Lighting the Way to Optimal Cow Performance

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Abstract

Management of lighting in dairy housing has recently received interest as a method to improve production. In addition, recent evidence suggests that photoperiod manipulation can be used to enhance disease resistance, especially during the dry period. As with any management approach, there are certain guidelines that require consideration for successful implementation. This review covers the biology of photoperiod responses in cattle, impacts on production and health, and suggestions for implementation.

Introduction

Photoperiod is defined as the duration of light an animal is exposed to within a 24 hour period. Animals and other organisms use photoperiod to track the length of the day; in this context "daylength" is the number of hours of light[28]. A long day is considered continuous exposure to 16-18 hrs of light along with a 6-8 hr period of darkness. Photoperiod is of interest to dairy producers and veterinarians because at least 10 published research studies show that milk production is increased in cows exposed to long days relative to those on natural photoperiod (Figure 1)[9, 14, 16, 19, 21, 22, 23, 26, 27, 30]. Photoperiod also affects growth and reproduction in younger cattle[17, 32, 33], and recent evidence suggests that lighting may affect immune function.

Physiology of the Response

It is important to note that the response to lighting is driven by a physiologic response within the animal rather than a behavioral response to increased duration of illumination. Exposure to light suppresses secretion of the hormone melatonin in cows as in other species[18, 28]. Thus, as the length of photoperiod increases, there is a reduced duration that melatonin is at high concentrations in the blood. The pattern of melatonin influences secretion of other hormones, particularly prolactin (PRL) and insulin-like growth factor-I (IGF-I)[14, 29]. It appears that the changes in IGF-I are important to the increase in milk yield observed in lactating cows on long days. Changes in secretion and sensitivity to PRL are thought to mediate the production and immune responses observed in cows as they transition through the dry period into lactation (discussed below).

Understanding the hormonal changes that occur under different photoperiods is critical when considering how long a duration of light exposure is appropriate. Simply put, some more light is good, but continuous lighting is not better. As stated previously, animals use the pattern of melatonin to track daylength. In the absence of any darkness, there is no cue for relative daylength, and it appears that cows default to a short day response. Indeed, cows on continuous lighting do not produce more milk than cows on a natural photoperiod[19], likely because the hormonal shifts associated with higher milk production do not occur[29].

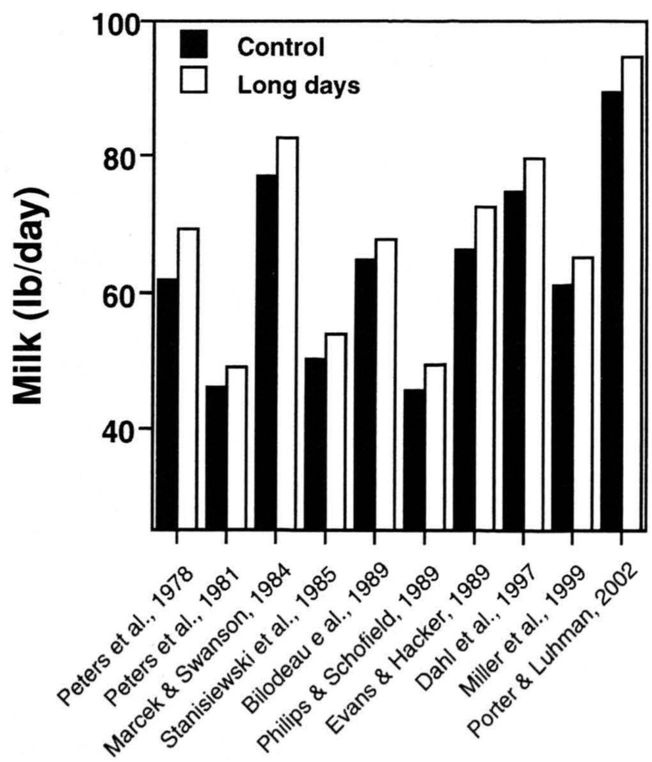

Figure 1. Summary of published studies examining the effect of increased photoperiod on milk yield in lactating cows. Full references are listed in the references section.

