Photoperiod Management of Dairy Cattle for Performance and Health

Geoffrey E. Dahl

230 ASL, MC-630, Dept. of Animal Sciences, University of Illinois, 1207 W. Gregory Dr., Urbana, IL 61801
E-mail: gdahl@uiuc.edu

Take Home Messages:

- Lactating cows should be under long day photoperiod of 16 to 18 hours of light to increase milk production.
- In late pregnancy expose cows to short day photoperiod of less than 10 hours of light to maximize production and improve health status in the transition period.

Introduction

Dairy producers are constantly searching out new management techniques to improve production efficiency and cash flow. Photoperiod management has received interest lately as a cost effective method to increase production in lactating cows. That is because in cows exposed to long days, i.e. 16 to 18 hours of light and a 6 to 8 hour period of darkness, daily milk production increases an average of 2 liters/cow, relative to those on natural photoperiods (Dahl et al., 2000). The purpose of this paper is to review the evidence for a response of lactating and dry cows to photoperiod, describe the physiologic basis for those responses, and discuss the economic justification for implementing photoperiod management.

While almost all animals respond to photoperiod in some way, it is usually associated with reproductive events (Tucker and Ringer, 1982). Indeed, poultry producers use lighting to stimulate layers and sheep and horse breeders manipulate the breeding season with light exposure. Though not seasonal breeders, photoperiod can affect reproduction in cattle. For example, long days hasten puberty in heifers relative to natural daylength. Long days are also thought to reduce the delay in return to cyclicity following parturition, particularly in the winter (Hansen, 1985). However, reproductive changes in response to photoperiod are subtle in cattle in comparison with the effect on lactation.

Effect of Photoperiod in Lactating Cows

The impact of long days on milk production was first observed in 1978 by researchers at Michigan State University (Peters et al., 1978). Cows were placed on 16 hours of light, 8 hours of darkness (16L:8D) or left on natural photoperiod at calving. The study was conducted between September and March, when natural light was limited to less than 12 hours each day. Over the first 100 days postpartum, cows on long days produced 2.0 L/d more milk than those on natural photoperiod. At 100 days, the treatments were switched and the cows previously on natural photoperiod increased milk production, whereas the cows previously on 16L:8D decreased milk yield. Those results suggested that exposure to long days increased milk yield and did so across production levels. Since that first study, at least ten other experiments at 7 different laboratories across North America and Europe have confirmed the response (summarized in Dahl and Petitclerc, 2003). Based on those studies it is expected that cows on long days will produce an average of 2 liters more than control animals on natural photoperiod.

What is the basis of the response? Recent studies reveal a potential physiologic mechanism for the increase in yield from cows on long days. Differences in light exposure alter secretion of a number of hormones. Indeed, those hormonal shifts drive the commonly observed changes in reproductive activity in other species. The first hormone impacted by photoperiod is melatonin, which is secreted in response to darkness. Thus, in cows and other animals, a long day actually reduces the duration of elevated melatonin (Dahl et al., 2000). Animals use this pattern of melatonin to track daylength, and then alter secretion of other hormones. In cows, a long day pattern is associated with higher secretion of the hormone insulin-like growth factor-I (IGF-I; Dahl et al., 1997). Higher IGF-I, in turn, is thought to increase milk yield. It is of interest that bovine somatotropin (bST), which also increases milk yield, stimulates IGF-I release as well (Bauman, 1999). Miller et al. (1999) treated cows with either long days or natural photoperiod, and half of each of those groups received bST as well. Relative to cows on natural photoperiod, milk yield increased 1.9 L/d in the cows on long days, and 5.7 L/d in bST. The combination of long days and bST improved production 7.7 L/d, clearly an additive response, which suggests that the two manipulations are not antagonistic.

What about combining long days with other management techniques that improve performance, for example 3X milking and ionophores? Although there are no reports of the effect of either combination on production, there is no reason to believe that additive responses would not be realized, and anecdotal evidence supports that view. One producer installed lighting to extend photoperiod in roughly one half of a 2000 cow herd that is milked 3X. Long days increased production relative to those cows that remained on natural lighting. It is critical, however, that cows milked 3X maintain a 6 hr period of darkness between 2 of the 3 milkings, as continuous lighting will not allow for a sustained response to long days. As for ionophores, there is no overlap between photoperiodic and ionophore modes of action, though both increase milk production. Because ionophore treatment provides higher levels of glucose precursors that are essential to milk synthesis, the combination with long days is expected to cause an additive response with regard to milk yield.

▪ Photoperiod Treatment of Dry Cows

Lactation, however, is not the only time during the annual milk production cycle when photoperiod treatment is recommended. Recent studies suggest that appropriate photoperiod treatment of the dry cow can markedly enhance milk yield in the subsequent lactation. We treated cows with either long or short (8L:16D) days during the entire 60-d dry period (Miller et al., 2000). Cows were then exposed to natural photoperiod after parturition, which occurred between November and January. Surprisingly, over the first 120 days of lactation, cows treated with short days when dry produced 3.2 L/d more milk than the cows on long days. It is important to note that all cows were housed together, fed the same diet, and managed identically following parturition. Our data are consistent with other reports of the impact of photoperiod manipulation during the dry period (Aharoni et al., 2000; Petitclerc et al., 1998). Thus, in contrast to the benefits of long day photoperiod for lactating cows, treatment with short days is recommended for dry cows.

