

## SIMPLE AND EFFECTIVE STRATEGIES TO ENHANCE MILK PRODUCTION IN CATTLE

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Sustainable improvement in livestock production and reproduction has become imperative to satisfy the needs of every day increasing human population. Genetic selection for elite livestock has achieved reasonable success but environmental, nutritional and management conditions are very important to allow genetical potential to be realized. There have been many strategies to improve the milk production in cattle viz, nutritional modulations, hormone treatments and of course changes in animal management. Two of the simplest and most cost effective tools to enhance milk production in cattle is to manipulate the photoperiod and milking frequency. Continuous light exposure for 16-18 hours (long day photoperiod) and darkness for 8-6 hours per day in lactating animals has enhanced milk yield by 10-12% irrespective of original production level. Long day photoperiods in post-weaning phase has also shortened the age at first AI and first calving. Similarly, light exposure for less than 12 hours (short day photoperiod) during dry period of the animal has maximized milk yield in subsequent lactation, besides boosting immune system during transition period. Three times milking instead of two times has increased the milk yield by 15-20%. Further, the animal is responsive to frequent milking during early lactation and the effects of frequent milking persists even after a lower milking frequency is resumed. Thus these two strategies can be adopted at farm and backyard level to augment milk production with very little investment and labour.

**Key words:** Photoperiod management, milking frequency, production strategies, cow

Livestock sector plays an important role in the national economy and socio-economic development of many countries. This sector of agriculture also provides nutritional security in the rural population. Two key points in the progress of animal husbandry sector and improvement in socio-economic scenario of rural population include:

1. Optimization of milk production per lactating cow and
2. Maximising reproductive potential of dairy animals.

Milk is one of the most nutrient-dense foods and has a lot of protein, energy, vitamins and minerals, which provides a high level of essential nutrients compared with its calories. Milk constitutes the essential part of human diet, thus production of milk need to be augmented to keep pace with the increasing human population. There are few strategies that can be employed to increase the milk production, which include:

- a. Genetic selection
- b. Hormonal manipulation
- c. Nutritional modulation
- d. Managemental tools.

Genetic improvement, hormonal manipulations and nutritional modulations are strategies that demand scientific skill, expertise, labour and money, besides being long term. However, some strategies of animal management are simple, feasible, effective and economical to increase milk production. Two simple and cost effective

practices that can prove surprising in many situations include:

1. Altering Extension (Increasing) of photoperiod and
2. Increasing milking frequency

### 1. Photoperiodic Management

Management of photoperiod (duration of light exposure within a 24-hour period) in dairy cattle is a profitable tool for producers in many economic situations, requires little capital investment and has a quick asset turnover. A long-day photoperiod (LDPP) means exposure to 16-18 hours of continuous light followed by 6-8 hours of continuous darkness. A short-day photoperiod (SDPP) means continuous exposure to 8 hours of light followed by a continuous 16-hour period of darkness. In practice, SDPP is anything less than 12 hours of light. Peters et al. (1978) made the initial discovery that long days increased milk yield in cows relative to those exposed to an ambient photoperiod between September and April in Michigan. Subsequently, many researchers reported increase in milk yield on exposure to LDPP (Marcek and Swanson, 1984; Evans and Hacker, 1989). Relative to a natural or short day photoperiod, exposure of lactating cows to long days is consistently linked to increase in milk production. Cows respond to long days at any stage of lactation and across a range of production levels, besides long day responses are observed at cold temperatures, too (Peters et al, 1981). Continuous lighting is not associated with greater milk yield and production between cows on natural photoperiod and those under 24 h of light did not differ (Marcek and Swanson, 1984).

Lactating cows exposed to LDPP consistently show an 8-10 percent increase in milk production regardless of their original production level. Photoperiodic effects on lactation have been studied most frequently in dairy cows and similar responses have been observed in other domestic species, including sheep (Bocquier et al, 1990), goats (Terqui et al, 1984) and pigs (Stevenson et al, 1983). The LDPP management should begin immediately after calving to have effective results and the increased milk production becomes fully

apparent 3- 4 weeks later. Dahl et al. (1997) reported that the long photoperiod increased milk yield ( $36.1 \pm 0.6$  vs.  $33.9 \pm 0.6$  kg/d), relative to the natural photoperiod, the increase became significant after 28 days of treatment and was maintained for the duration of the study. Reksen et al. (1999) reported not only increase in milk yield but also reduction in age at first AI and first calving by exposing the animals to LDPP. Management of photoperiod can be used to improve heifer performance. Heifers exposed to LDPP exhibit increased growth rates, earlier puberty, increased mammary development and parenchymal cell number relative to short days that gives additional positive production responses.

