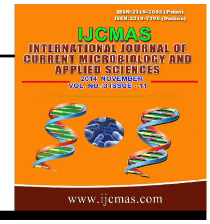

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Original Research Article

Effect of lighting on the growth, development, behaviour, production and reproduction traits in dairy cows

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A B S T R A C T

Diurnal cycles and sunlight are essential for living beings on Earth. During their evolutionary development, many animal species have become capable to detect and react to changes in light intensity and photoperiod durations caused by seasonal changes, which influence their physiological state and dynamic stereotype. This is demonstrates in poultry reared in industrial production systems, where the egg production throughout the year is controlled via photoperiod alteration, in horse husbandry for prolonging or restarting the reproduction period, whereas in dairy cattle farming it is applied for increasing milk yield and disease resistance. With this regard, a number of researchers investigated the effect of light day duration and light intensity on factors associated with better economic results in dairy cattle farms. Light is one of primary components of microclimate of farm animal environment. Lighting of animal premises is essential for one of most important elements of animal welfare – the contact with mates from the same species. The effects of lighting on animal morphology, physiology and behaviour have been described in the number of studies. The increased day length by artificial lighting during the winter caused earlier change of the winter with summer coat. So far, there are no reports showing a negative effect of coat change on the health of cows. Anyhow, the energy losses for body temperature maintenance related to the thinner coat during the winter should be taken into consideration. The problem was not yet elucidated, although important for the practice. Lighting intensity and duration are of great significance for health and life span of cows. According to the authors, cows prefer light over dark places. Probably, the better illumination and visual contact between cows contribute for social hierarchy build-up and prevention of traumatism. This fact has cause researchers and manufacturers of farm equipment to develop and implement technologies for best possible illumination and microclimate and thus, to provide optimal rearing conditions. Proper illuminati0n of animal premises is important for both animal welfare and safe, healthy working conditions for farm personnel.

Introduction

Diurnal cycles and sunlight are essential for living beings on Earth. During their evolutionary development, many animal species have become capable to detect and react to changes in light intensity and photoperiod durations caused by seasonal changes, which influence their physiological state and dynamic stereotype (Wright and Shelford, 2013). This is demonstrates in poultry reared in industrial production systems, where the egg production throughout the year is controlled via photoperiod alteration, in horse husbandry for prolonging or restarting the reproduction period, whereas in dairy cattle farming it is applied for increasing milk yield and disease resistance. With this regard, a number of researchers (Phillips and Schofield, 1989; Dahl *et al.,* 2000; Miller *et al.,* 2000; Ulimbashev, 2011) investigated the effect of light day duration and light intensity on factors associated with better economic results in dairy cattle farms.

Light is one of primary components of microclimate of farm animal environment. Lighting of animal premises is essential for one of most important elements of animal welfare – the contact with mates from the same species (Mitev, 2012). The effects of lighting on animal morphology, physiology and behaviour have been described in the number of studies (Rendic, 2002; Hayes, 2007). The increased day length by artificial lighting during the winter caused earlier change of the winter with summer coat (Yeates, 1955). So far, there are no reports showing a negative effect of coat change on the health of cows. Anyhow, the energy losses for body temperature maintenance related to the thinner coat during the winter should be taken into consideration. The problem was not yet elucidated, although important for the practice. Lighting intensity and duration are of great significance for health and life span of cows (Doležal *et al.,* 2002; Šoch, 2005). According to the authors, cows prefer light over dark places. Probably, the better illumination and visual contact between cows contribute for social hierarchy build-up and prevention of traumatism. This fact has cause researchers and manufacturers of farm equipment to develop and implement technologies for best possible illumination and microclimate and thus, to provide optimal rearing conditions (Šístková *et al.,* 2010). Proper illuminati0n of animal premises is important for both animal welfare and safe, healthy working conditions for farm personnel (Belyaev and Gorbunova, 1973; Miteva, 2012).

Materials and Methods

Perception of environmental stimuli – significant of the temperament type

The complexity of body's behavioural reactions is associated with the intricate nervous system. In general, individuals with more complicated nervous system possess a higher potential for learning and therefore, for adaptation of their behaviour to the environment. An essential feature of living beings is to obtain, convey and exchange continuously information with the environment. This ability for interaction and communication with the environment is the primary and most important function of vital significance, because it enables the organism to receive signals for incessantly changing environmental conditions. The existence of living beings depends on the orientation and adequate reactions to the changes. In modern industrial production systems, lighting is one of environmental factors with greatest impact on behaviour and general status of animals. The bovine eye is able to distinguish a difference in light intensity of 3-4 Lx, but when choosing food, the sight comes second after the olfaction (Varlyakov, 1999). Due to the well developed sensors, animals receive numerous signals which are transmitted to the brain. Out of the various stimuli, the organism selects those carrying the most relevant information and by nervous centers, using the feedback principle, alters the functional state of conductive paths and enhances or attenuates the sensitivity of receptors. The resulting response is listening, smelling, observing. It largely depends on the potential of the central nervous system, which determines the type of higher nervous activity type of the individual (Varlyakov, 1999).

