > 0.05$) from cool-white fluorescent light in terms of capacity to affect PRL concentrations in the bulls. Concentrations of PRL decreased ($P < 0.01$) in both groups exposed to incandescent and cool-white fluorescent over the 6-hr period at Week 14.

In samples collected twice weekly throughout the 6 weeks of 16L:8D, PRL concentrations increased ($P < 0.01$) linearly over time (Fig. 3B). PRL responses to the cool white fluorescent and incandescent lamps were not different ($P > 0.05$). Similarly to Experiment 1, PRL concentrations were generally elevated in samples collected by venipuncture as compared with collection by cannula.

Experiment 3. At Week 8, PRL averaged 9.7 and 10.1 (±1.4) ng/ml of serum ($P > 0.05$) during the 6-hr blood collection period (Fig.

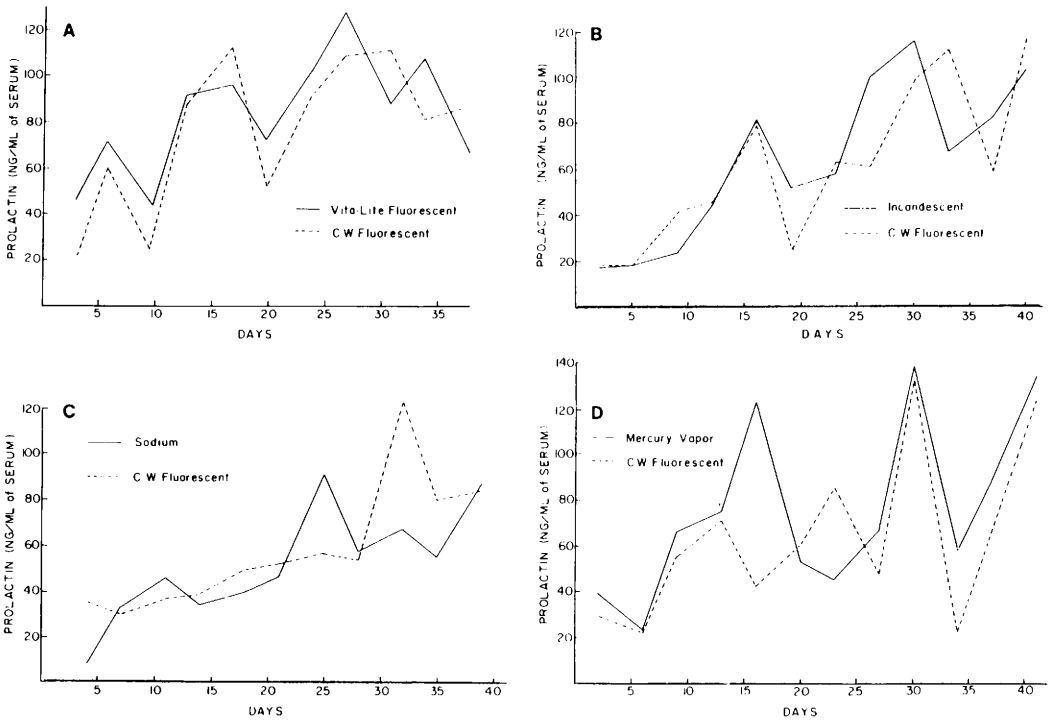

FIG. 3. Prolactin in serum from prepubertal bulls after switching from 8 hr per day of cool-white fluorescent to 16 hr per day of cool-white fluorescent, Vita-Lite fluorescent (A), incandescent (B), high-pressure sodium (C), or mercury vapor (D) lamps at Day 0. Samples were collected via jugular venipuncture. There were four bulls per observation.

2C). Six weeks later PRL concentrations increased ($P < 0.01$) to 41.4 and 46.7 (±5.2) ng/ml after 16 hr/day exposure to light from cool-white fluorescent and sodium lamps, respectively (Fig. 2C). Source of light did not affect the PRL increment ($P > 0.05$). Average PRL concentrations declined ($P < 0.01$) over the 6-hr interval in each group of calves given 16L:8D.

