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Fakulteten för veterinärmedicin och husdjursvetenskap

Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science

The cow eye – Function and effect of light on milk yield
Koögat – Funktion samt effekt av ljus på mjölkproduktionen

Hanna Tiilikainen

Examensarbete / SLU, Institutionen för husdjurens utfodring och vård, **514**

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Handledare:	
Supervisor:	Emma Ternman, SLU, Inst. för husdjurens utfodring och vård
Ämnesansvarig:	
Subject resonsibility:	Olle Håstad, SLU, Inst. för anatomi, fysiologi och biokemi
Examinator:	
Examiner:	Björn Ekesten, SLU, Inst. för kliniska vetenskaper
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Abstract

The purpose of this review was to study the cow’s eye physiology, focusing on how light affects the cow’s milk yield. It has been shown in studies that more hours of light per day (16 hours of light a day, as opposed to about 9-12 hours of light a day), increases milk yield for dairy cows. This review contains suggestions on how this is connected with the physiology of the eye.

Vision is an important sense for most mammals and is used to check out the animals’ surroundings. Sensory neurons in the retina of the globe help in turning photons from the light into signals to the brain. The brain can then translate the information and start a range of responses in the animals. For instance, ganglion cells in the eye´s retina send signals to the pineal gland in the brain, to stimulate or inhibit production of melatonin.

Increased light hours decrease the secretion of melatonin, important for sleep patterns and regulation of seasonal reproduction. Artificial light seems to work as well as natural light, in this aspect. Studies have shown relations between longer photoperiods (16 hours of light per day) and elevated prolactin levels, which leads to increased milk production. However, in dry cows, short photoperiods (8 hours of light per day) show an increase in milk yield in the subsequent lactation. Studies also show connections between increased levels of the growth hormone bovine somatotropoin (BST) and longer photoperiods.

Sammanfattning

Syftet med denna litteraturstudie var att studera koögats fysiologi, med fokus på hur ljus påverkar kornas mjölkavkastning. Det har tidigare visats i studier att fler ljusa timmar på dygnet (16 timmar per dygn, i stället för cirka 9-12 timmar per dygn), ökar mjölkavkastningen hos mjölkkor. Den här litteraturstudien innehåller förslag på hur detta är kopplat till ögats fysiologi.

Synen är ett viktigt sinne för de flesta däggdjur, och används för att ta in information från djurets omgivning. Synceller i ögats näthinna hjälper till att omvandla fotoner ifrån ljuset till signaler som sedan överförs till hjärnan. Hjärnan kan därefter översätta informationen och starta olika responser hos djuren. Ett exempel är ganglieceller i ögats näthinna som sänder signaler till tallkottkörteln i hjärnan som stimulerar eller inhiberar produktionen av melatonin.

Fler ljustimmar minskar även utsöndringen av melatonin, viktigt för sömn och säsongsmässig reglering av reproduktionen. Artificiellt ljus verkar fungera lika bra som naturligt ljus i detta fall. Studier har visat samband mellan längre fotoperioder (16 timmar ljus/dygn) och förhöjda prolaktinnivåer, vilket kan leda till ökad mjölkproduktion. Hos sinkor har det motsatta visats. Korta fotoperioder (8 timmar ljus/dygn) ger ökad mjölkproduktion i kommande laktation. Studier har även visat samband mellan ökade nivåer av tillväxthormonet bovint somatotropin (BST) och längre fotoperioder.

Introduction

The importance of sufficient lighting in milk production has been investigated in several studies (for example Miller et al., 1999; Peters et al., 1978; Peters et al., 1981). Peters et al. (1981) showed that subjecting dairy cows to 16 hours of light instead of 9-12 hours of light increased milk yield. However, the cow's perception of light and the physiological reactions in the cow are not fully understood.