Production Responses in Lactating Cows

As with most management interventions, there is a range in response to long days. However, a typical response is 5 lb/cow/day[13]. Note that the response does not become apparent right away; it usually takes four weeks to observe a change relative to normal daily variation in milk production. A metric for producers to use to gauge the response in their cows is the "150 day" or "management level milk" value from DHI records. This allows for comparison of the herds' response to lighting if all other factors are held constant.

Review of all the published data on the lactational response to photoperiod indicates that long days stimulate milk production across production levels[13]. Similar to bST and 3X milking, responses to long days appear to be fixed rather than production-dependent[8, 15, 31]. That is, cows across production levels are all expected to increase by about 5 lb/day. For example, cows in the experiment with the lowest average yield of 45 lb/day had increased milk production to a similar extent as cows in the experiment that averaged 90 lb/day. This is of interest when making financial decisions about adoption photoperiod management, as an expectation based on a certain percentage of production is likely to be less accurate than an assumption of a fixed response.

Despite the substantial increases in milk and component yield, there is little evidence that photoperiod affects concentrations of milk lactose, protein, or solids[13]. Slight variance in fat has been observed, with an increase in one experiment and a decrease in another. In general, there is no effect on fat or other components. Remember that milkfat yield will increase in response to longer photoperiod, even if there is a slight reduction in milkfat percentage.

Cows exposed to long days while lactating consume more feed than those on natural photoperiod, but in response to higher milk production rather than the opposite. In other words, cows do not eat more and then produce more milk. Rather, they produce more milk and consume more feed to meet the increased demand for energy to make that milk. This is an important point when considering light placement in a barn. Some popular press information advocates placement of lights only over the feed alley in a freestall barn. This is a misconception about the basis for the response. Cows do not respond to photoperiod by eating more and then producing more milk. Rather, cows experience a physiologic stimulus to produce more milk and then dry matter intake increases to support the greater milk yield. Because cows spend the majority of their time lying in stalls rather than at the bunk eating[11, 12], putting lights only over the feed alley severely limits the exposure to extra lighting.

Another common misconception regarding feed intake and photoperiod is that cows require a low level of illumination (i.e. a "night light") in order to access feed and water during darkness. This is not necessary, and may detract from the response. Cows are able to find both feed and water in the dark. It is important to remember that at least a six hour period of darkness is required, and "night lighting" may interfere with that. Low intensity red lighting (7.5W bulbs at 20-30 ft intervals; mounted 10 ft from the floor) has been used successfully for observation and movement of cows during dark periods.

Table 1. Milk price sensitivity to photoperiod management for a typical 80 cow tie-stall barn.

Milk price[a]	$14.00	$13.00	$12.00	$11.00	$10.00	$9.00
Milk response[b]	5	5	5	5	5	5
Milk income[c]	$0.70	$0.65	$0.60	$0.55	$0.50	$0.45
Feed[d]	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11
Electricity[e]	$0.18	$0.18	$0.18	$0.18	$0.18	$0.18
Total cost	$0.29	$0.29	$0.29	$0.29	$0.29	$0.29
Net profit	$0.41	$0.36	$0.31	$0.26	$0.21	$0.16
Profit/mo	$984.00	$864.00	$744.00	$624.00	$504.00	$384.00
Annual profit[f]	$9,840.00	$8,640.00	$7,440.00	$6,240.00	$5,040.00	$3,840.00

[a]Mailbox price per cwt.
[b]Average response in lb per cow each day.
[c]Per cow each day.
[d]Assume 1.8 lb increase in dry matter to support 5 lb increase in milk.
[e]Electricity to power supplemental lighting 16 hr/day.
[f]Assumes response only 10 month each year.

Photoperiod and bST, 3X Milking

Milking cows 3X can present a logistical challenge to adoption of photoperiod management, but if cows receive adequate dark periods they will respond to long days. Remember to keep a six hour uninterrupted period of darkness between two of the three milkings. This may require coordination of milking schedules and darkness in different sections or barns. Inevitably the question arises as to "How dark is dark?". There is limited data available on the lower limit of light that a cow can detect. However, it appears that cows can not detect light at less than 5 footcandles (FC). It should be noted that cows may experience a shift in their ability to perceive light depending on the difference in intensity of the light relative to dark. Therefore rather than limiting light to lees than 5 FC, it is recommended that no illumination at all be provided during the dark phase of the cycle.

