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PHOTOPERIODIC MANIPULATION FOR AUGMENTATION OF DAIRY ANIMAL PERFORMANCE

T.K. Patbandha*[1], D.K. Swain[2], Rupal Pathak[3], S.K. Mohapatra[4] and S.K. Sahoo[5]
[1]College of Veterinary Science & Animal Husbandry, JAU, Junagadh-362001, Gujarat (India)
[2]College of Veterinary Science & Animal Husbandry, DUVASU, Mathura – 281001, U.P. (India)
[3]College of Veterinary Science & A.H., Sarkanda, Bilaspur - 495001, Chhattisgarh Kamdhenu Vishwavidyalaya, Chhattisgarh (India)
[4]College of Veterinary Science & Animal Husbandry, SDAU, Dantiwada- 385506, Gujarat (India)
[5]College of Veterinary Science, GADVASU, Ludhiana-141004, Punjab (India)
E-mail: patbandhavet@gmail.com (**Corresponding Author*)

Abstract: Photoperiod is a non-invasive managemental tool, significantly improves dairy animal's performances. Calves and heifers reared under long day photoperiod (16-18 hours light) achieved higher growth. Leaner growth in heifer results early age at sexual maturity. Dairy cows and buffaloes reared under long day photoperiod during early lactation produced on an average 2-3 liters/day more milk than those reared under natural photoperiod. However, dry pregnant bovines reared under short day photoperiod (16-18 hours darkness) for at least 35-60 days before calving produced 3-4 kg more milk/day. Additionally, cows exposed to short day photoperiod during dry and pregnancy stage but long day photoperiod during early lactation improves health and immunity. Photoperiod effect on dairy animals is visibly seen after 3-4 weeks of exposure and has no carry over effect on animal's performance. Taken together, we concluded that performance of dairy animals could be improved by manipulating photoperiod.
Keywords: Photoperiod, dairy animal, growth, production, reproduction, immunity.

Introduction

Photoperiod is defined as relative duration of light and dark period experienced by an animal during 24 hours. When, an animal is exposed to 16-18 hours light and 6-8 hours darkness in 24 hours, called as long day photoperiod (LDPP) and reversal of this is short day photoperiod (SDPP) (Dahl *et al*., 2012). Photoperiod acts as an important environmental factor which significantly regulates animals' performance. Being a non-invasive tool, now-a-days photoperiod is gaining more importance in dairy industry under intensive management system to improve growth, productive and reproductive performances as well as health and welfare of animals. Melatonin hormone is the mediator that influences underline

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physiological mechanisms responsible for animals' performance. Melatonin secretion from pineal gland is regulated by light, which further influences secretion of number of other hormones like prolactin (PRL), gonadotropins, and IGF-I. Alterations in these circulating hormones influence long term physiological responses like growth, reproduction, lactation and immunity of dairy animals (Dahl *et al*., 2000; Dahl *et al*., 2012). Though, photoperiod has positive effect on animals' performances, but constant exposure beyond recommendation induces photo refractoriness (Dahl *et al*., 2000). Hence, proper understanding of photoperiod effect on animal would be helpful to implement it as a non-invasive managemental tool to improve growth, production, reproduction, health and immunity of dairy cattle and buffaloes.

Light and its effect on endocrine system

Light is an electromagnetic radiation (390 to 740 nm in wavelength); light intensity or luminance indicates flow of light on a surface and expressed in foot-candles (FC; English) or lux (Lx; metric). The FC is lumen per square foot whereas lux is lumen per square meter and 10.76 Lux is equivalent to 1 FC. Light intensity should be at least 15 FC preferably 15-20 FC at animal's eye level, approximately one meter from floor level for a light period (Buyserie *et al*., 2001; Dahl, 2005). However, intensity should be 0.5-1.0 FC during dark period to avoid physiological changes (Buyserie *et al*., 2001). Though cows get feed and water without any difficulty at night time, to observe or move them at night, low intensity red light (7.5-15 W bulbs at 20-30 ft intervals) should be used (Buyserie *et al*., 2001; Dahl, 2005).

