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Production aspect of photoperiodism in dairy cattle

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A B S T R A C T

Photoperiod is defined as the virtual duration of light and dark that a cattle experiences during a day. It is classified into Long day photoperiod (LDPP) and short day photoperiod (SDPP). 16–18 hours of light and 6-8 hours of dark exposure is considered as LDPP and vice versa for SDPP. Photoperiod is primarily influenced by melatonin. The increased level of melatonin concentration in the blood results in shift in the secretion of various hormones. Calves raised under LDPP during the growth phase yields larger and leaner body at maturity, with greater mammary parenchymal growth. LDPP exposed lactating cattle produced higher milk yield due to its lower melatonin concentration and higher prolactin concentration, whereas SDPP during the dry period of multiparous cows enhances milk production in the following lactation. These signify the importance of Photoperiodism in dairy cattle for an optimized production.

Introduction

Photoperiod is defined as the virtual duration of light and dark that a cow experiences during a day. It is classified as Long-day photoperiod (LDPP) and Short-day photoperiod (SDPP). LDPP comprised of 16–18 hours of light and 6–8 hours of darkness in 24 hour period, whereas a SDPP is 6–8 hours of light and 16–18 hours of darkness (Dahl *et al.*, 2012). Pineal gland mediates its action by secreting melatonin, whose level was highly modulated by photo period. This review will ascertain the various roles of Photoperiod in different stages of dairy cattle in relation with production.

Melatonin synthesis and its mechanism of action

Mealtonin (N-acetyl-5-methoxytryptamine) is an indolic hormone synthesis and secreted by the pineal gland (Arendt and Ravault,

1988) in response to darkness (Fig. 1). The light stimulus actively inhibits the rate-limiting enzyme [Hydroxyindolo-o-methyl transferase (HIOMT)] of the melatonin synthesis in the pineal gland and thus, decreases circulating concentrations of melatonin (Buchanan *et al.*, 1992).

Photoperiodic response begins with light perception at photoreceptors in the retina, which sends signals to suprachiasmatic nucleus (SCN), then to the superior cervical ganglion (SCG). Finally it reaches the pineal gland, where melatonin is secreted (Reiter, 1991). In cattle, increased level of melatonin concentration in the blood results in shift in the secretion of other hormones, including prolactin (PRL), gonadotropins and IGF-I, all of which increase under LDPP when compared to SDPP (Dahl *et al.*, 2012).

Role of photoperiod in growth

Neonatal calves from birth to 8 weeks of age reared under LDPP showed enhanced overall body growth, because of more ruminal volatile fatty acid (VFA) generation in relation with calves raised under SDPP (Osborne *et al.*, 2007). Calves that were reared under LDPP achieve more lean tissue and body weight gain (Rius *et al.*, 2005), this may be either due to the increased persistent concentration of IGF-I than the calves reared under SDPP at the same level of dry matter intake (DMI) (Spicer *et al.*, 2007) or increased intake, due to lengthier light exposure rather than metabolism of ingested nutrients (Petitclerc *et al.*, 1983). Heifers raised under LDPP during its pre-pubertal period till first lactation were showing increased mammary parenchyma (Petitclerc *et al.*, 1984, 1985), more milk production, heavier and taller body conformation at parturition, that were associated with increased production (Rius and Dahl, 2006).

Role of photoperiod in reproduction

Impact of photoperiod on cattle reproduction is of minor importance when compared with the seasonal breeders (Dahl *et al.*, 2012). LDPP exposed heifers achieve puberty faster than the heifers exposed on normal day length because of greater release of Leutinizing Hormone (LH) in response to estradiol (Hansen *et al.*, 1982; 1983) and decrease time to the first breeding (Rius and Dahl, 2006). During summer, the time required for return to estrous cyclicity after calving is shorter when compared with those calved during winter and natural short days (Hansen, 1985).

Role of photoperiod in lactation

Prolactin (PRL) concentration and Insulin like Growth factor binding protein-5 (IGFBP-5) are inversely proportional, whereas IGFBP-5 enhances apoptosis. Cows exposed to LDPP had increased PRL concentration resulting in slower losses of mammary cells caused by inhibiting IGFBP-5, thus slows decline in milk yield (Dahl *et al.*, 1997). This finding was supported by Accorsi *et al.* (2002) who observed increase in IGFBP-5 expression in cultured mammary explants in the absence of PRL (Accorsi *et al.*, 2002). In lactating cows, melatonin implants during summer shows decreased PRL concentration and lactation persistency (Auldist *et al.*, 2007).