The environment and microclimate of animal premises interacts with their physiology forming a communication system".

In a communication system, the "emitter" – i.e. the environment, "codes" a message and transmit it to the receiver via a "communication path". For instance, light could be seen as a message transmitted through physical electromagnetic waves, transformed into electric signals by the eye, decoded by the brain which finally "codes" the respective reaction to them, that is an adequate response. The reflex is the response of the body to the altered environment.

Modern production systems for dairy cattle are associated with a substantial numbers of stressors for their nervous systems. The type of the nervous system (strength, motility) determines the interaction between the organism and the environment (Kokorina, 1988). Animals with strong, stable and motile nervous system type could form stable conditional reflexes ensuring a high reactivity to environmental stimuli (Kokorina, 1988). Nervous system type determines the sensitivity to various stressors such as changing light and sound intensity, and technology flaws (Filippova, 1988). The author believes that different effects of light on neurohumoral regulation, behavior, production and reproduction traits could be anticipated with connection to the nervous system. Therefore, the investigations on changes in light regimen and light intensity should also consider the temperament type of studied cattle to avoid inconsistent and conflicting results. Thus, such research would assist both the science and the practice for elaboration of adequate lighting systems with more physiological benefits.

Effects of light on neurohumoral regulation in the organism of cows

Under the effect of light, photoreceptors the retina are stimulated. The nerve impulse is transformed into an inhibitory signal to the pineal gland via a series of interneuronal retinohypothalamic connections (Rieter, 1991). The pineal gland secretes a number of hormones, but the prolonged light stimulation reduces the synthesis of melatonin (Rieter, 1980; Petkov *et al.*, 2000). Light inhibits the production of N-acetyl-transferase, the primary enzyme for melatonin synthesis (Illnerova and Sumova, 1997). Melatonin production is elevated during sleep and when the dark hours of the day increase. Melatonin causes slow down of metabolism, increase body fat content and reduces the productivity of animals. According to Phillips and Schofield (1989) light-induced changes in animals depend mostly on blood glucocorticoid concentrations. Peters *et al.* (1981) evidenced 1.5 to 1.8 times higher levels of prolactin, which is derived from thyrotropin-releasing hormone, in cows reared under increased photoperiod duration (16 Light : 8 Dark), compared to cows reared under natural lighting condition (9–12 hours). The authors refuted the beliefs of Peters and Tucker (1978) who affirmed that prolactin release is blocked when ambient temperatures were low, as well as the suggestions of Koprowski and Tucker (1973) about considerably enhanced prolactin release in low ambient temperatures. Therefore, the increased photoperiod logically entails high milk yields in dairy cows. According to Dahl (2003), the body of animals (including cows) is able to utilise the changes in melatonin concentration to modulate the changes in the secretion of other hormones. In dairy cows, the prolonged photoperiod is associated with increased secretion of insulin-like growth factor – I (IGF-I) (Dahl *et al.,* 1997). Higher blood IGF-I in cows leads to increased milk yields (Dahl, 2003). Growth hormone (GH) is another product of the endocrine system probably related to increased milk yield in longer photoperiod conditions (Dahl *et al.,* 2000). Increased exogenous (Bauman and Vernon, 1993) or endogenous (Dahl *et al.,* 1991) GH levels are beneficial for milk yields of dairy cattle, but the exact mechanism of GH secretion change according to photoperiod duration is not still clear. Anderson *et al.* (1999) reported seasonal differences in GH concentrations in cattle, but it is not indicated whether this was related to photoperiod length or not. So far, there are no studies on the variations of GH secretion in cattle related to the light and resulting higher milk yields.

Apart its effects during the lactation, photoperiod has also a significant impact on the growth of replacement heifers and dry cows. It is proved that during the months with long days, heifers exhibited better body growth and attained earlier sexual maturity (Dahl *et al.,* 2000). A similar effect was observed in heifers (16 L: 8 D) – higher weight gain, earlier sexual maturity and higher blood prolactin vs heifers reared in conditions of shorter photoperiod (from 8 to 15 h light) (Small *et al.,* 2003).

Playshtenko and Leonova (1977) performed experiments to assess the effect of various artificial lighting regimens on physiological condition, growth and meat productivity of feedlot calves. Those reared under short artificial light duration (6 L: 18 D) demonstrated significantly higher daily weight gain/ According to the authors, this could be mostly due to the comfort and fewer of sexual behaviour manifestations. In these animals reduced blood calcium concentrations s as well as altered blood globulin profile are established. In groups reared fewer than 6 and 9 hours light, α and β globulins were increased whereas in the group reared less than 12 hours light - α and γ globulins were higher. These results were supported by Auchtung *et al.* (2002a) by providing evidence that short photoperiods improved lymphocytic proliferation and chemotaxis. According to other studies, blood content was influences not only by light duration, but also on its intensity. Belyaev and Gorbunova (1973) reported light intensity increase from 5 to 50 lx was associated with higher haemoglobin, calcium, bicarbonates, leukocyte and erythrocyte counts. The studies of Tihomirova and Kolchin (1978) established that calves born from cows reared under 16 L: 8 D photoperiods with higher light intensity (50 – 100 lx) had a higher average body weight by 2.1 kg and higher resistance to diseases. The morbidity rate during the first month was 29% in experimental calves vs 43% in the control group, whose dams were reared under natural photoperiod conditions (10-15 lx). Dorzh (1985) reported that the photoperiod increase (14 L: 10D) with UV rays resulted in higher resistance in calves as evidenced by higher blood serum total protein levels.

