ORIGINAL SCIENTIFIC ARTICLE / IZVORNI ZNANSTVENI ČLANAK

Effect of melatonin administration prior to calving on milk secretion in the next lactation in dairy cows

*Giorgio Morini, Maicol Pittella, Andrea Poli and Fabio De Rensis**

Introduction

Photoperiodism induces physiological alterations in growth, reproduction, and lactation (Dahl et al., 2000; Dahl and Petitclerc, 2003; Lopez Gatius et al., 2003; Garcia Ispierto et al., 2013; De Rensis et al., 2015; De Rensis et al., 2017). Photoperiod is strictly linked to the secretion of melatonin. In cattle, melatonin secretion increases at night and decreases during the day (Hedlund et al., 1977; Ogino et al., 2013) with low concentrations of melatonin during the long-day photoperiod and an increase during the short-day photoperiod (Peters et al., 1978; Tucker and Ringer, 1982; Dahl et al., 2000; Dahl and Petitclerc, 2003). It should be noted that melatonin secretion in cows, as determined by spectral analysis, did not differ among seasons, though the duration of melatonin secretion was longer during winter (Ogino et al., 2013).

Modulating the photoperiod, and therefore the relative duration of light and dark exposure within a day, affects milk production (Auldist et al., 2007; Ponchon et al., 2017). During lactation, cows exposed to a long-day photoperiod (LDPP; more than 16 h of light/d) produce more milk than those exposed to a short-day photoperiod (SDPP; less than 12 h of light/d) (Peters et al., 1981). When the photoperiod is modulated during the drying-off period, cows exposed to SDPP during the drying-off period produced more milk during the following lactation than cows exposed to LDPP (Miller et al., 2000; Auchtung et al., 2005; Lacasse et al., 2014).

These effects can be due to the fact that exposure of dairy cows during lactation to a long-day photoperiod is associated with an increase in prolactin concentration and therefore milk production (Dahl et al., 2003), with an evident effect in early lactation compared to late lactation stages (Lacasse et al., 2014).

The mechanisms by which photoperiod influences prolactin secretion and milk secretion is yet to be elucidated. One mechanism can be related to the fact that the photoperiod, melatonin and circulating prolactin show a consistent

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relationship (Auchtung et al., 2005; Wall et al., 2005; Dahl et al., 2012), and administering melatonin results in a decline in circulating prolactin concentrations (Auldist et al., 2007).

The drying-off period takes place at the end of lactation and is a remodelling process through which the gland returns to a non-lactating state. The process has an important effect on the following lactation. This process starts as soon as 2 d after the last milk removal (Holst et al., 1987) and is typically complete after approximately 21 d (Hurley, 1989; Akers et al., 1990). However, in high producer dairy cows, during the initial days of the drying-off period, the mammary gland continues to synthesize milk components, with milk accumulating in the gland. This effect may cause engorgement of the udder, leading to milk leakage and facilitating the entry of microorganisms. Consequently, a strategy that accelerates the involution process at drying-off would be a valuable tool to improve mammary gland health and resistance to microorganisms.

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). Melatonin, in addition to other effects, also has an inhibitory effect on prolactin secretion. Furthermore, melatonin and its metabolites are also considered indirect antioxidants and powerful direct free radical scavengers (Adriaens et al., 2006; Kang et al., 2009; Matsuzuka et al., 2005). Therefore, melatonin could be a candidate for controlling milk yield at dry off. This study examined whether the administration of melatonin could influence milk yield and mammary gland involution during the dry-off, with a positive effect on the following milk production.

Materials and Methods

Animals and farm

The study was performed on a dairy herd in Pianura Padana, northern Italy (45°41′56″04 N, 09°40′12″00 E), and included a mean of 500 lactating cows during the study period. Mean annual milk production was 11,300 kg per cow. Cows were housed at the farm (intensive management). The animals were reared within the herd and milked two times a day before drying-off that occurred 60 days prior to expect calving. Herd management included housing in free stalls with cubicles inside, with straw and a system of fans activated during the summer season. Exclusion criteria were the following pathologies: mastitis, lameness, digestive disorders and postpartum disorders of the reproductive tract detectable by ultrasonography.

Treatments

A total of 120 high producer dairy cows were randomly divided into four groups: animals treated with melatonin (MEL group) during winter (n=30) or summer season (n=30), and untreated animals serving as the control (CONT group) during winter (n=30) or summer season (n=30).

In treated cows, melatonin was administered for 60 days prior to the expected date of calving through 12 slow-releasing subcutaneous implants, each containing 18-mg melatonin (Papachristoforou 2007; Garcia Ispierto et al., 2013). These implants were designed to release melatonin for 60 days. This treatment has been shown to elevate plasma concentrations of melatonin in dairy cow (Sanchez-Barcelo et al., 1991). In the "winter" group, cows received the implants near the winter solstice (21 December), a time of the year when melatonin discharge by the pineal gland is at its maximum, while cow in the "summer" group received the implants

Table 1. Average milk yield (kg) in dairy cows treated or untreated with melatonin during the drying-off period (mean±SD).

