

Photoperiod Control Improves Production and Profit of Dairy Cows

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Environmental factors that potentially depress milk production efficiency are often planned for in dairy housing. For example, cooling to abate heat stress, bunk management to maximize dry matter intake, and bedding choices that improve cow comfort all act to prevent a loss of production. One environmental factor, photoperiod, can be used to effectively improve production efficiency in lactating cows. As with any management approach, there are certain guidelines that require consideration for successful implementation. Combination of long day lighting with other management technologies such as bST and three times a day (3X) milking increase the complexity of effectively implementing the technique.

What is photoperiod? Photoperiod is defined as the duration of light an animal is exposed to within a 24-hour period. Animals use photoperiod to track the length of the day. A long day photoperiod (LDPP) is considered continuous exposure to 16 to 18 hours of light along with a 6- to 8-hour period of darkness. In contrast, a short day photoperiod (SDPP) is usually 8 hours of light and 16 hours of darkness. Poultry producers have used light manipulation for decades to improve growth and egg laying efficiency (22). Data is now available to support application of photoperiod management to dairy cattle in all housing situations (7).

At least nine published research studies (2, 8, 9, 11, 13, 14, 15, 18, 20; summarized in Figure 1) show that milk production is increased in cows exposed to long days relative to those on natural photoperiod. The consistency of the response is striking and averages about 5 lbs/cow/day. Milk production increased in cows regardless of production level, suggesting that the response is fixed rather than yield dependent. In addition, the types of housing, ration and other management factors were variable; further evidence that long days would be effective in any dairy facility. There is no effect of photoperiod on milk lactose, protein, or solids. 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 (7). From a milk yield perspective there is overwhelming evidence that extending the duration of light exposure to lactating cows increases milk yield.

Exposure to light suppresses secretion of the hormone melatonin in cows as in other species (7,19). 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). We believe that the changes in IGF-I are important to the increase in milk yield observed in cows on long days (8). This is the same hormone thought to mediate the effects of bST (1), but it appears that photoperiod and bST act via slightly different pathways to produce the response. Indeed, long day lighting can be combined with bST for an additive response (13). In addition, cows on LDPP and bST increased dry matter intakes sooner than cows receiving bST under natural photoperiod. With photoperiod, as with bST, we are manipulating the cow's physiology with a signal to increase milk production.

As cows produce more milk after exposure to long days, they will eventually increase dry matter intake (7, 13). The added feed cost, however, is more than covered by the higher milk production. It is important to point out that the intake lags the increase in production; it is not that improved lighting somehow drives the cow to eat more and thus make more milk. This concept is critical in evaluating where and how many lights are placed in a barn. Lights should never be limited to the area over the feedbunk in freestall housing. Rather, the entire barn should be illuminated to an intensity of 15 footcandles (FC). This based on the fact that cows spend a majority of their time lying in stalls versus at the feedbunk (5, 6). To effectively influence the cow's physiology, exposure to light is necessary for at least 16 hours. Thus, placement over the feedbunk alone will not be effective.

It is important to remember that cows need some darkness — it will not be possible to sustain a response if the lights are left on continuously. As stated earlier, 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. This does not mean that continuous lighting will reduce production, only that a long day induced increment will not be sustainable. Likewise, it is not necessary to leave a "night light" on for cows to see the waterer or feed. Cows are able to find both feed and water in the dark. Remember that at least a 6 hour period of darkness is required, and "night lighting" may interfere with that. Low

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intensity red lighting (7.5W bulbs at 20- to 30-foot intervals) has been used successfully for observation and movement of cows during dark periods.

One question often asked is "how dark is "dark?" Light intensity is measured in FC or lux (lx), with 1 FC = 10.8 lx. There are 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 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. Extraneous light sources, therefore, should be limited whenever possible. This includes yard lights, night lights, etc.

Milking cows 3X poses a logistical challenge in maintaining the dark period when milking occurs at 8-hour intervals. Yet, if cows receive adequate dark periods, they will respond, even if milked three times daily. Remember to keep a 6 hour uninterrupted period of darkness between two of the milkings. This may require coordination of milking schedules and darkness in different sections or barns. On one farm, approximately 1000 cows were exposed to 18 hours of light and milked 3X. Milking times were scheduled such that different strings received darkness for 6 hours based on their time spent in the parlor, though the dark period was asynchronous among strings. Cows on long days produced 6.5 pounds per day more milk than a similar group on natural photoperiod. Of interest, when the second group of cows was placed on long days, it was impossible to maintain an uninterrupted dark period, and their response was much less.

Because responses to long days have been observed in cows exposed to fluorescent, metal halide (MH), and high pressure sodium (HPS) lighting, the type of light selected for long day lighting does not matter (7). The choice of lighting type should be made according to efficiency and the mounting height most appropriate to the barn. In freestalls, lights can often be mounted at heights of 14 to 16 feet or higher, thus, MH or HPS are appropriate. These lamps provide the desired intensity with high efficiency and are, therefore, the lowest in operating cost. 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.

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 gives a buffer for

dirty lamps, burned out bulbs, etc. Estimation of the number of fixtures required to achieve a 15 FC intensity is straightforward (3, 4). The first equation, $(Area) \times (FC) \times (K)$, yields the total lumens needed. Area is the square footage of the barn, FC is the desired footcandles of intensity (i.e. 15), and K is a constant for outdoor lighting conditions (versus indoors where wall reflectance would be a factor). An open or curtain sided barn would use a K of "3", whereas an enclosed stanchion style barn would require a K of "2". Once Total Lumens have been determined, simply divide by the lumen output of the lamp in question, to yield the number of fixtures required. Manufacturers provide luminal output information for all lamps. As for spacing, a maximum distance between lamps can be estimated by dividing the recommended mounting height by a factor of 1.5 (3).