Long day lighting can be combined with bST for an additive response[21]. That is, cows respond to bST and long days with the expected increase in production to both treatments. In addition, cows on long day photoperiod (LDPP) and bST increased dry matter intake sooner than cows receiving bST under natural photoperiod.

Photoperiod for Dry Cows

In contrast to lactating cows, recent experiments from the US and Canada indicate that a short day photoperiod (SDPP) is most appropriate for dry cows[20, 24, 25]. In one study, cows on SDPP when dry produced 7 lb/day more than cows on LDPP when dry[20]. First calf heifers respond similarly when they are exposed to SDPP for the final two months of gestation[24]. We suspect that the short days "reset" the cow's ability to respond to a longer photoperiod in the subsequent lactation. From a practical view then, this means that dry cows should not remain under the same lighting as lactating cows. In most situations, pasture or other facilities removed from the barn housing lactating cows will be exposed to less than 12 hours of lighting each day, which should be enough of a decrease in photoperiod to ensure a response to long days after calving.

Such a response to shorter photoperiod when dry is consistent with the effects of calving season on milk yield[34]. Cows calving in late winter in the Northern Hemisphere produce more milk than those that calve in summer. This has previously been attributed to post-calving influences of heat stress on dry matter intake. Based on the critical role of PRL in lactogenesis[3], another hypothesis is that the environmental effects on PRL secretion and sensitivity during the dry period have a dramatic influence on subsequent milk yield[6]. Physiologically, we would expect that cows dry during the winter would experience the lowest concentrations of PRL under ambient conditions of short days and low temperatures, whereas cows dry in the summer would have elevated PRL secretion when dry because of high ambient temperature and long days. In fact, recent reports from Israel support this concept, as much of the seasonal variation in milk yield among cows could be explained by the environmental conditions a cow was exposed to during the late dry period, particularly the photoperiod[1, 2, 7].

Perhaps of greater interest to dry cow management

Table 2. Milk price sensitivity to photoperiod management for a typical 250 cow free-stall barn.

Milk price[a]	$14.00	$13.00	$12.00	$11.00	$10.00	$9.00
Milk response[b]	5	5	5	5	5	5
Milk income[c]	$0.70	$0.65	$0.60	$0.55	$0.50	$0.45
Feed[d]	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11
Electricity[e]	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Total cost	$0.15	$0.15	$0.15	$0.15	$0.15	$0.15
Net profit	$0.55	$0.50	$0.45	$0.40	$0.35	$0.30
Profit/mo	$4,125.00	$3,750.00	$3,375.00	$3,000.00	$2,625.00	$2,250.00
Annual profit[f]	$41,250.00	$37,500.00	$33,750.00	$30,000.00	$26,250.00	$22,500.00

[a]Mailbox price per cwt.
[b]Average response per cow each day.
[c]Per cow each day.
[d]Assume 1.8 lb increase in dry matter to support 5 lb increase in milk.
[e]Electricity to power supplemental lighting 8 hr/day.
[f]Assumes response only 10 month each year.

are the apparent effects of SDPP on udder health and disease resistance. Preliminary data from ongoing studies in our laboratory suggest that cows exposed to SDPP when dry have greater capacity to resist new infection, as assessed by *in vitro* measurements of lymphocyte proliferation and chemotaxis[4,5]. We are also testing the ability of cows to respond to a mastitis challenge after exposure to different photoperiods when dry. Because cows are at the greatest risk for new infections during the transition period, photoperiod manipulation may offer a non-invasive management approach to enhance immune function at this critical period in the lactation cycle.

Implementing Photoperiod Management

Responses to long days have been observed in cows exposed to fluorescent, metal halide, and high pressure sodium (HPS) lighting. The choice of lighting type should be made according to efficiency and the mounting height most appropriate to the barn[10]. For example, in tie-stall and stanchion barns the relatively low ceilings allow use of fluorescent lights only (mounting height of 8-10 ft). In freestalls, lights can often be mounted at heights of 12 to 16 ft, thus, metal halide or high pressure sodium lamps are appropriate. One caution to the use of HPS is that many people do not respond well to the yellow light output from those lamps. Therefore, worker acceptability should be considered in lamp choices.