Some researchers have assumed that increased photoperiod could contribute to intensive growth. Under the influence of intensive and long-term illumination, neuromuscular tone was increased and the locomotion of animals was more intense (Yurkov, 1980). This change, in the belief of the author, is observed in almost all farm animal species, especially in growing animals. For example, the increase in luminance emittance of a premise from 5 to 100 lx and photoperiod from 6 to 18 hours, calves and piglets moved by 2.5 to 4 hours more than usual, slept and lied down less, feed intake was higher and the metabolic processes – more intensive, contributing to enhanced growth and development. The behavioural changes related to altered photoperiod intensity and duration were largely dependent on animal age. Yurkov (1980) provided proofs that 6 to 9 hours of artificial lighting sin windowless barns caused feedlot calves to lie down 4 hours more that in premises with natural lighting. With age, the active period of calves was reduced, but when the photoperiod increased, the animals remained awake up to 13-20% of the day. The different parts of the light spectrum exerted various effects on the neuromuscular apparatus of animals, with maximum irritability after illumination with red light and minimum – with blue or violet light (Yurkov, 1980). According to the author, green and orange lights did not influence considerably the behaviour of animals.

Effects of light on the growth and development of different cattle categories

Sunlight and ultraviolet radiation are beneficial for the health of large ruminants and increase their productivity, provided that they are not accompanied by extremely high ambient temperatures (Varlyakov, 1999). It is acknowledged that increased photoperiod enhanced growth until the onset of sexual maturity (Hansen *et al.,* 1983). Before that age, the enhanced growth was due to lower protein recovery rate (Zinn *et al.,* 1986), and that caused animals to use more efficiency the ration (Petitclerc *et al.,* 1983; Mossberg and Jonsson, 1996). After the puberty, body fat deposition in animals was higher in short photoperiod conditions (Zinn *et al.,* 1986). In pigs, the opposite tendency towards increased live body weight (5.5%) and body condition score (4.3%) occurred in 16-18-hour photoperiod with mean intensity of 88 lx (Pavlenya *et al.,* 1991). With regard to the impact of the photoperiod on bovine udder growth and development, Petitclerc *et al.* (1984) observed that increased photoperiod (16 L: 8 D) stimulated gland tissue development and reduced fat tissue in heifers. Some reports have shown that the proper photoperiod management during the dry period could increase the efficacy of dairy cattle farming during the next lactation. Miller *et al.* (2000) established that dry cows reared under short photoperiod (8 L: 16 D) during the first 120 lactation days had higher milk yields vs cows reared under long photoperiod during the dry period. Under the same conditions Velasco *et al.* (2008) demonstrated higher daily lactation yield by 3.6 kg/day in cows reared under short vs long photoperiod during the dry period. The tendency was confirmed by other investigations that stated clearly that during the dry period unlike lactation, cows should be kept under short photoperiod conditions (Petitclerc *et al.,* 1998; Aharoni *et al.,* 2000). Wall *et al.* (2005) supposed that the higher milk yield of cows exposed to short photoperiod during the dry period was due to improved growth and development of udder tissue. According to Todorov and Mitev (2000) the short photoperiod during the dry period facilitated the more rapid body condition recovery of pregnant animals up to BSC of 3–3.5 on the five-point score system. The investigations of Aharoni *et al.* (2000) provided additional information about the observed difference between summer and winter periods. They rejected the thesis that lower summer milk yield of cows was due to heat stress and showed that longer photoperiod during the dry period was of greatest significance. Milk losses of cows that had calved in the summer, according to researchers, were by 1.5 to 2 L/day by reason of the longer photoperiod during the last three weeks of the dry period.