	Melatonin	Control
Summer	44.2±3.0 (n=30)	42.8±2.3 (n=30)
Winter	45.4±3.7 (n=30)	49.2±3.0 (n=30)
Total	43.8±5.0 (n=60)	47.1±3.0 (n=60)

near the summer solstice (21 June), when melatonin plasma levels are at their minimum. Controls cows received no implants.

Statistical analysis

The effects of melatonin treatment and season (winter or summer) and their interaction were analysed by one-way ANOVA. Differences were considered to be significant at $P<0.05$.

Results

The data on milk yield are presented in Table 1. There were no differences in the average (mean ± SD) milk yield between animals treated with melatonin and the control animals (44.5±3.7 and 44.8±5.0 kg/day, respectively). There was an overall effect of season, with higher milk yield in winter than in summer (43.8±5.0 and 47.11±3.0, kg/day of milk for MEL and CONT group, respectively). The interaction between melatonin and season showed no significant differences, however, during winter, milk yield tended to be higher ($P=0.06$) in control animals compared melatonin treated animals (45.3±3.7 and 49.2±3.0 for control and melatonin treated cows, respectively).

Discussion

Photoperiod can modify milk secretion (Miller et al., 2000; Auchtung et al., 2005; Auldist et al., 2007) and in multiparous cows, milk production in the first 20 weeks of lactation is enhanced by about 10% with previous exposure to a short-day photoperiod (Lacasse et al., 2014). This can be related to the fact that during lactation, melatonin mediates the mammogenic and galactopoietic effects of photoperiod (Dahl et al., 1997; Spicer et al., 2007) and promotes, among other things, the increase of the mammary gland. The latter is positively correlated to milk production in the next lactation. However, another recent study (Ponchon et al., 2017) on lactating cows treated with melatonin during an artificially induced long-day photoperiod, suggested that melatonin treatment did not modify milk yield during lactation.

When the effects of melatonin treatment during the drying-off period are considered, as in the present study, the overall milk production during the next lactation should not be modified (Garcia Ispierto et al., 2013). Our results confirm and expand these observations. The present study also considered the winter and summer seasons, and therefore animals under the natural photoperiod. Our results show a difference in the overall milk yield between summer and winter, though this effect was not modified by melatonin treatment. However, during winter, animals treated with melatonin showed a tendency to have reduced milk production ($P=0.06$) compared to untreated animals.

In conclusion, this study indicates that treatment with melatonin during the drying-off period does not modify milk yield during the following lactation. However, the tendency for a reduction in milk yield during the winter season after melatonin treatment should be taken into account.

Abstract

This study evaluated the effects of melatonin administration 60 days prior to expect calving (drying-off period) on milk yield during the next lactation. Sixty dairy cows were treated with subcutaneous melatonin implants during summer (n=30) or winter (n=30) period. Another 60 animals were not treated and served as the control. There were no differences in the average milk yield between treated and untreated animals (44.5±3.7 and 44.8±5.0 kg/day for melatonin and control cows, respectively). There was an effect of season with a higher winter milk yield than in summer (43.8±5.0 and 47.1±3.0 kg/day for melatonin and control groups, respectively). The interaction between melatonin and season showed no significant effect; however, during winter, milk yield tended to be higher (P=0.06) in control cows than in melatonin treated cows (45.3±3.7 and 49.2±3.0, respectively). This study indicates that treatment with melatonin prior to calving did not modify milk yield during the following lactation. Only a tendency for a reduction in milk yield during winter was observed in melatonin treated cows.

Key words: *melatonin, dairy cow, milk yield*

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Učinak primjene melatonina prije teljenja na izlučivanje mlijeka tijekom laktacije u mliječnih krava

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U ovom istraživanju procjenjivan je učinak primjene melatonina 60 dana prije očekivanog teljenja (razdoblje isušivanja) na proizvodnju mlijeka tijekom kasnije laktacije. Šezdeset mliječnih krava tretirano je potkožnim implantatima melatonina tijekom ljetnog (n=30), odnosno zimskog (n=30) razdoblja. Drugih 60 životinja nije tretirano i one su poslužile kao kontrola. Nije bilo razlika u prosječnoj proizvodnji mlijeka između tretiranih i netretiranih životinja (44,5±3,7 kg/dan u krava tretiranih melatoninom, odnosno 44,8±5,0 kg/dan u kontrolnih krava). Postojao je učinak sezone, pri čemu je proizvodnja mlijeka bila veća zimi u odnosu na ljeto (43,8±5,0 kg/dan u krava tretiranih melatoninom, odnosno 47,1±3,0 kg/dan u kontrolnoj skupini). Interakcija između melatonina i sezone nije pokazala značajniji učinak, ali tijekom zimske sezone proizvodnja mlijeka u kontrolnih krava bila je veća (P=0,06) u odnosu na krave tretirane melatoninom (45,3±3,7 u kontrolnoj skupini, odnosno 49,2±3,0 u krava tretiranih melatoninom). Ova studija ukazuje da tretman melatoninom prije teljenja ne mijenja proizvodnju mlijeka tijekom kasnije laktacije. Primijećena je samo tendencija smanjenja proizvodnje mlijeka u zimskoj sezoni u krava tretiranih melatoninom.

Ključne riječi: *melatonin, mliječna krava, proizvodnja mlijeka*