Vision provides detailed information of the animals' surroundings and can be considered one of the main senses for mammals when taking in information from its surroundings (Sjaastad et al., 2010). After light has entered the eye various hormonal processes start in the animal. Some of those processes can have an impact on the milk yield. Hormones mentioned in the study are prolactin (Peters et al., 1981) that increases when exposed to 16 hours of light a day, melatonin (Stanisiewski et al., 1988) that is affected by light (Sjaastad et al., 2010) and bovine somatotropin (Miller et al., 1999) that together with 16 hours of light a day could increase the milk yield.

The aim of this review is to examine how light, and different light regimes, can affect the milk yield in dairy cows. The focus will be on the physiology of the cow eye and how light can affect milk yields.

Literature review

Function of the eye

Cattle have their eyes placed laterally (on the sides of the head) which enables them to have wide monocular visual fields and a small binocular field (see figure 1). This eye position is common among our large grass-eaters and gives the animal a wide field of view but with a blind spot right in front of the animal and right behind the animal. To compensate for this the head of the animal can be moved in different angels (Dyce et al., 2010).

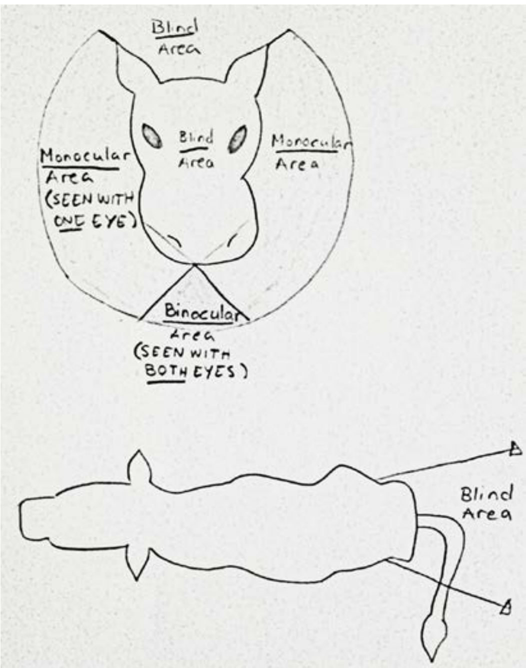

Figure 1: Schematic picture of the visual fields of cattle and horses.

The eye of mammals consists of the globe and accessory structures, such as the extraocular muscles for movement and the eyelids for protection (Dyce et al., 2010). The globe in cattle is shaped like a sphere but is a bit compressed from the sides. The transparent part of the globe is called the cornea. Around the centre there are three layers, or tunics (see figure 2): the cornea and the sclera, the uvea, and the retina connected to the brain via the optic nerve. The retina and the optic nerve can be regarded as an extension of the brain, as it connects the visual cortex with the eye globe.

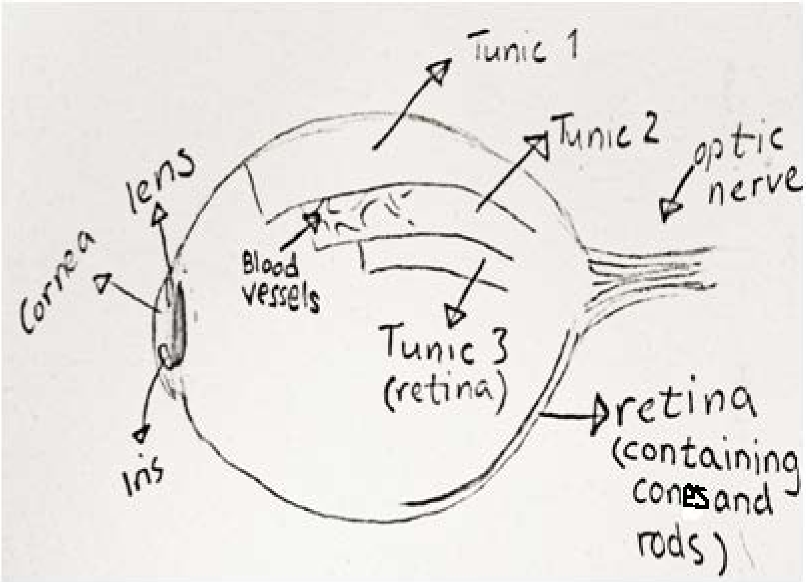

Figure 2: Schematic picture of the globe, showing different parts of the eye.

