Original scientific paper
Journal of Central European Agriculture, 2023, 24(4), p.845-854

DOI: /10.5513/JCEA01/24.4.4027

Association of light intensity with semen parameters in Duroc boars

Vliv intensity světla na parametry spermatu kanců plemene duroc

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Received: July 7, 2023; accepted: September 29, 2023

ABSTRACT

This study aimed to investigate whether the intensity of lighting may affect Duroc boars' semen parameters in different seasons and in different periods from the beginning of the use of boars for semen collection. A total of 6879 ejaculates were collected from 21 boars and kept under natural low light intensity and daylight length conditions, and 3141 ejaculates from 10 boars were kept under high light intensity (190-210 lx) and natural daylight length conditions. Experimental groups were divided according to the intensity of lighting (low, high), season (winter, spring, summer, fall), and the period from the beginning of the use of boars for semen collection (0-1 year, 1.1-2 years, 2.1-3 years). Selected parameters were analyzed: semen volume, sperm concentration, total number of sperms, sperm motility, percentage of sperms with an abnormal morphology and number of insemination doses from one ejaculate. Semen volume, sperm concentration, and rate of sperms with an abnormal morphology were associated with the two-way interaction between light intensity and season ($P < 0.0001$), and between light intensity and period from the first semen collection ($P < 0.0001$). The total number of sperms and number of insemination doses from one ejaculate were associated with the two-way interaction between light intensity and season ($P < 0.0001$). Sperm motility was associated with the two-way interaction between light intensity and season ($P < 0.0001$), and between light intensity and period from the first semen collection ($P < 0.01$). In conclusion, the intensity of lighting can affect Duroc boars' semen parameters in different seasons and different periods from the beginning of the use of boars for semen collection.

Keywords: boar, light, season, semen volume, sperm concentration, total number of sperms, sperm motility, abnormal sperm

ABSTRAKT

Cílem práce bylo zjistit, zda intenzita osvětlení, roční období a doba od zařazení kanců do skupiny pro odběr spermatu může ovlivnit parametry spermatu kanců plemene duroc. Celkem bylo odebráno 6879 ejakulátů od 21 kanců, kteří byli chováni v podmínkách přirozené nízké intenzity osvětlení a délky denního světla a 3141 ejakulátů od 10 kanců, kteří byli chováni v podmínkách vysoké intenzity světla (190-210 lx) a přirozené délky denního světla. Experimentální skupiny byly rozděleny podle: intenzity osvětlení (nízká, vysoká), ročního období (zima, jaro, léto, podzim) a období, od začátku používání kanců k odběru spermatu (0-1 rok, 1,1-2 roky, 2,1-3 roky). Byly analyzovány vybrané parametry:

objem spermatu, koncentrace spermií, celkový počet spermií, pohyblivost spermií, procento spermií s abnormální morfologií a počet inseminačních dávek z jednoho ejakulátu. Objem spermatu, koncentrace spermií a procento spermií s abnormální morfologií byly spojeny s obousměrnou interakcí mezi intenzitou světla a ročním obdobím (P < 0.0001) a mezi intenzitou světla a obdobím od prvního odběru spermatu (P < 0.0001). Celkový počet spermií a počet inseminačních dávek z jednoho ejakulátu byly spojeny s obousměrnou interakcí mezi intenzitou světla a ročním obdobím (P < 0.0001). Pohyblivost spermií byla spojena s obousměrnou interakcí mezi intenzitou světla a ročním obdobím (P < 0.0001) a mezi intenzitou světla a periodou, od prvního odběru spermatu (P < 0.01). Závěrem lze říci, že intenzita osvětlení může ovlivnit parametry spermatu kanců duroc v různých ročních obdobích a v různých obdobích, od začátku používání kanců pro odběr spermatu.