Cows treated with recombinant bovine somatotrophin (rbST) showed inconsistent IGF-I responses. During LDPP/summer, the IGF-1 was higher, whereas lesser values observed during SDPP/winter (Collier *et al.*, 2008). Lacasse *et al.*, (2011) conducted a study in lactating cows using Quinogolide (PRL release inhibitor) treatment last for 8 weeks. The milking induced PRL surge was decreased in quinagolide treated cows results in less milk production than control group. This reveals that the depression of the milking-induced PRL surge can alter yield even in the absence of effects on basal PRL (Lacasse *et al.*, 2011).

Role of Photoperiod in Dry Period

The cows exposed to SDPP during dry period produced 3-4 kg/d more milk in subsequent lactation than LDPP exposed cows (Auchtung *et al.*, 2005). The same trend was observed in sheep (Mikolayunas *et al.*, 2008) and goats (Mabjeesh *et al.*, 2007) as well. The enhanced milk output under SDPP, is due to increased mammary gland development, decreased cell apoptosis during the dry period and increased number of functional mammary secretary cells at parturition (Wall *et al.*, 2005a). Under SDPP, circulating concentrations of PRL decline and concomitant increase in expression of PRL receptor (PRL-r) in many tissues (Liver, Mammary gland and Lymphocytes) was observed (Auchtung *et al.*, 2003). A decrease in Suppressors of cytokine signaling (SOCS) expression would be expected to enhance mammary growth because expression of the SOCS family of genes is generally associated with feedback inhibition of PRL signaling (Wall *et al.*, 2005b).

The effect of SDPP on cattle is dependent on the duration of treatment. Cow exposed to last 21d of dry period didn't exhibit increased production (Reid *et al.*, 2004) whereas last 42d of dry period showed greater milk yield (Valasco *et al.*, 2008).

This suggests on an average of 35d (35-60 d) should be given to exhibit this effect during dry period for the next lactation (Valasco *et al.*, 2008). Study on primiparous heifers and multiparous cows on LDPP, SDPP, LDPP+Melatonin feeding on milk production and PRL concentration revealed that multiparous cows exposed under SDPP (dry period) showed 10% rise in milk production in the following lactation but this effect was gradually lost up to 20 weeks of lactation whereas photoperiod effect on primiparous heifers during dry period don't have any effect on the following lactation.

Feeding of melatonin during LDPP was not mimicking the SDPP, thus no effect observed during lactation (Lacasse *et al.*, 2014). Crawford *et al.* (2005) conducted a study on cows on LDPP, SDPP and SDPP+PRL administration for 6 wks during dry period. They observed that the PRL concentration was in descending fashion and milk yield was in ascending fashion at LDPP, SDPP+PRL, SDPP respectively (Fig. 2). Administration of melatonin implants to dairy cows at drying-off moderately suppressed prepartum PRL concentration but did not affect milk production (Garcia-Ispierto *et al.*, 2013).

Other Roles

To suppress the development of spontaneous and carcinogen-induced mammary cancer (Blask *et al.*, 1991) the mechanisms include

(a) Repression of the mitogenic E2 signaling pathway (Kiefer *et al.*, 2002) via repression of E2-induced transcriptional activation of the estrogen receptor alpha (ERα).

(b) Inhibition of tumour uptake of the omega 3 fatty acid linoleic acid and its conversion to 13-hydroxyoctadecadienoic (13-HODE) (Blask *et al.*, 2004).

(c) Antioxidatnt properties (Fuentes-Broto *et al.*, 2010).

