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Effects of photoperiod modulation and melatonin feeding around drying-off on bovine mammary gland involution

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ABSTRACT

The risk for a dairy cow to acquire new intramammary infections is high during the transition from lactation to the dry period, because of udder engorgement and altered immune functions. Once the gland is fully involuted, it becomes much more resistant to intramammary infections. Therefore, strategies to depress milk yield before drying-off and accelerate the involution process after drying-off could be beneficial for udder health. The objective of this study was to assess the effect of photoperiod manipulation and melatonin feeding from 14 d before to 14 d after drying-off on the speed of the involution process. Thirty Holstein cows in late lactation were randomly allocated to one of the following treatments: (1) a long-day photoperiod (16 h of light: 8 h of darkness), (2) a short-day photoperiod (8 h of light: 16 h of darkness), and (3) a long-day photoperiod supplemented by melatonin feeding (4 mg/kg of body weight). Milk and blood samples were collected on d −26, −19, −12, −5, −1, 1, 3, 5, 7, 10, and 14 relative to the last milking to determine concentrations of mammary gland involution markers and serum prolactin. Additional blood samples were taken around milking on d −15, before the start of the treatments, and on d −1, before drying-off, to evaluate the treatment effects on milking-induced prolactin release. The short-day photoperiod slightly decreased milk production and basal prolactin secretion during the dry period. The milking-induced prolactin surge was smaller on d −1 than on d −15 regardless of the treatments. Lactoferrin concentration, somatic cell count, and BSA concentration as well as matrix metalloproteinase-2 and -9 activities increased in mammary secretions during the first 2 wk of the dry period, whereas milk citrate concentration and the citrate:lactoferrin molar ratio decreased. The rates of change of these parameters were not significantly affected by the treatments. The long-day photoperiod supplemented by melatonin feeding did not affect milk production, prolactin secretion, or mammary gland involution. Under the conditions in this study, photoperiod modulation and melatonin feeding did not appear to affect the rate of mammary gland involution.

Key words: dairy cow, mammary gland involution, photoperiod, prolactin

INTRODUCTION

After cessation of milking, the bovine mammary gland continues to synthesize milk components during the first days of the dry period, with milk accumulating in the gland. In modern high-producing dairy cows, this accumulation may cause engorgement of the udder, leading to milk leakage and facilitating the entry of microorganisms. The first days of drying-off are therefore critical for dairy cows because of the high susceptibility to acquire new IMI. It has been established that the risk of IMI at calving increases by 77% for every 5 kg of milk produced above 12.5 kg at the time when milking is stopped (Rajala-Schultz et al., 2005). Dingwell et al. (2002) estimated that 16.7% of quarters that are bacteriologically negative before the cessation of milking become infected during the dry period regardless of antibiotic treatments. The beginning of a dry period is also the time of starting active involution in mammary glands. Active involution is a remodeling process that takes place at the end of a lactation period after cessation of milking or suckling in female mammals and through which the gland returns to a nonlactating state. In cows, this process starts as soon as 2 d after the last milk removal (Holst et al., 1987) and seems to be complete after approximately 21 d (Hurley, 1989; Akers et al., 1990). When the involution process is advanced, mammary glands become much more resistant to new IMI (Oliver and Smith, 1982). Consequently, a strategy that speeds up the involution process would be a valuable tool to improve mammary gland resistance and udder health around drying-off.

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Prolactin plays a survival role during mammary gland involution by inhibiting the increase in metalloproteinase (**MMP**) expression and preventing mammary epithelial cell apoptosis (Accorsi et al., 2002; Flint et al., 2006). In rats, a deficiency in prolactin induced the involution process (Travers et al., 1996). Furthermore, there is compelling new evidence that prolactin plays a galactopoietic role during bovine lactation (Lacasse et al., 2011, 2012). Therefore, the inhibition of the prolactin signal around drying-off may help to decrease milk production before the start of a dry period and to hasten mammary gland involution by removing the inhibition exerted by prolactin. It has been shown that the inhibition of prolactin secretion by a dopaminergic agonist, quinagolide, successfully decreased milk production in cows (Lacasse et al., 2011) and hastened bovine mammary gland involution (Ollier et al., 2013). In addition, milk yield before drying-off influences the involution process and can affect natural defense systems during the dry period (Silanikove et al., 2013).