Perception of light and colour vision

Light can be divided into two categories: natural light and artificial light (Hörndahl et al., 2013). The natural light refers to the outdoor light (from the sun) or light that enters the building through windows (Hörndahl et al., 2013), and varies over the year. Artificial light can for example be fluorescent light. The artificial light can more easily be regulated than natural light.

Light (photons) enters the eye through the cornea (Sjaastad et al., 2010) and the pupil regulates the intake of light. The cornea is responsible for most of the refraction. The lens may vary its shape and make it possible to see clearly (focus) at different distances. The light is focused on the retina, and neurons in the retina create the fibres which the optic nerve consist of. The retina contains primarily two different sensory cells; cones and rods (Sjaastad et al., 2010). Visual information is sent through the optic nerve, exiting at the back of the globe, to the brain.

Adaption to dim light (close to darkness) makes it possible to distinguish objects even when there are low levels of light. Photons that get absorbed by the rods and the cones activate receptor molecules called photopigments (Sjaastad et al., 2010). The main types used for this adaption are the rods, since they are much more sensitive to light than the cones (Sjaastad et al., 2010). The eye will become light-adapted when most of the photopigments in the rods have been bleached (degraded). When the light is dimmed, the photopigments in the rods are re-synthesized. This is called dark adaption and allows the eye to discern different objects again. The cones adapt faster to lowered levels of light than the rods (Sjaastad et al., 2010), in humans it takes the cones about five minutes and the rods about half an hour (Hecht et al., 1937; Sjaastad et al., 2010).

Cones are the photoreceptors in the eye that allow colour vision, in most animals (Sjaastad et al., 2010). There are different kinds of cones that react to different wavelengths. Cattle have two types, one that is most sensitive to blue light and another to green light. However, cattle do not have the cones that are most sensitive to red light, as humans do. Infrared light cannot be seen by the mammalian eye since the wavelengths don't have enough energy to start the reactions in the photoreceptors (Sjaastad et al., 2010). Light consists of electromagnetic waves with visible wavelengths from about 400 nanometres (nm) to 700 nm for a human (Sjaastad et al., 2010). In a study on four cows, it was found that the peak wavelength value for cattle is at 555 nm for middle-to-long-wavelength sensitive cones and 451 nm for short-wavelength sensitive cones (Jacobs et al., 1998). The method used to measure the properties of the cones was electroretinogram flicker photometry (ERG).

Different colours are perceived depending on which wavelengths are reflected on the object. Philips & Lomas (2001) tested if calves could discriminate between long (red) and medium (green) wavelengths. Calves were trained to choose a light of a certain wavelength (colour) by rewarding them with concentrate as they entered a pen with the correct wavelength. It was found that the calves had problems to differentiate between the short wavelengths and the medium wavelengths, but not between the short and the long wavelengths.

Axons from ganglion cells (in the retina) form the optical nerve (Sjaastad et al., 2010). They convey visual signals to the brain, from the eyes, and connect to the pineal gland. The retina, through nerve pathways, conveys information to the pineal gland about lightness and darkness (Sjaastad et al., 2010). The pineal gland then stimulates or inhibits production of melatonin, which control sleep (Sjaastad et al., 2010) and circadian rhythm (Sjaastad et al., 2010). A special type of ganglion cells, called intrinsically photosensitive ganglion cells, has been shown to have an effect on circadian rhythm. In a study in rats (Berson et al., 2002), the sensory input of the cones and rods in the eye were blocked. Their results showed that these ganglion cells depolarized when they were stimulated by light, showing properties of photoreceptors, but responding independently of cones and rods.