Klíčová slova: kanec, osvětlení, sezóna, objem spermatu, koncentrace spermií, celkový počet spermií, pohyblivost spermií, abnormální spermie

INTRODUCTION

Boar semen quality is influenced by many factors, such as season, age, and breed (Ciereszko et al., 2000; Knecht et al., 2013). Among these factors, seasonal variations have been shown to be one of the most noticeable factors that affect boar semen quality (Zasiadczyk et al., 2015). Reproductive seasonality in the boar is a trait inherited from its ancestor, the European wild boar (Sus scrofa ferus), whose breeding activity occurs in the late winter and early spring, whereas reproductive inactivity is in the summer and early fall (Kozdrowski and Dubiel, 2004). Reproductive performance is not only associated with the duration of the photoperiod but also with the photophase light intensity (Kunavongkrit et al., 2005). The hormone melatonin is synthesized and secreted during the night (Lu et al., 2022). If the intensity and duration of light are above a specific threshold melatonin production or concentration may be inhibited (Andersson, 2000, Tast et al., 2001). Pigs can distinguish the day when the photo phase light intensity reaches 40 lx, and the scotophase is less than 1 lx. At a threshold light intensity of <40 lx, photophase light intensity would not affect the scotophase melatonin response (Tast et al., 2001). Short light length positively influences pubertal maturation of spermatogenesis (Andersson, 2000). Kunavongkrit et al. (2005) indicate that fertility can be affected by day length in temperate zones. This is evident in sows served after the summer solstice because the regular drop-in herd fertility is usually noticed in September and October under natural lighting conditions. Local weather conditions such as cloud cover or bright sunshine can enhance or reduce fertility. Photoperiod stimulates feed intake, which correlates with reproductive performance (Stevenson et al., 1983). Factors that affect fertility can be associated with the environment (cooling or heating), humidity and nutrition, so it is advisable to adjust the daily feeding time (Kunavongkrit et al., 1989). The development of artificial insemination (AI) changed the housing and management of commercial boars in AI studs (Knox, 2016). The breeding farms are designed to control the environment and management systems to optimize the health and fertility of the boars. Boars require housing facilities where microclimate parameters can be maintained within optimal limits throughout the year (Knecht et al., 2013).

Until now, the effect of various light intensities on semen parameters has only been examined in turkeys and rabbits, but not in boars. Light treatment did not affect sperm concentration in turkeys but influenced semen volumes and the number of sperms per ejaculate (Cecil, 1986). In rabbits, semen volume was not affected by a higher intensity of lighting (Besenfelder et al., 2004). This study aimed to examine whether the intensity of lighting may affect Duroc boars' semen parameters in different seasons and different periods from the beginning of the use of boars for semen collection.

MATERIAL AND METHODS

Study location and design

The experiment occurred at a boar farm in the southwest Czech Republic at a latitude of 490 North.

The study was conducted at the Boar Exploitation Station in a temperate climate zone and included 10020 ejaculates obtained from 31 Duroc boars over three years. Experimental groups were divided according to the intensity of lighting (low, high), season (winter, spring, summer, fall), and the period from the beginning of the use of boars for semen collection (0-1 year, 1.1-2 years, 2.1-3 years), without monitoring their body weight.

Boars were kept in individual pens with a concrete floor. The individual pen area was 10 m^2/boar. The microclimate of the pen was adapted to the requirements of the animals in accordance with welfare principles. The temperature in the shed ranged between 17 and 24 °C, with the humidity being approximately 60%. This building was equipped with an additional ventilation system. The air circulation inside the building was equal to 0.15 m/s in winter and 0.20 m/s in the summer.

At nine months of age, after undergoing training for semen collection, boars were randomly allocated to two different groups. The first group (21 boars) was kept under standard farming conditions, with a natural low light intensity of 45-65 lx and natural daylight length. The second group (10 boars) was kept under an artificial lighting system with a high light intensity of 190-210 lx and corresponding daylight length. Dawning was gradual, with the rise of one hour. Ceiling-mounted light fixtures (two cool white fluorescent tubes/fixtures suspended 2.4 m above the floor of each pen) were controlled by an automatic timer in the group with high light intensity. They provided the length of illumination equal to the natural daylight length. Light intensity was measured with a photoelectric light meter that ranged between 0 and 500 lx. The measurements were carried out in the central part of a pen with the sensor directed in six planes perpendicular to each other. An arithmetic mean was calculated from the results of the six exposures at a given point.