It also modulates the function of the immune and hemopoietic systems (Skwarlo-Sonta K. 2002)

Fig.1 Synthesis of Melatonin in the pineal gland from tryptophan (Adapted from Konturek *et al.*, 2006)

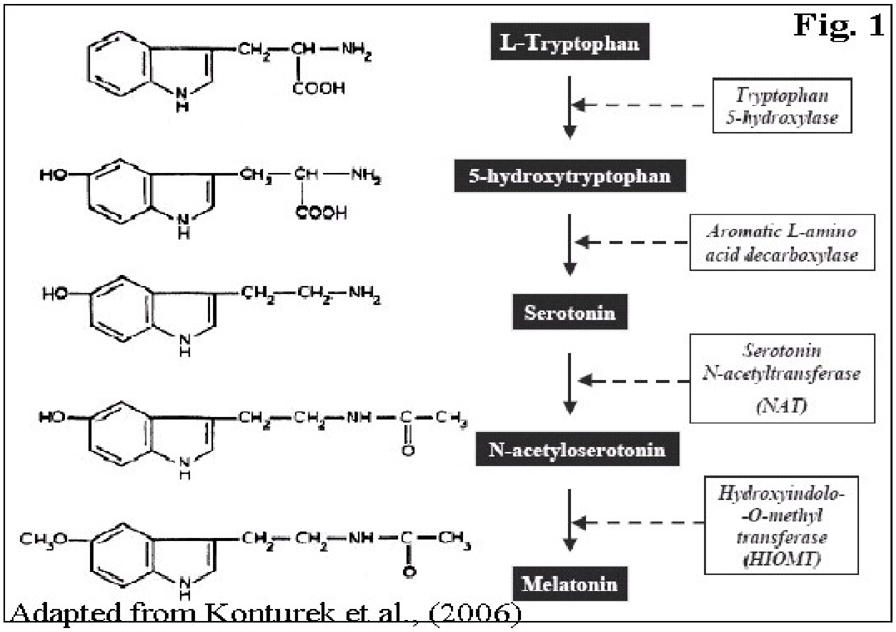


Fig.2 Effect of photoperiod and prolactin (PRL) treatments during the dry period on subsequent milk production (Crawford *et al.*, 2005)