Effects of light on cows' behaviour

The problem about the effect of supplementary artificial light and features as duration and intensity on all aspects of dairy cows behaviour is still disputed. According to Phillips and Schofield (1989) supplementary light (16 L : 8 D) in dairy cow barns results in two types of changes – short-term and long-term. The first type consisted in increased activity, increased feed intake, longer time spent standing and reduced time spent lying, stronger oestrus and aggression signs. On the other side, Tanida *et al.* (1984) affirmed no relationship between photoperiod and feeding behaviour and milk yield of cows. The experiments of Phillips *et al.* (1998) demonstrated that photoperiod duration did not influence the lying time, milk yield and body weight of dairy cows but had an insignificant impact on the amount of consumed feed. The authors showed that cows had a marked affinity to light vs dark areas of the barn and that the lack of enough light on the feeding alley was a significant stressor resulting in reduced feed intake. One of commonest mistakes during the interpretation of prolonged photoperiod effects on the feeding behaviour of cows was the erroneous belief that the placement of light bulbs over the feeding alley would stimulate cows to visit it more frequently and thus, increased dry matter intake. According to Dahl *et al.* (2000) and Dahl (2005), light stimulates milk production in cows, increased energy requirements makes feeding behaviour predominant and caused greater feed consumption. It should be noted that cows spend most of their time resting in cubicles, but not on the feeding alley (Dado and Allen, 1993; Dado and Allen, 1995). Supplementary light through artificial lighting up to 18 h, according to Somparn *et al.* (2007), did not influence the feeding behaviour of buffaloes (*Bubalus bubalis*), with reduction of the time spent feeding by almost 4 min daily in the group with supplementary artificial lighting. At the same time Peters *et al.* (1981) affirm that additional artificial light (16 L : 8 D) especially on the feeding alley, stimulated feed intake and increased yields. This fact is attributed to physiological alterations in animals, as they are sensitive to lighting regimen which influences the levels of some hormones and neurohumoral regulation of milk secretion and milk let-down reflex. After many years of research, Varlyakov (1991) and Varlyakov *et al.* (1993, 2007, 2010a, 2010b) established that in industrial production systems, the time for intake and conversion of feed and indirectly, the productivity, were influenced at a higher extent by the physiological state and hierarchy in the group than by the season and photoperiod. Dahl (2006) demonstrated that cows reared under short photoperiod schedule from the beginning to the middle of the dry period ingested more dry matter as compared to cows in the same physiological condition exposed to long photoperiod. This circumstance could be used practically by farmers to bring dry animals into optimum body condition for the next lactation. Another important factor influenced by light duration is the daily time spent feeding. The visits of cows on the feeding alley are largely dependent on the photoperiod duration (Karvetski *et al.*, 2006). The authors have shown that dairy cows reared in conditions of increased photoperiod exhibited longer feeding activity, distributed more regularly as compared to cows reared under short photoperiod. This, in the view of researchers, could be taken into consideration in barn design and feeding area management, because the maximum utilisation of the feeding alley would differ among the technological categories.

The studies on the impact of light on some physiological processes as breathing and heart activity of cows are relatively few. With this regard, Abrosimova (1978) reported valuable information according to which the amount of used oxygen and released carbon dioxide by cows increased proportionally to light intensity. The author supported its thesis by demonstrating increased amount of heat generated by one unit of weight in cows reared under lighting of higher intensity. This difference represents 34-41% more heat in cows reared under 100-120 lx vs control animals (15-20 lx). Some indirect evidence are provided in support of the theory of Abrosimova (1978). Tihomirova and Kolchin (1978) observed that calves whose dams were reared under 16 L: 8 D and 50-100 lx light regimen exhibited higher heart (16/min) and respiratory rates (3/min) during the first 10 days of life. This, in the belief of authors, confirmed that the metabolism of the experimental group was enhanced consequently to the rearing conditions of the dams. A substantial effect on the described behavioural, production and reproduction traits could be anticipated with altering the light spectrum in barns. In the view of Yurkov, (1980) metabolic processes were most intensive under the influence of violet light. Light spectrum had a various effect on protein utilisation and deposition in tissues. Blue and green light benefited the intense protein metabolism, accompanying the growth (Yurkov, 1980). At the same time, red, orange and yellow light were found to delay dietary protein utilisation and protein accumulation in the animal body. The effect of white light on protein metabolism held an intermediate position between red and blue light from the visible spectrum. (Yurkov, 1980). The cause is the fact, the cows perceive better long-wavelength light spectrum (about 600 nm and more) – yellow, orange and red (Phillips, 1993). Therefore, additional research is needed to elucidate light spectrum effect on physiological processes. It is acknowledged that in men, blue light with wavelength between 446–477 nm was most effective for inhibition of melatonin synthesis from the pineal gland (West *et al.*, 2011). This is extremely important proving that different light properties could have an impact on human and animal physiology (Wright and Shelford, 2013). The last authors, together with research teams from the USA have explored the possibility to use LED lights on farms. The technology was promising with regard to energy saving, regular distribution of light and LED lights life, but Wright and Shelford (2013) recommend further studies before putting into operation the LED technology for lighting animal premises. The effects of light on cows were successfully implemented in the practice by some companies. One of them (www.lely.com) trades with lighting plans and products allowing farmers to obtain more income with minimum investments in lighting equipment. According to other producers of farm equipment (www.wilsonagri.co.uk) evening lighting should be 5 lx, enough for reading printed text. This is confirmed also by recommendations for design of animal premises in Russia from the 1970s stating that lighting plans in dairy cattle farms should be two – working (100 lx) and emergency (5 lx). The use of red light with such intensity in the view of www.wilsonagri.co.uk is sufficient for farm workers to watch over animals without influencing their perception for darkness and melatonin secretion, as cows are less sensitive to light intensity than humans (Phillips and Weiguo, 1991; Phillips, 1993). The proposal of Ustinov and Nechiporuk (1970) are also in concordance with these suggestions affirming that the night control and care for cows in barns should be performed under blue lighting. In the view of authors, this type of light does not provoke photoperiod reactions and tension for CNS of animals. The colour spectrum of light reception from cows is not clearly established, because modern lighting systems recommend using red light during the dark hours (www.lely.com) in order not to put a burden on cows but to allow the farm personnel to watch over them. Possibly, cows could perceive red light, but it could soothe them without triggered a major response. That is why, both science and practice are facing the challenge for investigation and implementation of technologies which satisfy the physiological needs of cows.