Photoperiod

The hormonal response to a photoperiod starts when photoreceptors (ganglion cells) in the eye perceive light and send that signal on to the pineal gland located in the brain (Dahl et al., 2012).

In a study by Peters et al. (1978), 92 lactating Holstein cows in two groups were subjected to different light programs. The cows were group-housed and were either exposed to natural light for 9-12 hours per 24 hours (short photoperiod) or artificial light for 16 hours per 24 hours (long photoperiod). The study showed that cows with more light hours had a higher milk yield compared to cows with short photoperiod period, even though the light source for the longer photoperiod was artificial. The cows exposed to the long photoperiod with artificial light had a higher milk yield for the first 100 days of the treatment. However, from day 100 and onwards the cows in the natural light treatment had the highest yields instead.

Rius & Dahl (2006) conducted a study to see if long-day photoperiods had an effect on milk production in the subsequent lactation for pre-pubertal heifers. Thirty-two heifers were subjected to either 16 hours of light/day (long day photoperiod) or 8 hours of light/day (short day photoperiod), until the start of puberty. The heifers were put in with the rest of the herd; with a natural photoperiod when they reached puberty (the article does not state how long a natural photoperiod was). Body weight, hip height and withers height were measured at parturition. Heifers exposed to long day photoperiod had a greater body weight and withers height (at calving), than the short-day photoperiod group. They also showed a trend towards producing more milk during their first lactation.

Miller et al. (2000) dried of 34 lactating Holstein cows about 60 days prior to expected calving. They were then randomly assigned to either 16 hours of light/day (long-day photoperiod) or to eight hours of light/day (short-day photoperiod). This was done to study the effect of photoperiod during the dry period on subsequent lactation. At parturition the test-cows were moved in with the rest of the herd, with ambient lighting (ranging from 10,5 hours of light/day and 9,5 hours of light/day). After parturition, weekly (for 16 weeks), milk yield and composition were measured. IGF-1 was measured biweekly and then twice a day from 10 days before parturition, together with prolactin; with blood samples taken from a tail vessel. The samples were then centrifuged at 1970 X g for half an hour, to separate the plasma before being stored at -20°C, until being assayed. Concentration of prolactin was higher in the cows subjected to long-day photoperiods, except for peripartum. Milk yield, however, was higher in the cows previously exposed to the short-day photoperiod treatment. The same could be seen for energy-corrected milk (ECM). The milk composition, calf growth or concentration of plasma IGF-1 (in the cows) was not affected, by the different treatments.

Effects on milk yield caused by the length of the photoperiod and surrounding temperature were studied by Barash et al. (2001). The study was conducted on 107 herds of dairy cows in a Mediterranean climate (Israel) and the cows were in either their third or their fourth lactation. Long photoperiods (16 hours of light per day) showed a positive effect on milk production compared to 8 hours of light per day; however a reduction in surrounding temperature showed a negative effect instead as milk yield decreased when the temperature dropped, with the milk yields varying between -0.38 and +0.02 kg for each °C dropped. This drop was most prominent during their second month of lactation and in the month of September. The feed came from large feeding centres and had an even composition of milk components and -composition, over the year.

Hormones

Secretion of the hormone melatonin is inhibited by light and stimulated by darkness (Sjaastad et al., 2010). Melatonin regulates sleep in humans, and a high concentration of melatonin stimulates sleep. By subjecting calves to either 16-24 hours of light per 24 hours or 8 hours of light per 24 hours, Stanisiewski et al. (1988) showed that melatonin in calves is secreted during the dark hours. The calves subjected to 8 hours of light had the highest melatonin concentration in their blood serum. In the calves that had been subject to 24 hours of light the results did not show an increase of nocturnal melatonin in three of the four calves tested.