What is the minimum light intensity to produce the effect? Light is measured in footcandles (FC) or lux (lx), with 1 FC = 10.8 lx. To observe a production response in lactating cows, an intensity of 15 FC at 3 feet from the floor of the stall is recommended. Responses have been observed at intensities as low as 10 FC, but the extra 5 FC give a buffer for dirty lamps, burned out bulbs, etc. It is important to remember that the dispersion of light over an area should be as uniform as possible. Appropriate dispersion can be achieved with correct mounting height and distance. Lamps are sold with a recommended range of mounting height, and a rule of thumb for placement of lamps is a mounting distance that is 1.5 times the effective mounting height[10]. Effective mounting height is measured from the bottom of the lamp to a level 3 feet from the floor of the stall.

Light intensity is measured using a light meter, which can be obtained from electrical suppliers or photographic shops; they are usually priced between $75 – 125. Light meters are simple to operate and portable. Regardless of lighting design recommendations, all lighting systems should be tested with a light meter. Because photoperiod management requires light intensity to be monitored, a light meter will continue to be used after the initial installation.

Economic Benefits

Photoperiod management should yield rapid, positive returns to the bottom line of dairy production units of all sizes, even in times of low milk prices. Tables 1 and 2 present examples of the milk price sensitivity with adoption of photoperiod management on two different types of operations. Although LDPP is profitable on farms of every size, certain economies of scale factor in on larger farms and increase the profitability.

Summary

Photoperiod management offers another tool to dairy producers to optimize dairy cow performance and health. Alterations in light duration initiate shifts in hormone secretion that ultimately influence milk yield and disease resistance. A website is available at *http://il-traill.outreach.uiuc.edu/photoperiod*. This site contains more information on photoperiod, worksheets to assist producers in lighting design and cost analysis, expected economic returns, and other contact information.

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References

1. Aharoni Y, Brosh A, Ezra E: Short communication: prepartum photoperiod effect on milk yield and composition in dairy cows. *J Dairy Sci* 83:2779-2781, 2000.
2. Aharoni Y, Ravagnolo O, Misztal I: Comparison of lactational response of dairy cows in Georgia and Israel to heat load and photoperiod. *J Dairy Sci* 84: Abstract # 1101, 2001.
3. Akers, RM, Bauman DE, Capuco AV, Goodman GT, Tucker HA: Prolactin regulation of milk secretion and biochemical differentiation of mammary epithelial cells in periparturient cows. *Endocrinology* 109:23-30, 1981.
4. Auchtung TL, Kendall PE, Dahl GE: Bovine lymphocytes express prolactin receptor (PRL-R) mRNA: a potential mechanism for PRL effects on immune function. *J Anim Sci* 79:Abstract #37, 2001.
5. Auchtung TL, Salak-Johnson JL, Dahl GE: Short day photoperiod enhances lymphocyte proliferation in dairy cattle. *J Anim Sci* 80:Abstract #81, 2002.
6. Auchtung TL, Pollard BC, Kendall PE, McFadden TB, Dahl GE: Prolactin receptor expression responds to photoperiod similarly in multiple tissues in dairy cattle. *J Anim Sci* 80:Abstract #34, 2002.
7. Barash H, Silanikove N, Shamay A, Ezra E: Interrelationships among ambient temperature, day length, and milk yield in dairy cows under a Mediterranean climate. *J Dairy Sci* 84:2314-2320, 2001.
8. Bauman, DE: Bovine somatotropin and lactation: from basic sci-