The research of Abrosimova (1978) found out that adequate light intensity during milking could shorten the process by 8-12%. The necessary minimum light intensity for milking is 60-80 lx and this level assists milk let-down in the parlour and increases labour efficiency of milkers. Rist *et al.* (1974) recommend illuminance of 240-250 lx during milking. The current legislation in Bulgaria stipulates light intensity of 100 lx/m^2 (Ordinance 44/20.04.2006). Some authors propose minimum lighting in the different parts of the barn, pointing out a light flux of 100 lx in the waiting room before entering the parlour (Clarke and House, 2006), and 200 lx in the milking parlour (Clarke and House, 2006; Miteva, 2012). Proper lighting could influence oxytocin release and hence, milk let-down (Mačuhova and Bruckmaier, 2004). The researchers established significantly higher oxytocin concentrations when milking was during the day compared to night hours. Statistically significant ($P<0.05$) differences in oxytocin levels were found only in cows reared under 16 L: 8 D photoperiod. In such conditions, Mačuhova and Bruckmaier (2004) affirm that cows were more sensitive to light during milking, causing differences in oxytocin release. Uvnäs-Moberg and Petersson (2005) advance the hypothesis that light as well as certain types of sound are important physiological stimuli for oxytocin release. The daily exposure to such environmental stimuli in the barns during milking has a positive influence for activation of the oxytocin release system.

Effects of light on production traits in dairy cows

Bodurov (1979) reported that increased photoperiod (16 L: 8 D) obtained either by natural or artificial lighting increased milk yield of cows by 13%, and milk fat content – by 0.3%. The increased milk fat in experimental cattle in this study contradicts the already described physiological events because the decreased melatonin consequently to the longer photoperiod inhibits body fat metabolism. The most probable cause for increased milk fat in this study was the higher feed intake level (mainly corn silage). Data communicated by Stanisiewski *et al.* (1985) and Phillips and Schofield (1989) are opposite to those of Bodurov (1979) showing reduction of milk fat in cows reared under supplementary light (16 L: 8D). Despite the lower milk fat content (16 L: 8D) the research of Stanisiewski *et al.* (1985) established that when milk fat was corrected to standard fat content, it was higher than that produced by cows reared under short photoperiod (12 L: 12D). Phillips and Schofield (1989) found out that increased light intensity (from 101 to 529 lx) triggered other changes in milk composition related to lower milk protein. Despite the marked effect of lighting on milk yield and quality of produced milk, farmers should aim at maintaining the good health of cows. The short photoperiod during the dry period enhances the immune system of cows, with lower occurrence of mastitis and metritis during the first 10 postpartum days (Auchtung *et al.*, 2003). In this study, a substantial reduction of somatic cell counts in the period from drying off to calving was achieved under shorter photoperiod conditions. Ulimbashev (2011) showed that the highest yields and good health status during the lactation was accomplished under light intensity of 150 lx, with additionally 614 kg produced milk or by 14.8% more vs. control group. This shows that practically, an illuminance of 150 lx could be regarded upon as optimum luminous flux for satisfying the physiological needs of lactating dairy cows.

Effects of light on reproduction traits in dairy cows

The data reported by Petrusha *et al.* (1987) showed that lighting intensity was essential for improving the reproduction status of cows. According to the authors, the increased light intensity in the barn of 100, 150 and 200 lx shortened the service period with 12, 22 and 21 days vs. the control group exposed to 35 lx. It should be mentioned that the optimum results were not obtained with the highest light intensity of 200 lx. Probably, the excessively bright light has a negative effect, being perceived by animals as a stressor (Rist *et al.*, 1974). Velasco *et al.* (2008) established that cows reared under short photoperiod (8 L: 16 D) during the dry period gave birth to calves 4.8 days earlier as compared to animals reared under longer photoperiod (16 L: 8D). Very intriguing results have been obtained by Bodurov (1979), who proved that prolonged photoperiod (16 L: 8 D) improved the reproduction status through reduction of the service period by 22 days and the number of inseminations to conception by 0.6 vs controls. The cause for better reproduction traits was attributed to increased blood Ca, P, vitamin D and A, total protein, haemoglobin, erythrocytes and γ-globulins in cows reared under longer photoperiod (Bodurov, 1979; Simonova, 1984). According to other studies, the supplementary light resulted in lower activity and clinical manifestation of oestrus in cows (Phillips and Schofield, 1989). The opinion of Phillips and Schofield (1989) about long-term effects of supplementary lighting on reproduction traits of cows should be confirmed by additional studies in modern conditions and current cow breeds. Such investigations are mandatory before outlining recommendations for the practice because the problem with detection of cows in oestrus is extremely important and with serious impact on financial results of dairy cattle farms. The conflicting scientific results are also substantiated by the results of Rautala (1991) which showed no relationship between cow fertility and photoperiod variations.