Peters et al. (1981) showed that prolactin levels increased when 42 lactating cows were subjected to photoperiods of 16 hours of light. In the study, 24 cows in early lactation and 18 cows in late lactation were acclimatized to a 12-hour light program between October 25 and March 14. The cows were then divided into two groups, 21 cows in each group, with the two light treatments; natural light of 9-12 hours per 24 hours and artificial light (fluorescent light) of 16 hours per 24 hours. The cows exposed to the 16 hours light treatment had the highest levels of prolactin and it was also found that cows in early lactation had a higher amount of prolactin, in blood plasma, than cows in late lactation did.

Forty multiparous Holstein cows were exposed to 16 hours of light/day (long day) or 8 hours of light/day (short day) during the dry period which commenced 62 days before calving (Auchtung et al., 2005). The objective was to see if different photoperiods during the dry period have an effect on circulating prolactin and/or on the expression of prolactin receptor mRNA in lymphocytes or on mammary tissue, in the subsequent lactation. The levels of prolactin and prolactin receptor mRNA were measured every other week during the dry period in plasma and lymphocytes respectively. Prolactin was reduced in cows exposed to short days whilst milk yield, in the subsequent lactation, increased and prolactin receptor mRNA increased, in the mammary tissue and in the lymphocytes.

In a study made by Dahl et al. (1997), circulation of IGF-1 relative to exposure to long-day photoperiod was studied. In the study, 40 lactating cows were exposed to either ≤ 13hours of light/day (natural photoperiod) or to 18 hours of light/day (long photoperiod). The study was conducted over four continuous months. Blood samples were taken every other week and the plasma was then harvested and analyzed for IGF-1. Compared to the natural photoperiod, milk yield and concentrations of circulation IGF-1 was higher for the cows exposed to a long photoperiod. The increase of milk yield became significant after being treated for 28 days and then persisted during the rest of the test period.

Miller et al. (1999) showed that increased photoperiods together with synthetic Bovine somatotropin (rBST) can increase milk yield additively. Four different treatments were applied to 40 lactating Holstein cows, 10 cows per treatment. The treatments were natural photoperiod (9.5-14.5 hours of light per 24 hour), natural photoperiod combined with rBST, long daily photoperiod (16 hours of light per day) and long daily photoperiods combined with rBST. The largest increase in milk production was seen for the treatment with long photoperiod in combination with rBST.

Discussion

Light entering the eye can activate processes in the cow's body that increase milk yield (Dahl et al., 2012). Light entering the eyes stimulate the retina that then activate the pineal gland, in the brain. This, in turn, affects different hormones. Those hormones then activate processes that affect the milk yield (Dahl et al., 2012). It may also be other factors activating them. There are more hormones that are affected by photoperiod than those mentioned in the text. Some other hormones and hormone-like compounds that might affect milk production are IGF-1 and prostaglandins.

The ganglion cells, in the eye´s retina, are important in regulating sleep since they are connected to the pineal gland, in the brain, where melatonin is produced (Sjaastad et al., 2010). The ganglion cells react to contrast in light and when they are stimulated they decrease the production of melatonin. As mentioned before the production of melatonin is important in regulating sleep. When more hours of light are added to the day, as in the experiments by Peters et al. (1978), Peters et al. (1981) and Miller et al. (1999), the ganglion cells continue to send signals to inhibit melatonin production and the cows have more awake time to produce milk. Special ganglion cells called intrinsically photosensitive ganglion cells have been shown to function as photoreceptors without depending on input from cones and rods (Berson et al., 2002). These specialized ganglion cells help in regulating the circadian rhythm and therefore also have a role in regulating sleep.