A linear increase ($P < 0.01$) in PRL concentrations over time was observed in twice weekly samples collected between 8 and 14 weeks of age (Fig. 3C). Effectiveness of cool-white fluorescent and sodium lamps on concentrations of PRL was not different ($P > 0.05$). Concentrations of PRL were usually greater in venipuncture samples than in samples collected by cannula.

Experiment 4. Eight weeks of 8 hr daily of cool-white fluorescent light resulted in PRL concentrations of 21.2 and 26.3 (±3.8) ng/ml of serum ($P > 0.05$) in each group of bulls (Fig. 2D). After 6 weeks exposure to 16 hr/day of either cool-white fluorescent or mercury vapor lamps PRL increased ($P < 0.05$) to 52.9 and 53.8 (±6.3) ng/ml of serum in each group respectively (Fig. 2D). PRL concentration declined ($P < 0.01$) in each group of calves over the 6-hr bleeding time after 6 weeks of 16L:8D. Prolactin concentrations in calves exposed to mercury vapor lamps did not differ ($P > 0.05$) from concentrations in calves exposed to cool-white fluorescent light.

After the shift of photoperiod from 8L:16D to 16L:8D, blood samples collected twice weekly showed a linear increase ($P < 0.01$) in concentrations of PRL in each group (Fig. 3D). Both light sources stimulated PRL concentrations similarly ($P > 0.05$).

Month effects. Mean concentrations of PRL over the 6-hr bleeding periods were increased 1.8- to 7.8-fold among all treatment groups, when daily light exposure was increased from 8 to 16 hr (Fig. 4). Thus, all light sources tested influenced average PRL concentrations as effectively as cool-white fluorescent light.

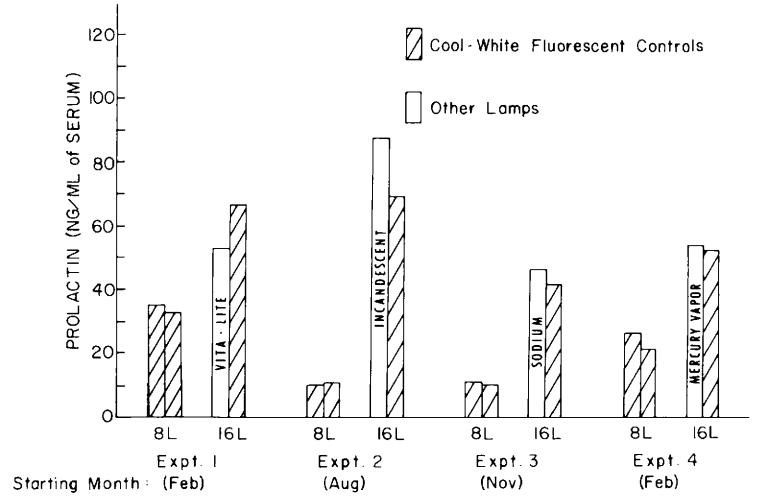

FIG. 4. Mean concentrations of prolactin in serum of prepubertal bulls after 8 weeks of 8L:16D (8L) or 6 weeks of 16L:8D (16L) from cool-white fluorescent or other light sources. There were four bulls per observation.

However, experiments starting during cooler months appeared to have greater initial (8L:16D) concentrations of PRL when compared with experiments starting during warmer months. In addition, switching the duration of daily light from 8 to 16 hr during warmer months (Aug) resulted in a greater magnitude of increase in mean PRL concentrations as compared with the changes observed during cooler months (Feb).

Discussion. Sixteen hr of light from Vita-Lite, incandescent, high-pressure sodium, or mercury vapor lamps, each with different efficiencies and spectral properties stimulated PRL secretion as effectively as cool-white fluorescent light. Although each of these light sources stimulated PRL release, it is not known if all these lamps will promote growth rates and lactation (13).

The PRL response to an abrupt photoperiod change (from 8L:16D to 16L:8D) with cool-white fluorescent light is sluggish, it may take a week or more to detect, and requires several weeks to attain a maximum (1, 2). This relatively slow response was confirmed in the results of the present study with each light source (Figs. 3A–D).