Short day photoperiod (SDPP) during the dry period is stimulatory to milk production during the subsequent lactation and that the effect persists throughout lactation (Petitclerc et al, 1998). In contrast to lactating cows, multiparous cows in dry period and primiparous cows in late pregnancy benefit from exposure to short days followed by long days or natural photoperiod after calving. Evans and Hacker (1989) reported that cows in their 8<sup>th</sup> month of gestation maintained in either a control light regimen 12 to 13h continuous light or three skeletal photoperiods exposed to a total of 8 h of light, cows in the skeletal photoperiods (6 h of light from 05 to 11 h and a 2 h light between 18 to 20) exhibited a higher persistency of lactation and a higher feed efficiency than the cows in the other light regimens. There were no differences between treatments in milk fat, protein, lactose, or SCC. Aharoni et al. (2000) examined the records of more than 2000 cows and found that photoperiod exposure during the final 21 d of the dry period was inversely related to milk yield in the subsequent lactation. The observed effect of SDPP during the dry period and late pregnancy in (primiparous animals) may be due to the fact that animals become refractory to a constant light pattern and exposure to SDPP resets the cow's responsiveness to longer photoperiods in the subsequent lactation.

### 1.1 Photoperiodic signal perception and hormone response

In cows and other mammals, photoperception occurs at the retina and cattle appear to be able to discriminate light at intensities as low as 5 lx (Phillips and Weiguo 1991). Light impinging on the eye stimulates retinal photoreceptors that transmit an inhibitory signal to the pineal gland through a series of interneurons via the retino-hypothalamic tract, inhibits activity of the rate-limiting enzyme (N-acetyltransferase) responsible for melatonin synthesis. Thus changes in melatonin production are generally accepted as an active mediator of photoperiodic responses (Reiter, 1991). Cows use the daily pattern of melatonin to set their internal clock, influencing the secretion of a number of other hormones, including insulin-like growth factor-1, prolactin and it is the endocrine effects of photoperiod that results in physiological alterations in growth, reproduction and lactation.

Prolactin has emerged as an initial candidate hormone responsible for the galactopoietic effects of photoperiod. Indeed, long days increase circulating concentrations of prolactin in a number of species, including cattle (Tucker et al, 1984) and short days or melatonin replacement decreased the prolactin secretion (Smith, 1998). Long days stimulate secretion of IGF-I in ruminants independent of changes in growth hormone secretion and provide a possible endocrine mechanism by which photoperiod affects lactation. Short days and melatonin replacement to mimic short days, decreased circulating prolactin and suppressed IGF-I (Dahl et al., 1997; Spicer et al., 1994). Dahl et al. (1997) revealed that cows exposed to a long photoperiod had greater circulating concentrations of IGF-I ( $60.1 \pm 2.0$  vs.  $52.6 \pm 2.0$  ng/ml) than did cows exposed to the ambient natural photoperiod. The elevated prolactin observed under long days is inversely related to IGFBP-5 expression, which is considered an apoptotic factor in mammary gland thus prolactin reduces cell loss in the mammary gland. Such an outcome would be consistent with higher persistency and greater overall milk yield. Interplay between prolactin and the IGF

system may play a role in lactational persistency and is a possible explanation for the galactopoietic impact of LDPP (Flint et al., 2001).

The apparent paradox of photoperiodic effects on lactating vs dry cows may be due to the different impacts of prolactin and IGF-I during each physiological state. Prolactin is believed to exert a developmental effect in the dry/transition period but this response is not present once lactation is fully established. In contrast, the impact of elevated IGF-I during lactation is a metabolic action at the mammary gland, which is absent in the nonlactating state. At the time of parturition, the periparturient prolactin surge is critical to the secondary stage of lactogenesis and early in lactation the interplay of prolactin and prolactin-receptor (PRL-r) may be important to maximize mammary epithelial cell recruitment and differentiation. Cows on SDPP during the dry period and transferred to a longer photoperiod in early lactation have greater PRL-r expression and an increasing concentration of circulating prolactin whereas cows on LDPP in the dry period have reduced PRL-r expression and a depressed prolactin secretory stimulus due to negative feedback. Therefore, an increase in circulating prolactin in the periparturient stage layered over a greater number of PRL-r maximizes cell numbers and hence lactation.