Photoperiods seem to be a deciding factor for the amount of produced prolactin (Peters et al., 1981). Prolactin has been shown to increase with more light hours (16 hours a day) (Peters et al., 1981). Hence, light appears to stimulate the production and release of the prolactin hormone. Prolactin can then start its stimulating effect on the production of milk. This increase in prolactin might be a reason for the higher milk yield that has been shown in studies with extended photoperiods of 16 hours or longer (since prolactin stimulates the production of milk (Sjaastad et al., 2010)). Thus, more hours of light might be used, in milk production, instead of yield enhancing synthetic hormones, since it seems to have a similar effect.

Melatonin induces sleep, and melatonin secretion is inhibited by light (Sjaastad et al., 2010). Melatonin production would therefore decrease when there are more light hours, during a day. This can cause a change in the circadian rhythm and increase the productive hours in the cow, since the time when the cow is alert increases. The above mentioned may mean that melatonin levels are an indirect reason for possible higher yields as the light hours increase. Stanisiewski et al. (1988) showed that calves that were subject to 24 hours of light/day did not produce any nocturnal melatonin. This change in melatonin secretion may mean that the cow will not get enough sleep when the dark hours decrease, since melatonin is an important factor for tiredness and sleep at night (Sjaastad et al., 2010), even if this is an extreme example.

Peter et al. (1978) showed that the effect of photoperiod subsided after 100 days with the 16 hours per 24-hour treatment. This could mean that the state of the lactation of the cow is important to consider when deciding when (and if) to use extra lighting. The reason for the milk yield subsiding after 100 days could be that the cows' physical limit was reached, and therefore could not continue to produce a higher yield.

In the article written by Rius & Dahl (2006), they tested the effects of the duration of the photoperiod on pre-puberty heifers that went back to a normal photoperiod and a diet that is standard for dairy heifers after the test period. What they mean by "normal" and "standard" is not specified in the text. The reason for only testing pre-pubertal heifers could be to see if a longer photoperiod in early life has an effect later on, as adults. Also, it might be because they wanted to be able to disregard any possible effects caused by sex hormones. It says in the article that the heifers exposed to long-day photoperiods had a greater milk yield during their first lactation, compared to the others. It also says that the heifer on this treatment got larger in height and width, so that might be a cause for the higher yields later on.

Miller et al. (2000) studied the effects of the duration of the photoperiod during the dry period on the subsequent lactation. The results showed an increase in prolactin in the long-day photoperiod treatment group, as in the study by Peters et al. (1981). It indicates that light could stimulate the production and release of the hormone. Milk yield, however, was higher in the short-day photoperiod treatment group (Miller et al., 2000). Other studies (Peters et al., 1978 & Peters et al., 1981) have shown increased milk production in lactating cows subject to 16 hours of light/day (long-day). It seems then that there is a difference, in how light treatments affect milk yield, between the dry period and the lactating period. In the study (Miller et al., 2000) it was found that long-day photoperiods, during the dry period, did not have a negative effect on subsequent lactations. The results indicate that short-day photoperiods during the dry period combined with long-day photoperiods during lactation could have the best effect on milk yield.

It has been shown that artificial light increases the prolactin levels, in the same way as long days with natural light (Peters et al., 1981). Results indicate that more light hours, rather than the type of light used, have a positive effect on milk yield, on the animals (Peters et al., (1978). This could be because the photons that get absorbed, by the eye, are the same, in both natural and artificial light, and therefore they send the same type of signals to the brain. If artificial light is being used, then the milk yield could increase even in the winter, with less natural light than during the summer. It could also make the production more even over the year.

Auchtung et al. (2005) studied the effect of photoperiod during the dry period on circulating prolactin and expression of prolactin receptor mRNA in lymphocytes or on mammary tissue, in subsequent lactation. Prolactin was reduced for the cows in the short-day photoperiod treatment. Milk yield and prolactin receptor mRNA (during the same treatment) increased, in the mammary tissue and in the lymphocytes. This shows that even though circulating prolactin decreased, the receptors in tissue increased, and therefore also the potential to bind prolactin molecules at start of lactation. The change in prolactin and milk yield in response to short-day photoperiod, during the dry period, is consistent with the study by Miller et al. (2000).