Within a given experiment, it was noted that when photoperiod from cool-white fluorescent lamps was shifted from 8 to 16 hr of light, PRL always increased. However, this increase ranged from 1.8- to 7.8-fold depending upon the trial, even though the same breed, age, ambient temperatures, photoperiod, pens, and cool-white light sources were used in each experiment. The magnitude of increase was independent of light intensity differences. Vines *et al.* (14) observed in dairy cattle that the quantity of TRH-induced PRL release was 3 to 16 times greater in summer than in winter. Examination of the current data (Fig. 4) shows that experiments which started in February (Experiments 1 and 4) had the least increase in PRL over the 6-week period, whereas the experiment starting in August had the greatest. One experiment starting in November showed an intermediate increase when daily light exposure was increased from 8 to 16 hr. Therefore, these results agree with the seasonal release patterns reported by Vines *et al.* (14).

Other workers have demonstrated in cattle (15, 16), goats (17, 18), and sheep (19, 20) that basal secretion of PRL is generally elevated during summer as compared with winter. The primary causes of these seasonal patterns are changes in temperature (21) and photoperiod (1). Over the first few days (or weeks) of life, hormonal concentrations of a newborn animal can be highly reflective of maternal hormone release. For example, fetuses of rats and monkeys are exposed to changing nutrients and hormone concentra-

tions which reflect the mother's circadian rhythmicity (22, 23). This rhythmical pattern may be entrained into the offspring for some portion of its newborn life. In fact, we found that 8-week-old calves exposed to 8L:16D photoperiods showed a pattern of basal PRL concentration which was high in winter and low in summer (Fig. 4). This result is opposite that observed in older cattle (15, 16). This pattern of PRL secretion during the first weeks of life may be due to a combination of maternal influence and ambient temperatures. For instance, as an inherent factor in the experimental design, calves raised during the winter were moved from ambient temperature chambers into controlled temperature chambers, which was a move from cool to warm. During summer, however, the move was from a warm to a cool environment. Whether these temperature changes affect basal PRL concentrations is uncertain. In any event, light intensity was not a cause of the differences in concentrations of PRL among experiments since it was similar (364 lx) in all groups exposed to 8L:16D.

Considering only 16L:8D data in the present study pooled across light sources, a seasonal pattern of PRL secretion existed which agrees with the seasonal pattern reported previously (15, 16). However, a shortfall of this observation from Experiments 1 through 4 is that different calves were used during each season. Mean concentrations of PRL in serum of calves attained a maximum (80 ng/ml) in August, whereas calves exposed to identical photoperiods (16L:8D) and temperature (21.0 ± 3°C) averaged about 55 ng/ml of serum during autumn (Nov) and winter months (Feb).

Others showed that PRL concentrations in cattle are highly influenced by stress (24, 25). Within similar time frames, we found that PRL concentrations were generally higher in samples collected by jugular venipuncture than in those collected by cannula. These results are likely due to the stress of capture, holding and venipuncture of the calves. This confirms the findings of Leining *et al.* (3).

In each experiment examining a different light source, PRL concentrations declined over the 6-hr bleeding time after 6 weeks exposure to 16L:8D. This phenomenon was observed previously (25), and may be a reflection of habituation of the animals to the sampling procedure. In contrast, PRL concentrations did not decline over the 6-hr bleeding period after 8 hr of daily light exposure. Based on our data, the occurrence of a declining baseline seems to be related to the absolute concentration of PRL; that is, PRL in serum remains more stable when concentrations are below 20 ng/ml.