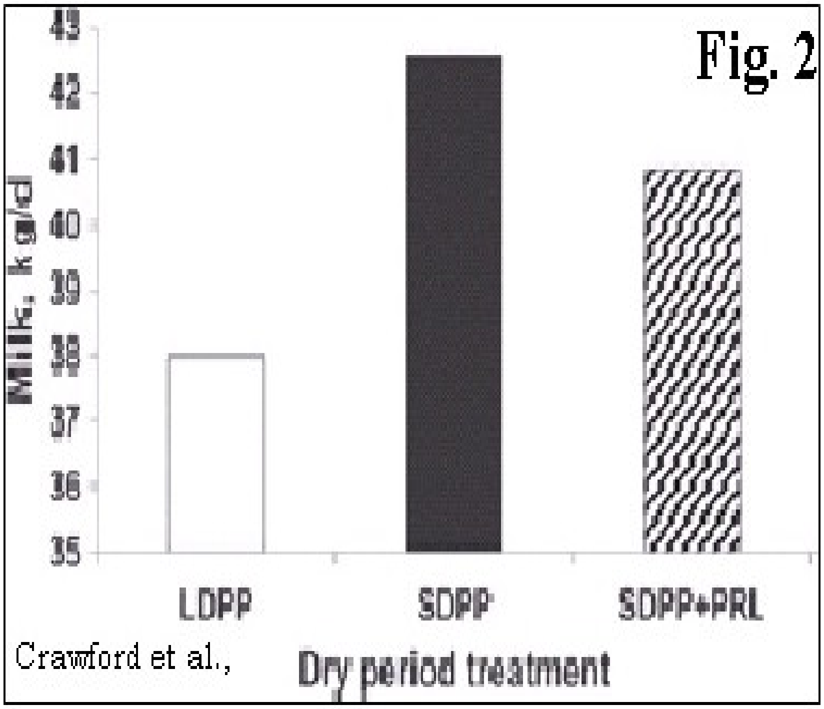
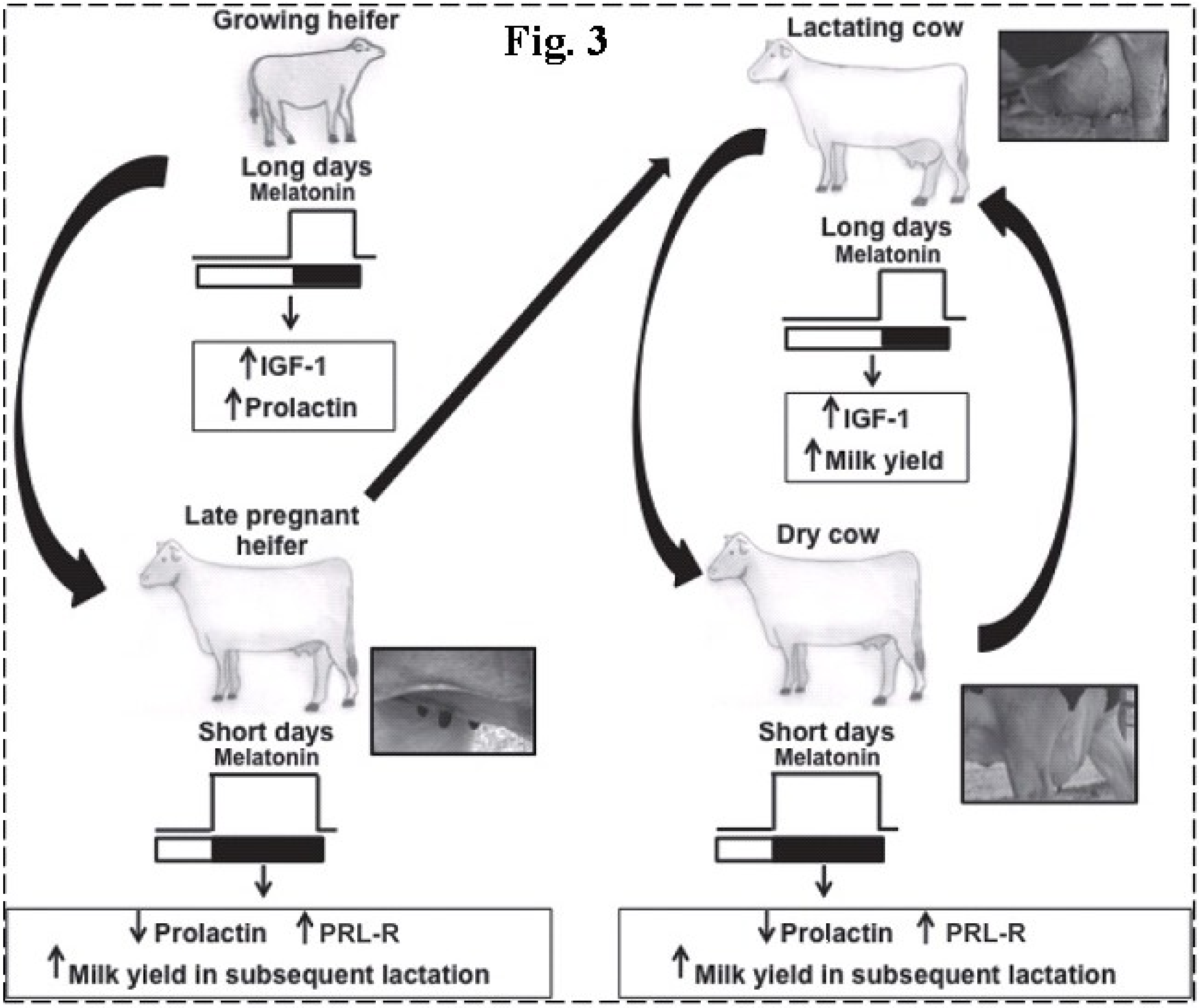


Fig.3 Overall physiological effects and management outcomes of photoperiod management of dairy cattle (Adapted from Dahl *et al.*, 2012)



Conclusion

From the preceding discussion, it is clear that photoperiod has a significant effect on reproduction, growth, lactation and dry period. Photoperiod treatments during the last 2 months of gestation do not appear to affect the following lactation in primiparous heifers, although feed efficiency was improved by precalving exposure to SDPP. SDPP during dry period produces increased milk production in multiparous cows in subsequent lactation but no significant effect in primiparious cows. LDPP during lactation period produced higher milk yield in lactating animals. Exposure of calves to LDPP during the growth phase yields larger, leaner animals at maturity, with greater mammary parenchymal growth, and these effects are associated with greater yield after calving (Fig. 3).

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