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. Light meters to test light intensity can be obtained from electrical suppliers or photographic shops; they are usually priced between \$75 to \$125.

Light meters are simple to operate and portable. Regardless of lighting design recommendations, all lighting systems should be tested with a light meter. Not only will this allow determination of the intensity, but meter readings throughout the facility will confirm that light is evenly distributed between lamps. Problems such as "spot-lighting" and low light corners can then be avoided. Photoperiod can also be used during the dry period and late gestation to improve milk yield in the subsequent lactation. In contrast to lactating cows, recent experiments from our laboratory and Canada indicate that a short day photoperiod is most appropriate for dry cows. Cows on SDPP when dry produced 7 lbs/day more than cows on LDPP when dry (Figure 2; 12). This is consistent with preliminary work by Petitclerc et al. in cows (17) and heifers (16, 17) that showed higher production in animals exposed to SDPP during the dry period (final 60 days of gestation in heifers) relative to those exposed to long days. We suspect that the short days before parturition "resets" the cow's ability to respond to LDPP in the subsequent lactation.

In addition to lactation and the dry period, photoperiod manipulation can affect cows in other ways. Although cows are not considered seasonal breeders, there are some subtle effects of photoperiod on the reproductive axis (10). Exposure to LDPP hastens puberty in heifers. Heifer calves exposed to long days grow faster and have greater secretory tissue growth of the mammary gland (21). In lactating

cows, no direct effect of photoperiod has been observed on reproduction, but seasonal effects associated with differences in photoperiod occur. Notably, cows calving in the winter, when days are short, have a longer delay in return to estrous cyclicity relative to cows that calve in summer, when days are long. Thus, extending the photoperiod in cows may hasten the return to estrus during the winter and fall. Certainly no adverse effects of long days on reproduction in cattle have been observed.

Table 1. Milk price sensitivity to photoperiod management for a typical 250 cow free-stall barn.

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|----------------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 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 |

^aMailbox price per cwt.
^bAverage response per cow each day.
^cPer cow each day.
^dAssume 1.8 lb increase in dry matter to support 5 lb increase in milk.
^eElectricity to power supplemental lighting 8 hr/day.
^fAssumes response only 10 month each year.

Even in times of low milk prices, photoperiod management profitable. Table 1 presents an example of the milk price sensitivity with adoption of photoperiod management in a typical freestall operation. Although LDPP is profitable on farms of all sizes, certain economies of scale factor in on larger farms and increase the profitability. These include the higher density of freestall barns, greater ability to use natural lighting in curtain-sided barns, and use of higher efficiency lamps to illuminate freestall facilities. Using a cost of \$50/cow, in all of the examples in Table1, the payoff time for a completely new lighting system would be less than 6 months. Even at a cost of \$75/cow, payoff time is less than a year.

The take home message of this paper is that extending photoperiod in lactating cows is simple to implement, easy to manage, and profitable. More information on the topic can be found at www.ansci.uiuc.edu/photoperiod. This site contains more information on photoperiod, worksheets to assist producers in light design and cost analysis, and other contact information.

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Figure 1. Summary of nine studies reporting the effect of long day photoperiod on milk yield in lactating cows.

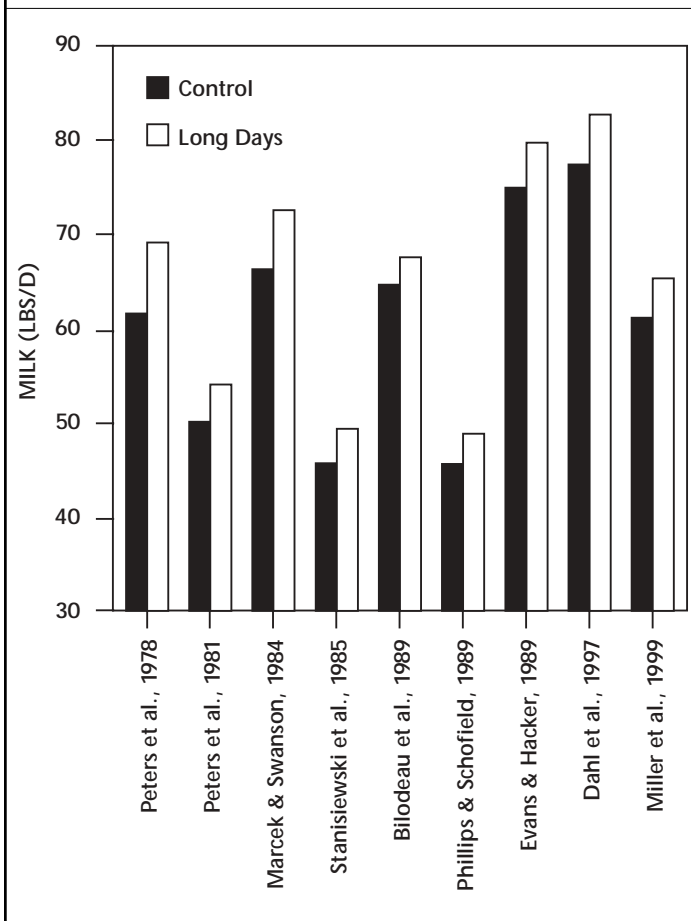


Figure 2. Group means for milk yield (lbs/d) during the subsequent lactation of cows exposed to long-day (LDPP = o, n = 18;) or short-day photoperiods (SDPP = n; n = 16) during the dry period. At calving all cows returned to natural photoperiodic conditions (January to June in Maryland). Each symbol represents the mean yield of the cows in that group for that week of lactation, through the first 16 wk of lactation. The inset depicts the average ME milk for the previous lactation, confirming that the groups were uniform with regard to production potential. Adapted from Dahl et al., 2000.