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1. Bourne RA, Tucker HA. Serum prolactin and LH responses to photoperiod in bull calves. Endocrinology **97**:473–475, 1975.
2. Peters RR, Tucker HA. Prolactin and growth hormone response to photoperiod in heifers. Endocrinology **103**:229–234, 1978.
3. Leining KB, Bourne RA, Tucker HA. Prolactin response to duration and wavelength of light in prepubertal bulls. Endocrinology **104**:289–294, 1979.
4. Howles CM, Webster GM, Haynes NB. The effect of rearing under a long or short photoperiod on testis growth, plasma testosterone and prolactin concentrations and the development of sexual behavior in rams. J Reprod Fert **60**:437–447, 1980.
5. Lincoln GA, McNeilly AS, Cameron CL. The effects of a sudden decrease or increase in daylength on prolactin secretion in the ram. J Reprod Fert **52**:305–311, 1978.
6. Pelletier J. Evidence for photoperiodic control of prolactin in rams. J Reprod Fert **35**:143–147, 1973.
7. Sanford LM, Beaton DB, Howland BE, Palmer WM. Photoperiod-induced changes in LH, FSH, prolactin and testosterone secretion in the ram. Canad J Anim Sci **58**:123–128, 1978.
8. Forbes JM, Driver PM, El Shahat AA, Soay TG, Scanes CG. The effect of day length and level of feeding on serum prolactin in growing lambs. J Endocrinol **64**:549–554, 1975.
9. Henderson ST, Marsden AM, eds. Lamps and Lighting. New York, Crane Russak, 1972.
10. Merik B. Light and Color of Small Lamps. USA, General Electric, 1971.
11. Wurtman RJ, Weisel J. Environmental lighting and neuroendocrine function: Relationship between spectrum of light source and gondal growth. Endocrinology **85**:1218–1221, 1969.
12. Koprowski JA, Tucker HA. Failure of oxytocin to initiate prolactin or luteinizing hormone release in lactating dairy cows. J Dairy Sci **54**:1675–1680, 1971.

13. Peters RR, Chapin LT, Leining KB, Tucker HA. Supplemental lighting stimulates growth and lactation in cattle. Science **199**:911–912, 1978.
14. Vines DT, Convey EM, Tucker HA. Serum prolactin and growth hormone responses to thyrotropin releasing hormone in postpubertal cattle. J Dairy Sci **60**:1949–1957, 1977.
15. Peters RR. Photoperiod regulation of serum hormones, body growth and lactation in dairy cattle. Ph.D. thesis, Michigan State University, 1980.
16. Schams D. Prolactin levels in bovine blood, influence by milking manipulation, genital stimulation and oxytocin administration with specific consideration of the seasonal variations. Acta Endocrinol **71**:684–696, 1972.
17. Buttle HL. Seasonal variation of prolactin in plasma of male goats. J Reprod Fert **37**:95–99, 1974.
18. Muduuli DS, Sanford LM, Palmer WM, Howland BE. Secretory patterns and circadian and seasonal changes in LH, FSH, prolactin, and testosterone in the male pygmy goat. J Anim Sci **49**:543–553, 1979.
19. Kennaway DJ, Obst JM, Dunstan EA, Friesen HG. Ultradian and seasonal rhythms in plasma gonadotropins, prolactin, cortisol, and testosterone in pinealectomized rams. Endocrinology **108**:639–646, 1981.
20. Munro CJ, McNatty KP, Renshaw L. Circa-annual rhythms of prolactin secretion in ewes and the effects of pinealectomy. J Endocrinol **84**:83–89, 1980.
21. Wettemann RP, Tucker HA. Relationship of ambient temperature to serum prolactin in heifers. Proc Soc Exp Biol Med **146**:908–911, 1974.
22. Deguchi T. Ontogenesis of a biological clock for serotonin: Acetyl coenzyme A *N*-acetyltransferase in pineal gland of rat. Proc Natl Acad Sci USA **72**:2814–2818, 1975.
23. Reppert SM, Chez RA, Anderson A, Klein DC. Maternal-fetal transfer of melatonin in the non-human primate. Pediatr Res **13**:788–791, 1979.
24. Johnson HD, Vanjonack WJ. Symposium: Stress and health of the dairy cow, effects of environmental and other stressors on blood hormone patterns in lactating animals. J Dairy Sci **59**:1603–1617, 1975.
25. Tucker HA. Hormonal response to milking. J Anim Sci **32**:137–141, 1971.

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