### 1.2. Intensity of effective light

The intensity of light is measured in footcandles (FC) and lux (lx) and one FC = 10.76 lx. For the light period, light intensity should be at least 15 FC at a height of 3 feet from the stall floor. Light must be distributed evenly throughout the barn, avoiding "spotlighting" and dark corners. Placing fixtures at an appropriate height can help achieve uniform distribution. Mounting height typically is 14 - 35 feet, depending on wattage. As mounting height decreases, more fixtures of lower wattage are required to minimize spotlighting and dark areas. Spacing of lights typically is 1.5 times the mounting height. A common mistake is to place lights above the feedbunk and not evenly throughout the entire freestall barn, as a cow typically is at the feedbunk only for

3-4 hours and resting in a freestall 9-14 hours per day. If the light is inadequate in the freestall, where the cow spends most of her time, she will not be exposed to the required photoperiod. During the dark period barn should be kept as dark as possible, no more than 1 FC. It is not necessary to leave a night-light on, as cows are able to find water and feed in the dark. If cows are to be observed or moved during the dark period, low intensity red lights (7.5W bulbs) at 20- to 30-ft intervals and 10 feet above the floor should be used which will not upset the photoperiodic response. Use a light meter to regularly test light intensity and the distribution of light in the barn. To calculate the number of lights required for a barn, following formula can be used (Stanisiewski et al, 1985);

Number of fixtures required = Square footage of barn x 15 FC x K / Lumen output per lamp

- *15 FC (footcandles) is the minimum intensity required for the light period.*
- *The K is a constant that accounts for light reflected in and escaping from the barn. Use K=2 in enclosed barns and K=3 in open-sided freestall barns.*

## 2. Milking Frequency

One of the key findings that has emerged in last century is that the milk yield of dairy cows is responsive to demands of offspring or milk removal. Frequent milking (3 or more times daily) of dairy cows has proved an effective managerial tool for dairy farmers to increase milk production. It is a relatively novel management practice and the original interest and research in this area dates back to the late 1800s. Rao and Ludri (1984) reported that relative to 2X, 3X increased milk production by 1.34 kg/d and that 4X increased milk production by 1.73 kg/d compared with 3X in dairy cows. The increase in milk production with 3X has been recorded to the tune of 12 to 16% compared to 2X (Smith et al, 2002). Campos et al. (1994) reported that relative to 2X, 3X increased milk production by 17.3 and 6.3%, fat by 12.3% and 6.2% and protein by 8.8% and 4.3% in Holsteins and

Jerseys respectively and this increase was both in primiparous as well as multiparous cows. Allen et al. (1986) reported that percentage increases in production with 3X was 19.4, 13.5, 11.7 and 13.4% for cows in parity one, two, three and four or later, respectively. Hale et al. (2003) reported that 4X milking for first 3 weeks of lactation was associated with an acute increase of 8.8 kg/d and a carryover effect of 2.6 kg/d for the remainder of lactation as compared to 2X. Thus frequent milking during early lactation on milk production persists even after a lower milking frequency is resumed. Wall and McFadden (2008) reported 20% increase in milk yield with 3 times daily milking as compared to 2X and established that frequent milking for a short duration within the first 3 weeks of lactation can increase milk production through the remainder of lactation. During middle and late lactation, frequent milking increased milk production, however, cessation of frequent milking resulted in an immediate decrease in milk yield to pretreatment levels (Svennersten et al, 1990). Milk production response to frequent milking was more pronounced in animals with smaller udder capacity, such as heifers, which may be a function of increased udder pressure associated with less udder capacity. In both cows and heifers, milk production of 4X udder halves increased by 10.4% relative to 2X udder halves (Hillerton et al, 1990). Wall and McFadden (2007a) used a half udder model in cows and assigned 4X milking to right udder half and 2X to left half for first 21 days of lactation, followed by 2X for the remainder of lactation and observed acute and long term milk yield responses in 4X udder halves. Increased milk production response to frequent milking is not specific to dairy cows but other dairy ruminants, including goats, sheep and buffalo responded similarly.