The impact of short days on dry cows is consistent with recognized effects of calving season on production in that lactation. That is, cows that calve in summer produce less milk than those that calve in winter, when all other genetic and management factors are accounted for. Previous dogma held that the seasonal effect was a negative response to high temperatures of the summer months, and the resultant depression of dry matter intake during early lactation. Yet a study by Aharoni et al. (2000) suggests that postpartum effects of heat are of less impact than prepartum photoperiod, and between 1.5 to 2.0 L/d of the milk production loss in summer calving cows is explained by the longer photoperiod exposure during the final 3 weeks of pregnancy relative to cows calving in winter.

In addition to the effects of short days during the dry period on subsequent milk production, we have generated evidence that supports a role for reduced photoperiod in improved mammary and general health during the transition. Seasonal shifts in immune function are observed in many species and these effects on immune tissues are related to photoperiod in rodents (Yellon et al., 1999). In growing steers, short days improve two indicators of immune function, lymphocyte proliferation and chemotaxis, relative to long days (Auchtung et al., 2002a). We observed that dry cows on short days had similar responses to the steers, and had lower rates if intramammary infection and metritis during the first 10 days of lactation. In addition, cows on short days had a significant reduction in SCC from dry off to parturition, whereas those on long days had an increase over that time (Auchtung et al., 2003). These data suggest that short days are associated with greater resistance to pathogenic insult during an immunocompromised period in the production cycle.

Shifts in secretion of and sensitivity to the hormone prolactin (PRL) may explain the effects of short day photoperiod during the dry period. We have shown that long days increase whereas short days decrease PRL secretion (Auchtung et al., 2002b). However, the lower PRL concentrations of cows on short days is associated with higher amounts of PRL-receptor expression, and likely sensitivity to that hormone (Auchtung et al., 2002b). Because PRL is critical to the process of mammary cell activation that occurs at parturition, and PRL has immunostimulatory effects, we speculate that the shifts in sensitivity that accompany short day treatment are producing the changes observed in production and mammary health.

■ Economics of Photoperiod Management

From the preceding discussion it is clear that photoperiod manipulation is an effective method to improve milk yield. But any new management tool must be economically beneficial as well. Tables 1 through 3 detail the expected returns and costs for implementing photoperiod management on a typical large dairy. All calculations are in Canadian dollars (CDN$). Assuming a response of 2 L/d from each cow, income in response to long days yields a gross return of $1.16/cow/d. It is expected that an increase of 1 kg/d in dry matter would be needed to support the higher milk yield ($0.19/cow/d). A cost unique to Canada relative to the United States is purchase of additional quota; this is estimated at $0.46/cow/d ($0.23/L x 2 L/d). The electrical cost has been calculated in Table 2 based on a lighting design appropriate for a 250 cow freestall barn. Technical details of design criteria are available at <http://il-traill.outreach.uiuc.edu/photoperiod>. Additional non-cash costs associated with capital investment (i.e. lights) total $0.03/cow/d. Subtraction of costs from milk income yields a net return of $0.43/cow/d, or $107.50/farm/d. This means that an investment of $116.08/cow for lights (Table 3) would be recovered in 9 months. An additional column has been provided in each table to assist producers in determining the economic justification unique to their farm.

In summary, photoperiod management offers dairy producers a novel tool to improve the efficiency of milk production. It is cost effective on dairies of all sizes, but economies of scale on larger dairies enhance the returns. Treatment to increase daylength is recommended during lactation and decrease daylength during the dry period to increase mammary health during the transition period and milk yield in the subsequent lactation.

Table 1. Net daily income per lactating cow, net farm income and payoff time for fixed costs (CDN$) associated with supplemental lighting for a 250 cow freestall barn.

	Example	Your Farm
Response, L	2	
Quota cost[1], L	$0.23	
Feed cost, kg DM	$0.19	
Electrical cost[2]	$0.05	
Other non-cash cost[3]	$0.03	
Milk income[4]	$1.16	
Net income/cow	$0.43	
Net farm income/day	$107.50	
Net farm income/year[5]	$32,250	
Pay-off time for capital costs, days[6]	270	

[1]Cost of financing increased quota over 15 years at current interest rate.
[2]Table 2.
[3]Interest on investment and depreciation.
[4]Two liters extra milk at $0.58/L.
[5]Calculated for a response 10 months of the year.
[6]Total capital cost (Table 3) divided by net farm income/day.

Table 2. Average daily electrical costs (CDN$) of operating supplemental lighting for a 250 cow freestall barn[1].

	Example	Your farm
Lighting type	Metal halide	
Lamp size in watts	250	
Lamps/fixture	1	
Electrical demand/fixture, kW	0.3	
Total number of fixtures	72	
Hours of operation/day	8	
Energy use, kW/day	172.8	
Daily energy cost[2]	12.10	
Rated lamp life, hours	15,000	
Lamp life, days	2,542	
Cost of lamp replacement, per day	$0.03	
Average operating cost	$12.13	
Daily operating cost/cow	$0.05	

[1]Six row barn approximately 62 meters long x 35 wide.
[2]$0.07/kWh.

Table 3. Cost (CDN$) of supplemental lighting for a 250 cow freestall barn.

	Example	Your farm
Lighting type	Metal halide	
Lamp size in watts	250	
Fixture cost[1]	$300	
Lamps/fixture	1	
Installation cost/fixture[2]	$100	
Total cost/fixture	$400	
Total number of fixtures	72	
Timer cost and installation[3]	$220	
Total capital cost	$29,020	
Capital cost/cow	$116.08	

[1]Lamp included with fixture – replacement cost is $65/lamp.
[2]Labor @ $65/hour.
[3]Automatic timer $125; installation $95.

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