References

Abrosimova R. 1978. Effect of lighting on gaseous exchange and productivity in large ruminants. *Anim. Sci.*, (RU) (2): 87–88.

Aharoni, Y., Brosh, A., Ezra, E. 2000. Short communication: Prepartum photoperiod effect on milk yield and composition in dairy cows. *J. Dairy Sci.*, 83: 2779–2781.

Anderson, L.L., Hard, D.L., Trenkle, A.H., Cho, S.J. 1999. Long-term growth after hypophyseal stalk transection and hypophysectomy of beef calves. *Endocrinology*, 140: 2405–2414.

Auchtung, T.L., Morin, D.E., Mallard, C.C., Dahl, G.E. 2003. Photoperiod manipulation during the dry period: effects on general health and mastitis occurrence. Proceeding of the National Mastitis Council Annual Meeting. Ft Worth TX Jan 26–29th, 2003.

Auchtung, T.L., Salak-Johnson, J., Dahl, G.E. 2002. Short day photoperiod enhances lymphocyte proliferation in dairy cattle. *J. Anim. Sci.*, 80(Suppl. 1): 21.

Bauman, D.E., Vernon, R.G. 1993. Effects of exogenous bovine somatotropin on lactation. *Annu. Rev. Nutr.*, 13: 437–461.

Belyaev, V., Gorbunova, E. 1973. Effect of lightning in premises on milk yield of cows. *Veterinaria*, 11: 29–31.

Bodurov, N. 1979. Effect of supplementary artificial illumination with visible rays on some biochemical parameters in the blood serum, milk production and fertility in cows during lactation. *Veterinarnomedicinski Nauki*, 16: 58–65.

Clarke, S., House, H. 2006. Energy efficient dairy lighting. Agricultural ingineering, Ontario, Order № 06–007.

Dado, R.G., Allen, M.S. 1993. Continuous computer acquisition of feed and water intakes, chewing, reticular motility, and ruminal pH of cattle. *J. Dairy Sci.*, 76: 1589–1600.

Dado, R.G., Allen, M.S. 1995. Intake limitations, feeding behaviour and rumen function of cows challenged with rumen fill from dietary fiber or inert bulk. *J. Dairy Sci.*, 78: 118–133.

Dahl, G. 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.

Dahl, G.E., 2003. Photoperiod management of dairy cattle for performance and health. *Adv. Dairy Technol.*, 15: 347–353.

Dahl, G.E., 2006. Effect of photoperiod on feed intake and animal performance. Tri-State Dairy Nutrition Conference, April 25 and 26, Pp. 33–36.

Dahl, G.E., Buchanan, B.A., Tucker, H.A. 2000. Photoperiodic effects on dairy cattle: A review. *J. Dairy Sci.*, 83: 885–893.

Dahl, G.E., Chapin, L.T., Allen, M.S., Moseley, W.M., Tucker, H.A. 1991. Comparison of somatotropin and growth hormone-releasing factor on milk yield, serum hormones, and energy status. *J. Dairy Sci.*, 74: 3421–3428.

Dahl, G.E., Elsasser, T.H., Capuco, A.V., Erdman, R.A., Peters, R.R. 1997. Effect of long day photoperiod on milk yield and circulating insulin-like growth factor-1. *J. Dairy Sci.*, 80: 2784–2789.

Doležal, O., Černá, D, Knížek, J. 2002. Komfortní ustájení vysokoprodukčních dojnic (Comfortable environment of high yielding cows). Prague, VÚŽV Prague.

Dorzh, B. 1985. Effect of artificial radiation and lighting on the reactivity of calves. Moscow Veterinary Academy № 145–85, Pp. 8.

Filippova, L.A. 1988. Adaptation of cows to various types of stress resistance. Physiological and biochemical background of the realisation of the genetic potential for milk – proceedings of scientific works, Pp. 13–20.

Hansen, P.J., Kamwanja, L.A., Hauser, E.R. 1983. Photoperiod influences age at puberty of heifers. *J. Anim. Sci.*, 57: 985–992.

Hayes, A.W. 2007. Principles and methods of toxicology, 5th edn. Informa Healthcare, New York, Pp. 1070–1071.