Many researchers have observed no effect of frequent milking on milk composition. Increasing milking frequency raises milk yield but also lower fat and protein levels in milk, yet overall yield of protein and fat gets increased (Dahl et al, 2004b). Increased milking frequency was also found to improve udder health status, with lower

somatic cell counts observed for 3X compared to 2X (Smith et al, 2002 and Dahl et al, 2004).

### **2.1. Endocrine response to frequent milking**

Multiple hormones are released during milking including glucocorticoids, oxytocin, and prolactin. Bar-Peled et al. (1995) reported increased concentrations of GH, IGF-I, oxytocin, and prolactin in circulation of cows that were frequently milked or suckled. Prolactin has been hypothesized as a candidate regulator of the effects of frequent milking on milk production (Dahl et al., 2004). Frequent milking exerted distinct effects on mammary cell growth and gene expression that probably increased milk yield (Wall et al., 2006). Hale et al. (2003) reported an increase in mammary cell proliferation and activity, both of which are critical to improved lactational performance in cows that were milked 4X for the first 3 wk of lactation, as compared to cows milked 2X. Prolactin, a hormone released during milking, is believed to encourage the growth of actively secreting mammary cells. It is a potential regulator of IGFBP-5 (an apoptotic factor) thus limiting the apoptosis of milk secreting cells, hence increasing yield. When milking frequency increases, these actively secreting cells increase in number due to more of prolactin hormone being released at each milking in early lactation which provides persistency to the increased yield observed over the lactation period. Hillerton et al. (1990) observed an increase in activity of mammary enzymes, protein and lactose synthesis as the frequency of milking increased.

### **2.2. Autocrine regulation of milk production**

There is substantial evidence in support of local regulation of milk production within the gland, independent of systemic factors. Half-udder designs are extremely powerful, because they eliminate variation among animals due to environment, nutrition, and genetics. Both halves are exposed to similar systemic factors and hence responses to frequent milking are at mammary gland level and there stands strong evidence in

local regulation of milk production from half udder experiments (Wall and McFadden, 2007a). Autocrine control refers to the local factors within the mammary gland that affects milk production. Milk removal three times per day reduces intra-mammary pressure, promotes milk synthesis and release, does not allow the accumulation of Feed back inhibitor of lactation (FIL). A milk whey protein (a small glycoprotein) has been identified as a feedback inhibitor of lactation (FIL) which may be involved in autocrine regulation of milk secretion (Wilde et al, 1995). The inhibitor is thought to be synthesized by the mammary secretory cell and in turn inhibits further milk secretion as it accumulates. Removal of milk potentiates secretion and action of prolactin and oxytocin while stasis of milk in the mammary gland increases intra-mammary pressure resulting in to vasoconstriction, breakdown of tight junctions and loss of epithelial function and sympathetic activation that leads to onset of cell death (Delamaire and Guinard-Flament, 2006). Wall et al. (2006) reported an increase in mammary expression of suppressor of cytokine signaling (SOCS -2) and a decrease in SOCS- 3 expression in response to 4X or prolactin injection. Expression of SOCS-3 in mammary tissue is regulated by milk accumulation in the mammary gland of mice and it may be involved in the inhibition of milk secretion during milk stasis (Wall et al, 2006).

### **CONCLUSION**

Knowledge of dairy cow physiology and nutrition has rapidly increased during the last decades. Data on the effects of suckling, milking, photoperiod, underfeeding and endocrine regulation gathered during past could probably be used as a basis for planning of livestock development in terms of production, reproduction and animal health. Considering the research to date, the following practices regarding light exposure and frequent milking during the life cycle of dairy cows can prove surprisingly beneficial.

First, heifers should be exposed to LDPP during the post weaning phase until puberty to maximize mammary parenchymal growth.

During lactation, exposure to LDPP is recommended to increase milk yield, particularly in cows where dry period exposure to SDPP is not possible.

During the final 60 d of pregnancy (primiparous heifers) and dry period should be under SDPP to maximize production in the next lactation and enhance immune function in the transition period.

During dark period barn should be kept as dark as possible, no more than 1 Foot candle.

It is not necessary to leave a night-light on during dark period. If cows are to be observed or moved during the dark period, low intensity red lights (7.5W bulbs) at 20- to 30-ft intervals and 10 feet above the floor should be used.

Designs using adjustable air inlets or tunnel ventilation can be used for dry cow housing.

Switching to three or four times milking for at least first 3 weeks of lactation and resuming two times milking thereafter.

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