Circulating IGF-1 relative to long-day photoperiod exposure was studied by Dahl et al. (1997). The results showed that circulating IGF-1 and milk yield increased with the long-day photoperiod treatment. Milk yield-increase became significant after 28 days of treatment. IGF-1 has been suggested to have a galactopoietic effect on maintaining lactation (Capuco & Akers., 2011), as it seems to have a role as an essential contributor to the galactopoietic reaction of bovine somatotropin (bST).

Miller et al. (1999) studied the effect on lactation of different photoperiods combined with artificial bovine somatotropin (rBST). The results showed that increased photoperiod together with rBST increased the milk yield additively. It indicates that rBST could have a similar effect as natural bovine somatotropin (bST) in its galactopoietic effect on lactation. The effect of rBST seems to be separate from photoperiodic effect as the effect added on the increased result from photoperiodic treatment. Alternatively they could have a combined effect that increases proportionally as either treatment is added.

Artificial light might improve the milk production of a cow (Dahl et al., 2012). Though artificial light has been shown to have a positive effect on milk yield it may be that the cows could get satiated with too much light, and thus reach a point were more light does not affect the yields. This since a point may be reached when the amount of sleep is affected, and thus it could possibly have a negative impact on the cow's milk production, meaning that the yields level out, and can't get any higher or that the physical limit of the cows' body is met.

It might also be possible to investigate if the photoperiod-sensitive hormones affect animal welfare and health, such as amount of sleep and physical stress on the cows' body (as mentioned above).

Temperature can have a negative effect on the yields, since there is a positive correlation between decreased temperature and decreased milk yield (Barash et al., 2001). This drop in yield was most prominent in the second month of lactation and in the month of September in this Israeli study. The feed had a similar composition throughout the year so it seems likely that it did not have an effect on the final results. It therefore seemed then that state of lactation and time of the year also had an effect on the milk yield. These results suggest that if the temperature is too low, it might be better to keep the animals indoors, where you are able to control the temperature. When it is a cold period, it may also be darker days (like in winter in, for example, northern Europe) and therefore it might also be beneficial to keep the animals indoors to control the amount of light.

Stanisiewski et al. (1988) showed that melatonin had the highest release when calves were subjected to 8 hours of light/day and that calves subjected to 24 hours of light/day showed no increase in nocturnal melatonin, in three of four calves. These calves seemed to have their melatonin release-pattern disrupted by the continuous light treatment. In the long run this could affect the calves negatively since this could have an effect on their sleep pattern as well. Lack of sleep could potentially lead to more problems later on.

More has been done in studying how lighting affects the milk yields in cows than this review contains. This review does not contain the exact mechanisms behind the physiological processes and further research would complement this review.

Conclusion

The conclusions of this study are that longer photoperiods (16 hours of light per 24 hour), in lactating cows increase prolactin levels, which in turn has shown to lead to higher milk yields.

Dry cows give higher milk yields in their next lactation, when subjected to short-day photoperiods.

Prolactin, IGF-1 and rBST have been shown to have a positive effect on milk yield.

Ganglion cells react to light and send signals to the pineal gland to inhibit or stimulate melatonin production.

Artificial light can be used instead of natural light to achieve this result.

References

Auchtung T L, Rius A G, Kendall P E, McFadden T B and Dahl G E, 2005. Effects of photoperiod during the dry period on prolactin , prolactin receptor, and milk production of dairy cows. Journal of Dairy Science 88, 121-127.

Barash H, Silanikove N, Shamay A and Ezra E, 2001. Interrelationships among ambient temperature, day length and milk yield in dairy cows under a Mediterranean climate. Journal of Dairy Science 84, 2314-2320.