Illnerova, H., Sumova, A. 1997. Photic entrainment of the mammalian rhythm in melatonin production. *J. Biol. Rhythms*, 12: 547–555.

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

Kokorina, E.P. 1988. Effect of the nervous system type on the realisation of the genetic potential for milk – proceedings of scientific works. Pp. 6–13.

Koprowski, J.A., Tucker, H.A. 1973. Serum prolactin during various physiological states and its relationship to milking production in the bovine. *Endocrinology*, 92(5): 1480–1487.

Mačuhova, J., Bruckmaier, R.M. 2004. Diurnal changes of oxytocin release during automatic milking. In: Meijering, A., Hogeveen, H., de Koning, C.J.A.M. (Eds). Automatic Milking – A Better Understanding. Wageningen Academic Publishers, Wageningen, The Netherlands, 502 Pp.

Mitev, Y. 2012. Contemporary aspects of welfare in dairy cattle farms, Stara Zagora. 280 Pp.

Miteva, Ch. 2012. Hygienic aspects of free-range production systems for dairy cows. Monograph, Academic Publishing House of the Trakia University.

Mossberg, I., Jonsson, H. 1996. The influence of day length and temperature on food intake and growth rate of bulls given concentrate or grass silage ad libitum in two housing systems. *Anim. Sci.*, 62: 233–240.

Ordinance No. 44/20.04.2006 for veterinary medical requirements to animal rearing facilities.

Pavlenya, V., Plyago, D., Kachko, A., Yakubovich, A., Funt, N. 1991. Lighting regimens in premises for sows and piglets. Scientific background of the development of livestock husbandry in the Belarus Soviet Republis, 71–9294: 228–231.

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. *J. Dairy Sci.*, 64: 1671–1678.

Peters, R.R., Tucker, H.A. 1978. Prolactin and growth hormone responses to photoperiod in heifers. *Endocrinology*, 103(1): 229–234.

Petitclerc, D., Chapin, L.T., Emery, R.S., Tucker, H.A. 1983. Body growth, growth hormone, prolactin and puberty response to photoperiod and plane of nutrition in Holstein heifers. *J. Anim. Sci.*, 57: 892–898.

Petitclerc, D., Chapin, L.T., Tucker, H.A. 1984. Carcass composition and mammary development responses to photoperiod and plane of nutrition in Holstein heifers. *J. Anim. Sci.*, 58: 913–919.

Petitclerc, D., Vinet, C., Roy, G., Lacasse, P. 1998. Prepartum photoperiod and melatonin feeding on milk production and prolactin concentrations of dairy heifers and cows. *J. Dairy Sci.*, 81(Suppl. 1): 251.

Petkov, A., Enev, E., Sivkova, K., Varlyakov, I. 2000. Textbook of animal physiology.

Petrusha, E.Z., Gavrilov, P.V., Lisichenko, N.L. 1987. Effect of increased artificial light level on health and productivity of cows. *Milk Meat Cattle Husbandry*, 70: 10–13.

Phillips, C., Weiguo, L. 1991. Brightness discrimination abilities of calves relative to those of humans. *Appl. Anim. Behaviour Sci.,* 31(1): 25–33.

Phillips, C.J.C. 1993. Cattle behaviour. Farming press books. Wharfdale Rd. Ipswich, UK.

Phillips, C.J.C., Lomas, C.A., Arab, T.M. 1998. Differential response of dairy cows to supplementary light during increasing or decreasing daylength. *Anim. Sci.,* 66: 55–63.

Phillips, C.J.C., Schofield, S.A. 1989. The effect of supplementary light on the production and behaviour of dairy cows. *Anim. Product.,* 48: 293–303.

Plyashtenko, S., Leonova, I. 1977. Effect of different light regimen on young cattle in windowless premises. *Agric. Biol.,* 12(1): 90–94.

Rautala, H. 1991. Fertility in Finnish dairy cattle. Impact on milk production, variation according to cow and environmental factors and characterization of fertility problem cows. Academic dissertation from Department of Animal Hygiene, College of Veterinary Medicine, Helsinki, Finland, 95 Pp.

Rendic, S. 2002. Summary of information on human CYP emzymes: Human P450 metabolism data. Drug Metabolism Reviews. New York, Informa Healthcare, 1–2: 83–448.

Rieter, R.J. 1980. The pineal and its hormones in the control of reproduction in mammals. *Endocrine Rev.,* 1: 109–131.

Rieter, R.J. 1991. Pineal melatonin, cell biology of its synthesis and of its physiological interactions. Endocrine Rev., 12: 151–180.

Rist, M., Berthound, A., Heusser, H. 1974. Über Belischtung und Beleuchtung in Ställen, under besonderer Berücksichtigung der Belichtuhgsverhältnisse in neueren schweizerischen Rindvichställen.

Simonova, N.P. 1984. Effect of various light levels on physiological and production traits of cows. Livestock Husbandry in the Transbaikal and Amur regions. Blagoveshtensk, Pp. 18–22.