Light is primarily received through eyes, then stimulates photoreceptor cells of retina which subsequently relay inhibitory signal to pineal gland for melatonin secretion via retinohypo-thalamic tract through a series of endogenous process (Dahl *et al*., 2000). After reception by photoreceptor cells, signal is transmitted to suprachiasmatic nucleus (SCN) of hypothalamus, known as "biological clock" of mammals and then through paraventricular nucleus (PVN) of the hypothalamus, intermediolateral cells (IML) of upper spinal cord and superior cervical ganglion (SCG) the signal reaches to pineal gland (**Figure 1**, Walton *et al*., 2011). Pineal gland is able to measure day length and accordingly adjust secretion of melatonin. Melatonin secretion inhibits magnocelluar neurons, the principal sites of secretion of gonadotropin releasing hormone (GnRH). Melatonin inhibits pulsation as well as rhythm of secretion of GnRH causing inhibition of secretion of anterior pituitary gonadotropins like luteinizing hormone (LH) and follicle stimulating hormone (FSH) (Dahl *et al*., 2000).

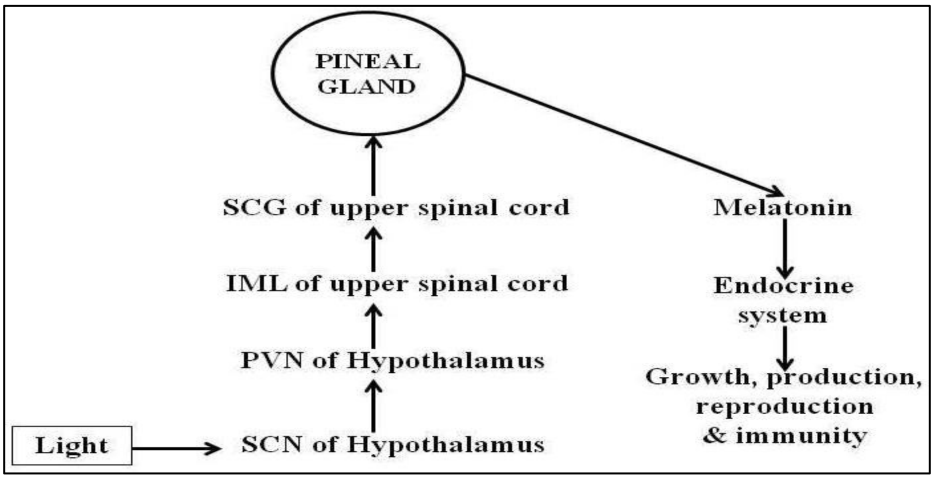

Figure 1: Endocrine rhythm of light signal (Suprachiasmatic nuclei, SCN; Paraventricular nucleus, PVN; Intermediolateral cells, IML; Superior cervical ganglion, SCG)

Photoperiod and performances of cattle and buffaloes

Growth: Duration of exposure to photoperiod directly affects the growth of growing calf and heifers, as well as the mammary tissue growth in heifers. Exposure to LDPP during the growth phase results larger, leaner animals at maturity, with greater mammary parenchymal growth, and these effects are associated with greater yield in first calver. Calves reared under LDPP during early post-natal period had greater starter intake (62.5%), resulted higher average daily weight gain (28%) than those reared under SDPP. Photoperiod effect was observed more pronounced after 4 weeks of exposure in calves (Osborne *et al*., 2007). Further, LDPP increase rumen development, digestibility and efficiency of nutrient utilization and thereby increase growth in calf (Osborne *et al*., 2007; Dhal *et al*., 2012; Penev *et al*., 2015). Effects of LDPP on growth are consistent and regulated by IGF-I due to its anabolic effect in growing calves (Kim *et al*., 2010). Similarly, owing to increase in lean growth, heifers reared under LDPP attend puberty at an early age than those reared under SDPP. Several studies reported that heifers reared under LDPP until the first lactation have more mammary parenchymal growth and produce more milk (Dhal *et al*., 2012; Penev *et al*., 2015). The LDPP during pre-pubertal period has carryover effect on lean body growth and mammary tissue growth till calving. Increased concentrations and positive effect of IGF-I and PRL on growth of mammary and lean tissue during LDPP is the key reason for better growth and early age at sexual maturity (Dhal *et al*., 2012).