Berson D M, Dunn F A and Takao M, 2002. Phototransduction by retinal ganglion cells that set the circadian clock. Science 295, 1070-1073. https://www.semanticscholar.org/paper/Phototransduction-by-retinal-ganglion-cells-that-Berson-Dunn/519a4046918ab5daa6e5cec8a37fc8108de8947f (2018-06-10)

Capuco A V,and Akers R M, 2011. Galactopoiesis/Effects of hormones and growth factors. Encyclopedia of Dairy Sciences, 26-31.

https://www.researchgate.net/publication/279522993 (2018-06-05)

Dahl G E, Elsasser T H, Capuco A V, Erdman R A and Peters R R, 1997. Effects of a long daily photoperiod on milk yield and circulating concentrations of Insulin-like growth factor-1. Journal of Dairy Science 80, 2784-2789.

Dahl G E, Tao S and Thompson I M, 2012. Lactation biology symposium: Effects of photoperiod on mammary gland development and lactation. Journal of Animal Science 90, 755-760.

Dyce K. M, Sack W O and Wensing C J G, 2010. Textbook of veterinary anatomy, fourth edition. (eds. K M Dyce, W O Sack and C J G Wensing) 332-354. Saunders, Elsevier, St Louis, Missouri, USA.

Hecht S, Haig C and Chase A M, 1937. The influence of light adaption on subsequent dark adaption of the eye. Journal of General Physiology 20, 831-850.

Hörndahl T, von Wachenfelt E and von Wachenfelt H, 2013. Belysning i stallbyggnader – Energieffektiv belysning och god djurvälfärd. Swedish University of agricultural science (SLU), Alnarp, Sweden. Report 2013:8, ISBN 978-91-87117-39-8

Jacobs G H, Deegan J F and Neitz J, 1998. Photopigment basis for dichromatic color vision in cows, goats and sheep. Journal of Visual Neuroscience 14, 581-584.

Jordbruksverket (SJV) april 2014. Får du göra operativa ingrepp eller ge hormoner till dina nötkreatur? http://www.jordbruksverket.se/amnesomraden/djur/olikaslagsdjur/notkreatur/operativaingreppochhormoner.4.4b00b7db11efe58e66b8000297.html (2012-08-15)

Miller A R E, Stanisiewski E P, Erdman R A, Douglass L W and Dahl G E, 1999. Effects of long daily photoperiod and Bovine somatotropin (Trobest®) on milk yield in cows. Journal of Dairy Science 82, 1716-1722.

Miller A R E, Erdman R A, Douglass L W and Dahl G E, 2000. Effects of photoperiodic manipulation during the dry period of dairy cows. Journal of Dairy Science 83, 962-967.

Philips C J C and Lomas C A, 2001. The perception of color by cattle and its influence on behavior. Journal of Dairy Science 84, 807-813.

Peters R. R, Chapin L. T, Leining K. B, Tucker H. A, 1978. Supplemental Lighting Stimulates Growth and Lactation in Cattle. Science, New Series, 199, 911-912.

Peters R.R, Chapin L.T, Emery R.S, Tucker H.A, 1981. Milk yield, Feed intake, Prolactin, Growth hormone, and Glucocorticoid Response of Cows to Supplemented light. Journal of Dairy Science 64, 1671-1678.

Rius A G and Dahl G E, 2006. Exposure to long-day photoperiod prepubertally may increase milk yield in first-lactation cows. Journal of Dairy Science 89, 2080-2083.

Sjaastad Ø, V Sand O and Hove K, 2010. Physiology of domestic animals, second edition. (eds. Ø V Sjaastad, O Sand and K Hove) 165-218, 219-259. Scandinavian Veterinary Press, Oslo, Norway.

Stanisiewski E P, Chapin L T, Ames N K, Zinn S A and Tucker H A, 1988. Melatonin and prolactin concentrations in blood of cattle exposed to 8, 16 or 24 hours of daily light. Journal of Animal Science 66, 727-7