Šístková, M., Peterka, A., Peterka, B. 2010. Light and noise conditions of buildings for breeding dairy cows. *Res. Agric. Eng.,* 56(3): 92–98.

Small, J.A., Glover, N.D., Kennedy, A.D., McCaughey, W.P., Ward, D.R. 2003. Photoperiod effects on the development of beef heifers. *Can. J. Anim. Sci.,* 83(4): 721–730.

Šoch, M. 2005. Vliv prostředí na vybrané ukazatele pohody skotu (Effect of environment on selected indices of cattle welfare). České Budějovice, JU ZF ČB, Pp. 82–83.

Somparn, P., Gibb, M.J., Markvichitr, K., Chaiyabutr, N., Thummabood, S., Vajrabukka, C. 2007. Effect of supplementary lighting on eating behaviour by corralled swamp buffalo (*Bubalus bubalis*) heifers in Thailand. *Songklanakarin J. Sci. Technol.,* 29(2): 399–411.

Stanisiewski, E.P., Mellenberger, R.W., Anderson, C.R., Tucker, H.A. 1985. Effect of photoperiod on milk yield and milk fat in commercial dairy herds. *J. Dairy Sci.,* 68: 1134–1140.

Tanida, H., Swanson, L.W., Hohenboken, W.D. 1984. Effect of Artificial photoperiod on eating behavior and other behavioral observations of dairy cows. *J. Dairy Sci.,* 67: 585–591.

Tihomirova, L., Kolchin, P. 1978. Effect of light regimen on cows and calves. *Veterinaria,* (5): 30–32.

Todorov, N., Mitev, Y. 2000. Unpublished data.

Ulimbashev, M. 2011. More light – more milk (effect of lightning of barns on milk production of cows). Animal Husbandry in Russia, N. 9 - C. 51.

Ustinov, D., Nechiporuk, L. 1970. Rays on Animal Farms. Kolos Publishing House, Moscow.

Uvnäs-Moberg, K., Petersson, M. 2005. Oxytocin, a Mediator of Anti-stress, Well-being, Social Interaction, Growth and Healing. *Z. Psychosom Med. Psychother.*, 51(1): 57–80.

Varlyakov, I. 1991. A study on the eating behaviour of lactating cows by a recording apparatus. Proceedings of the 7th International Congres on Animal Hygiene, Leipzig. Germany. 20–24 August 1991, Vol. III, Pp. 1101–1106.

Varlyakov, I. 1999. Cattle Behaviour. In: Animal Behaviour. Book of Ethology. KOTA, Stara Zagora, Pp. 59–90.

Varlyakov, I., Dinev, D., Radev, V., Slavov, T. 2007. Ethological evaluation of large measured building for dairy cows reared in individual cubicles. *Trakia J. Sci.,* 5(1): 52–58.

Varlyakov, I., Radev, V., Slavov, T., Grigorova, N. 2010a. Ethological evaluation of a building for free housing of dairy cows. I. Behavioral activities in the summer. *Trakia J. Sci.,* 8(Suppl.1): 222–229.

Varlyakov, I., Slavov, T., Grigorova, N. 2010b. Ethological evaluation of a building for free housing of dairy cows. II. Behavioural activities in the winter. *Agric. Sci. Technol.,* 2(1): 14–21.

Varlyakov, I., Tosev, A. Sivkova. K. 1993. Ethological assessment of free-range cattle production system on deep permanent litter. I. Feeding behaviour, rest, locomotion. *Anim. Sci. (Sofia),* 7: 10–16.

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

Wall, E.H., Auchtung, T.L., Dahl, G.E., Ellis, S.E., McFadden, T.B. 2005. Exposure to short day photoperiod during the dry period enhances mammary growth in dairy cows. *J. Dairy Sci.,* 88: 1994–2003.

West, K.E., Jablonski, M.R., Warfield, B., Cecil, K.S., James, M., Ayers, M.A., Maida, J., Bowen, C., Sliney, D.H., Rollag, M.D., Hanifin, J.P., Brainard, G.C. 2011. Blue light from light-emitting diodes elicits a dose-dependent suppression of melatonin in humans. *J. Appl. Physiol.,* 110(3): 619–626.

Wright, J., Shelford, T. 2013. Light spectrum and its implications on milk production. Dairy business, Pp. 27–28.

Yeates, N.T.M. 1955. Photoperiodicity in cattle. I. Seasonal changes in coat character and their importance in heat regulation. *Aust. J. Agric. Res.,* 6(6): 891–902.

Yurkov, V. 1980. Effect of lighting on animal productivity. Rosselhozizdat, Moscow.

Zinn, S.A., Purchas, R.W., Chapin, L.T., Petitclerc, D., Merkel, R.A., Bergen, W.G., Tucker, H.A. 1986. Effects of photoperiod on growth, carcass composition, prolactin, growth hormone and cortisol in prepubertal and postpubertal Holstein heifers. *J. Anim. Sci.,* 63: 1804–1815.