Reproduction: Duration of day length during autumn and winter is generally shorter, but cattle and buffaloes when exposed to LDPP show significant improvement of reproduction. Though cows are not considered as seasonal breeders, photoperiod must have some effects on the reproductive axis of cows (Dahl, 2005). Service period and number of services/conception decrease by 22 days and by 0.6 in cows exposed to LDPP during early lactation compared to without exposure. Improved reproduction in cows reared under LDPP may be associated with increased circulating Ca, P, vitamin D and A, total protein, haemoglobin, erythrocytes and γ-globulins (Penev *et al*., 2015). Kassim *et al*. (2008) also observed improved reproductive performances (decreased puberty and better expression of estrus) in buffalo heifers reared under LDPP during autumn and winter. In buffaloes, puberty and sexual maturity reduced by about 35 days and 21 days, respectively when buffalo heifers are reared 4 hours artificial light in addition to natural light during autumn and winter seasons (Kassim *et al*., 2008). Roy *et al*. (2016) reported early attainment of puberty in pre-pubertal buffaloes reared under extended photoperiod (4 hours/ day more photoperiod) during winter season, where 85.7% heifers attained puberty at the end of 3 months experimental period compared to 57.14% in control group.

Lactation: Lactating cows when exposed to LDPP produce more milk compared to those reared on natural light. Photoperiod effect on milk yield was first studied at Michigan State University, USA and about 2 lit more milk/day yield was observed in cows reared on LDPP during earl lactation than on natural photoperiod. Later consistently several authors reported on an average 2-3 lit/ day more milk (about 8-10%) in cows reared on LDPP during early lactation than on natural photoperiod (Dahl, 2003). Effect due to LDPP developed gradually and significant effect is observed after 3-4 weeks of exposure (Dahl *et al*., 2012). However, there is no carryover effect of photoperiod on milk production. In lactating Jaffrabadi buffaloes, Savaliya *et al*. (2016) also observed 1.35 lit/day more milk in buffaloes reared under LDPP during early lactation as compared to those reared under natural photoperiod. Further, LDPP has little effect on milk composition particularly milk fat depression (Dhal *et al*., 2000). Effect due to LDPP on milk yield may be due to elevated prolactin, growth hormone and IGF-I. However, Dhal *et al*. (2000) after reviewing several published reports concluded that increased milk production in LDPP is primarily controlled by elevated level of IGF-I.

In dry pregnant cows, photoperiod inversely affects productivity. Cows exposed to SDPP during last 60 days of dry period produced 3-4 kg/day more milk during early lactation than LDPP. However, SDPP exposure should be at least 35-60 days before expected date of calving to see marked effects of photoperiod (Dhal, 2003; Dhal, 2008; Dhal *et al*., 2012). Basis of photoperiod mediated mammary cell proliferation has not been understood.

Melatonin has anti-apoptotic roles and also inhibits apoptosis inducing genes, thereby promotes proliferation of mammary epithelial cells and lactation persistency (Wall *et al*., 2005).

Health and immunity: Similar to growth, production and reproduction, photoperiod also significantly affects health and immunity. Alteration of immune system under the influence of photoperiod in dairy animals is associated with PRL secretion. Heifers reared under SDPP had increased lymphocyte proliferation and enhanced neutrophil function than those reared under LDPP (Auchtung and Dahl, 2004). In addition to milk yield, SDPP exposure to dry cows improves the immune status and improve uterine and udder health immediately during post partum period (Dhal, 2003; Penev *et al*., 2015). Rearing of pregnant cows under SDPP during dry period produces more number of blood mononuclear cells in circulation, indicates improved immune status at calving than those on LDPP (Auchtung *et al*., 2004). Milk somatic cell counts also reduced in cows exposed to SDPP during dry period in contrast to cows under LDPP (Auchtung *et al*., 2004). Thus, proper manipulation of photoperiod could improve the udder health and productivity by reducing risk of new intramammary infection.