ence to commercial application. *Domest Anim Endocrinol* 17:101-116, 1999.
9. Bilodeau PP, Petitclerc D, St. Pierre N, Pelletier G, St. Laurent GJ: Effects of photoperiod and pair-feeding on lactation of cows fed corn or barley grain in total mixed rations. *J Dairy Sci* 72:2999-3005, 1989.
10. Chastain J: Lighting in freestall barns, in: *Proceedings of the Dairy Housing and Equipment Systems Conference*, Ithaca, NRAES-129, 2000. pp115-130.
11. Dado RG, Allen MS: Continuous computer acquisition of feed and water intakes, chewing, reticular motility, and ruminal pH of cattle. *J Dairy Sci* 76:1589-1600, 1993.
12. Dado RG, Allen MS: Intake limitations, feeding behavior, and rumen function of cows challenged with rumen fill from dietary fiber or inert bulk. *J Dairy Sci* 78:118-133, 1995.
13. Dahl GE, Buchanan BA, Tucker HA: Photoperiodic effects on dairy cattle: A review. *J Dairy Sci* 83:885-893, 2000.
14. Dahl GE, Elsasser TH, Capuco AV, Erdman RA, Peters RR: Effects of long day photoperiod on milk yield and circulating insulin-like growth factor-1. *J Dairy Sci* 80:2784 -2789, 1997.
15. Erdman RA, Varner M: Fixed yield responses to increased milking frequency. *J Dairy Sci* 78:1199-1203,1995.
16. Evans NM, Hacker RR: Effect of chronobiological manipulation of lactation in the dairy cow. *J Dairy Sci* 72:2921-2927, 1989.
17. Hansen PJ: Seasonal modulation of puberty and the postpartum anestrus in cattle: a review. *Livest Prod Sci* 12:309-327, 1985.
18. Hedlund LM, Lischko M, Rollag MD, Niswender GD: Melatonin: daily cycle in plasma and cerebrospinal fluid in calves. *Science* 195:686-687, 1977.
19. Marcek JM, Swanson LV: Effect of photoperiod on milk production and prolactin of Holstein dairy cows. *J Dairy Sci* 67:2380-2388, 1984.
20. Miller ARE, Erdman RA, Douglass LW, Dahl GE: Effects of photoperiodic manipulation during the dry period of dairy cows. *J Dairy Sci* 83:962-967, 2000.
21. Miller ARE, Stanisiewski EP, Erdman RA, Douglass LW, Dahl GE: Effects of long daily photoperiod and bovine somatotropin (Trobest®) on milk yield in cows. *J Dairy Sci* 82:1716-1722, 1999.
22. Peters RR, Chapin LT, Emery RS, Tucker HA: Milk yield, feed intake, prolactin, growth hormone, and glucocorticoid response of cows to supplemental light. *J Dairy Sci* 64:1671-1678, 1981.
23. Peters RR, Chapin LT, Leining KB, Tucker HA: Supplemental lighting stimulates growth and lactation in cattle. *Science* 199:911-912, 1978.
24. Petitclerc D, Vinet CM, Lacasse P: Peripartum effects of photoperiod and lactose on primiparous Holstein heifers. *41st Ann Mtg Eur Assoc Anim Prod* P86 (Abstr.), 1989.
25. Petitclerc D, Vinet C, Roy G, Lacasse P: Prepartum photoperiod and melatonin feeding on milk production and prolactin concentrations of dairy heifers and cows. *J Dairy Sci* 81:251, 1998
26. Phillips CJC, Schofield SA: The effect of supplementary light on the production and behavior of dairy cows. *Anim Prod* 48:293-303, 1989.
27. Porter PA, Luhman CM: Changing photoperiod improves persistency in high producing Holstein cows. Abstract # 49 presented at the Midwest Meeting of the American Society of Animal Science / American Dairy Science Association, 2002.
28. Rieter RJ: Pineal melatonin: cell biology of its synthesis and of its physiological interactions. *Endocrine Rev* 12:151-180, 1991.
29. Spicer LJ, Buchanan BA, Chapin LT, Tucker HA: Effect of 4 months of exposure to various durations of light on serum insulin-like growth factor-1 (IGF-1) in prepubertal Holstein heifers. *J Anim Sci* 72:178, 1994.
30. Stanisiewski EP, Mellenberger RW, Anderson CR, Tucker HA: Effect of photoperiod on milk yield and milk fat in commercial dairy herds. *J Dairy Sci* 68:1134-1140, 1985.
31. Thomas JW, Erdman RA, Galton DM, Lamb RC, Arambel MJ, Olson JD, Madsen KS, Samuels WA, Peel CJ, Green GA: Responses by lactating cows in commercial dairy herds to recombinant bovine somatotropin. *J Dairy Sci* 74:945-964, 1991.
32. Tucker HA, Petitclerc D, Zinn SA: The influence of photoperiod on body weight gain, body composition, nutrient intake and hormone secretion. *J Anim Sci* 59:1610-1620, 1984.
33. Tucker HA, Ringer RK: Controlled photoperiodic environments for food animals. *Science* 216:1381-1386, 1982.
34. Wunder WW, McGilliard LD: Seasons of calving: Age, management, and genetic differences for milk. *J Dairy Sci* 54:1652-1661, 1971.