Modulating the photoperiod, which is the relative duration of light and dark exposure within a day, affects both prolactin secretion and milk production. Ewes (Morrissey et al., 2008), goats (Garcia-Hernandez et al., 2007), and cows (Peters et al., 1981) exposed to a long day photoperiod (**LDPP**; more than 16 h of light/d) during lactation produce more milk than those exposed to a short day photoperiod (**SDPP**; less than 12 h of light/d). When the photoperiod is modulated during a dry period, the effects on milk production during the subsequent lactation are different. Cows exposed to SDPP during the dry period produce more milk during the following lactation than cows exposed to LDPP (Miller et al., 2000; Auchtung et al., 2005; Lacasse et al., 2014). During either lactation or the dry period, LDPP stimulated prolactin secretion, whereas SDPP reduced it (Dahl et al., 1997; Miller et al., 2000; Auchtung et al., 2005). Moreover, treatment with melatonin, which is a hormone synthesized during darkness by the pineal gland, induced a reduction in both milk yield and circulating prolactin concentrations (Auldist et al., 2007). Therefore, exposing cows to SDPP during late lactation or treating them with melatonin during late lactation could decrease milk production before drying-off and reduce the prolactin signal, thus facilitating mammary gland involution.

The objective of this study was to evaluate the effect of photoperiod manipulation and melatonin feeding on the speed of the involution process. Different involution markers, such as SCC, lactoferrin, BSA, and citrate concentrations in milk and mammary secretions, as well as matrix metalloproteinase-2 (**MMP-2**) and -9 (**MMP-9**) activities, were determined to assess the extent of the involution process. In particular, our primary focus was on investigating the changes of lactoferrin, BSA, prolactin, and citrate concentrations among the treatments.

MATERIALS AND METHODS

Animals and Experimental Design

The experiment was conducted in accordance with the guidelines of the Canadian Council on Animal Care (CCAC, 1993) and approved by the Animal Ethics Committee of McGill University. A total of 30 first- to third-parity Holstein dairy cows in late lactation (327 ± 10 DIM at the start of the treatments) were used in this experiment. The cows were randomly assigned to 1 of 3 groups of 10 animals according to their milk production, parity, and SCC. Before the treatments, the cows were exposed to LDPP [16 h of light (from natural light and artificial light): 8 h of darkness]. Each group received 1 of the following treatments: (1) LDPP, (2) SDPP (12 h of darkness/1 h of light/4 h of darkness/7 h of light), and (3) LDPP supplemented with melatonin feeding (**LDPP+MEL**; 4 mg/100 kg of BW). The melatonin dosage was chosen based on previous studies (Sanchez-Barcelo et al., 1991; Lacasse et al., 2014). In the SDPP group, 1 h of light had been inserted during the 16 h of darkness schedule to allow morning milking, observing the animals and cleaning the stalls. The cows exposed to SDPP were housed in a room separated from the rest of the herd. The lights in that room were controlled by an automatic timer and were on from 0700 to 0800 h and from 1200 to 1900 h. Each treatment started 14 d before drying-off and lasted 14 d after drying-off, for a total duration of 28 d. Melatonin (Sigma-Aldrich Canada Co., Oakville, ON) was dissolved in sterile distilled water (1 g/L), and a sufficient volume of the melatonin solution to reach a concentration of 4 mg/100 kg of BW was mixed into the diet of the LDPP+MEL cows 1 h after the morning milking.

The cows were milked twice daily at around 0700 and 1800 h, and milk yield was recorded during the last 4 wk before drying off. The cows exposed to SDPP were moved to the regular barn for milking only. However, to avoid IMI and to maintain health of the cows engaged in the experiment, an extra milking was performed on d 2 to 3 of the dry period to release udder pressure and to reduce mammary gland engorgement. The cows were fed ad libitum a late-lactation diet containing (on a DM basis) 59.0% corn silage, 3.1% dry hay, 26.5% corn