Feeding behaviour and intake: The LDPP in lactating cows enhances dry matter intake (DMI) by 1kg/day compared to cows reared under SDPP. However, advanced pregnant dry cows under SDPP have about 1 kg/day more DMI than cows under LDPP (Dhal, 2006; Velasco *et al*., 2008). Increased DMI may increase milk yield in dairy animals, but photoperiod has no carryover effect on DMI (Dhal, 2006). Although, photoperiod does not alter total duration of feeding time, the distribution pattern of feeding bouts alters significantly. Dry pregnant cows on SDPP spent more time in feeding just after fresh feed delivery compared to on LDPP (Karvetski *et al*., 2006).

Lighting system

Photoperiod significantly influences performance and health of dairy animals. However, practically how this system can be implemented by farmers under field condition is a prime concern. Fluorescent, metal halide and high pressure sodium vapour lamps are most common types of light used in dairy facilities. Lumen output per lamp is most important for calculating number of fixtures needed for a particular place. Following formula can be used for calculating required number of lights for a dairy barn:

$$\text{Total fixtures needed} = \frac{\text{Total lumens}}{\text{Lumen output per lamp}}$$

Where, total lumens needed = Area (sq. ft. of barn) x 15 FC x K

[15FC, minimum intensity required for light period; K, barn constant = 2 for closed barn or 3 for open barn].

Light intensity and distribution of light in a particular place can be measured by light meter. The LDPP can be adjusted using timer alone or with a photocell connected in series. Timer generally turns lights on and off at a pre-set time point, while photocell overrides the timer (turns the lights off). Photocell adjusts pre-set time point according to availability of sufficient natural sunlight (at least 15FC). Photocell should be shielded well from both interior and exterior lighting to work properly and always fix under a side eave outside (Janni, 2000; Buyserie *et al*., 2001).

In addition, one should have idea about how to fix the light sources? Light sources should be mounted in such a way that there should be uniform illumination of required level of light at animals' eye level. Mounting height and horizontal separation distance should be taken into care while fixing lighting system. When lights are mounted at a higher place from ground it causes waste of light by dispersing to a large area. However, if separation distances increase then it decreases uniformity of illumination (Janni, 2000). Separation distances of lights should be more than mounting height i.e., 1.2 and 1.7 times (on an average 1.5 times) of mounting height. Mounting height should be 14-35 ft depending on type of sheds (Janni, 2000; Buyserie *et al*., 2001; Dahl, 2005).

Conclusion

Photoperiod significantly affects performances particularly growth, production, reproduction, health and immunity of dairy animals. Lean growth in dairy calves and heifers is stimulated by LDPP and reduces their age at puberty and sexual maturity. Additionally, LDPP enhances mammary growth and ultimately improves productivity of cows and buffaloes. Postpartum reproductive performances are also improved by LDPP noticeably in dairy cattle and buffaloes. In heifers and cows, during last stage of pregnancy the SDPP improves mammary development and immune status and yield in subsequent lactation. In a country like India, where photoperiod length is more and also ambient temperature is high, it is possible to take in to consideration for photoperiod control and manipulation. As a non invasive tool, it can be implemented to augment animal production as stated. Another major concern is climate change and a consequent change in photoperiodic duration. It is going to be more pronounced in near future. That is why, the role of photoperiod and its manipulation will be of great value in increasing animal performance in terms of animal production.

References

[1] Auchtung, T.L. and Dahl, G.E. (2004). Prolactin mediates photoperiodic immune enhancement: Effects of administration of exogenous prolactin on circulating concentrations, receptor expression, and immune function in steers. *Biol. Reprod.*, **71**:1913-1918.

[2] Auchtung, T.L., Salak-Johnson, J.L., Morin, D.E., Mallard, C.C. and Dahl, G.E. (2004). Effects of photoperiod during the dry period on cellular immune function of dairy cows. *J. Dairy Sci.*, **87**:3683-3689.

[3] Buyserie, A. Gamroth, M. and Dhal, G. (2001). Managing light in dairy barn for increased milk production. Oregon State University. *PNW 551*, pp. 1-3.

[4] Dahl, G. E. (2008). Effects of short day photoperiod on prolactin signaling in dry cows: A common mechanism among tissues and environments? *J. Anim. Sci.*, **86**:10-14.

[5] Dahl, G.E. (2003). Photoperiod management of dairy cattle for performance and health. *Adv. Dairy Technol.*, **15**:347-353.

[6] Dahl, G.E. (2005). Let there be light: Photoperiod management of cows for production and health. *Proceedings 42nd Florida dairy production conference*, Gainesville, May 3. pp. 35-41.

[7] Dahl, G.E. (2006). Effect of photoperiod on feed intake and animal performance. *Tri-State Dairy Nutrition Conference*, April 25-26. pp. 33-36.

[8] Dahl, G.E., Buchanan, B.A. and Tucker, H.A. (2000). Photoperiodic effects on dairy cattle: A review. *J. Dairy Sci.*, **83**:885-893.

[9] Dahl, G.E., Tao, S. and Thompson, I.M. (2012). Effects of photoperiod on mammary gland development and lactation. *J. Anim. Sci.*, **90**:755-760.

[10] Janni, K. (2000). Lighting Dairy Facilities. Retrieved October 12, 2016, from http://www.bae.umn.edu/extens/ennotes/ensum99/ lighting.

[11] Karvetski, K.E., Velasco, J.M., Reid, E.D., Salak-Johnson, J.L. and Dahl, G.E. (2006). Behavioral time budget of dry cows: Photoperiod alters distribution of maintenance behaviours. *J. Anim. Sci.*, **84**(Suppl. 1): 410.

[12] Kassim, N.S.I., Afify, A.A. and Hassan, H.Z. (2008). Effect of Photoperiod Length on Some reproductive traits and hormonal profiles in buffalo heifers. *American-Eurasian J. Agric. Environ. Sci.*, **3**(4):646-55.

[13] Kim, J.S., Ellman, M.B., An, H.S., van Wijnen, A.J., Borgia, J.A. and Im, H.J. (2010). Insulin-like growth factor 1 synergizes with bone morphogenetic protein 7-mediated anabolism in bovine inter-vertebral disc cells. *Arthritis Rheum.*, **62**:3706-3715.

[14] Osborne, V.R., Odongo, N.E., Edwards, A.M. and McBride, B.W. (2007). Effects of photoperiod and glucose-supplemented drinking water on the performance of dairy calves. *J. Dairy Sci.*, **90**:5199-5207.

[15] Penev, T., Radev, V., Slavov, T., Kirov, V., Dimov, D., Atanassov, A. and Marinov, I. (2015). Effect of lighting on the growth, development, behaviour, production and reproduction traits in dairy cows. *Int. J. Curr. Microbiol. App. Sci*., **3**(11):798-810.

[16] Roy, A.K., Singh, M., Kumar, P. and Kumar, B.S.B. (2016). Effect of extended photoperiod during winter on growth and onset of puberty in Murrah buffalo heifers, *Vet. World*, **9**(2): 216-221.

[17] Savaliya, B.D., Ravikala, K., Murthy, K.S. and Gajbhiye, P.U. (2016). Effect of long day photoperiod and showering on milk yield and economic returns in Jaffrabadi buffaloes. *India J. Dairy Sci*., 6**9**:481-486.

[18] Velasco, J.M., Reid, E.D., Fried, K.K., Gressley, T.F., Wallace, R.L. and Dahl, G. E. (2008). Short-day photoperiod increases milk yield in cows with a reduced dry period length. *J. Dairy Sci*., **91**:3467-3473.

[19] Wall, E.H., Auchtung, T.L., Dahl, G.E., Ellis, S.E. and Mc-Fadden, T.B. (2005). Exposure to short day photoperiod enhances mammary growth during the dry period of dairy cows. *J. Dairy Sci*., **88**:1994-2003.

[20] Walton, J.C., Weil, Z.M. and Nelson, R.J. (2011). Influence of photoperiod on hormones, behavior, and immune function. Front. *Neuroendocrinol*., **32**:303-319.