The ejaculate collection from the boars began at the age of 9 months. The study included 6879 ejaculates from 21 boars kept under natural low light intensity and 3141 ejaculates from 10 boars kept under high light intensity. Selected quantitative and qualitative parameters were analyzed and calculated: semen volume (ml), sperm concentration (x 10^6/ml), the total number of sperms (x 10^9), the percentage of motile sperms, the percentage of abnormal sperms, and number of insemination doses from one ejaculate.

Semen was regularly collected (twice a week) from boars via the manual method (King and Macpherson, 1973), using a container with a filter. Only sperm-rich fractions were analyzed. The gelatinous fraction was separated using a special filter. Collections were made in almost homogenous terms during the season. Immediately after collection, semen volume was measured using a scalar cylinder. The concentration of sperms was evaluated using a SpermaCue device, Model 12300/0500, Minitube International, Verona, USA. Based on the semen volume and sperm concentration, the total number of sperms in the ejaculate was calculated and expressed as 10^9 sperms per ejaculate. In native semen, the percentage of motile sperms was determined microscopically, and the proportion of abnormal sperms as a percentage (sperms deformed or otherwise changed) was also evaluated microscopically.

Statistical evaluation

Statistical analyses were performed using the SAS software (SAS Institute Inc., Cary, NC, USA). The effects on semen parameters were analyzed using the mixed model procedure (Littell et al., 2006). Two-way interactions were examined: season (winter, spring, summer, fall) x the intensity of lighting (low, high) and the period from the beginning of the use of boars for semen collection (0-1 year, 1.1-2 years, 2.1-3 years) x the intensity of lighting (low, high). The statistical models used for semen volume, sperm concentration, and percentage of sperms with an abnormal morphology were as follows:

$$M = \mu + S_a + L_{ab} + P_{abc} + Interactions_{ab} + Interactions_{bc} + \varepsilon_{abc}$$

where M represents the observed semen volume, sperm concentration, or percentage of sperms with abnormal morphology, and the mean is represented by μ. S represents the fixed class effect of season (winter, spring, summer, fall). *L* represents the fixed class effect of the lighting intensity (low, high). *P* represents the fixed class effect of the period from the beginning of the use of boars for semen collection (0-1 year, 1.1-2 years, 2.1-3 years). $Interactions_{ab}$ and $interactions_{cd}$ are presented as significant effects from Season × Intensity of lighting + effect of the Period from the beginning of using boars for semen collection × Intensity of lighting. The models included the random boar effect and random residual effect. Only interactions with a significance level of $P < 0.05$ were left in the models.

RESULTS

Factors affecting sperm parameters

Semen volume, sperm concentration, and percentage of sperms with an abnormal morphology were associated with the two-way interaction between light intensity and season ($P < 0.0001$) and between light intensity and period from the first semen collection ($P < 0.0001$). The total number of sperms and number of insemination doses from one ejaculate were associated with the two-way interaction between light intensity and season ($P < 0.0001$). Sperm motility was associated with the two-way interaction between light intensity and season ($P < 0.0001$) and between light intensity and period from the first semen collection ($P < 0.01$).

Effect of season on sperm parameters of boars housed under two light intensities

Semen volume was lower (A: $P < 0.0001$) under the low light intensity than the high light intensity in all four seasons (Figure 1). Under the low light intensity, the semen volume was higher in the fall than in other periods of the year ($P < 0.0001$) and in the winter compared with the spring and summer ($P < 0.05$). Under the high light intensity, the semen volume was higher in the fall than in other periods of the year ($P < 0.01$).

The sperm concentration was higher (a: $P < 0.0001$) under the low light intensity than the high light intensity in all four seasons (Figure 2). Under the low light intensity, the sperm concentration was higher in the winter and spring compared with the summer and fall (L: $P < 0.0001$). Under the high light intensity, the sperm concentration was higher in the winter compared with other periods of the year ($P < 0.001$) and in the spring compared with the fall ($P < 0.001$).

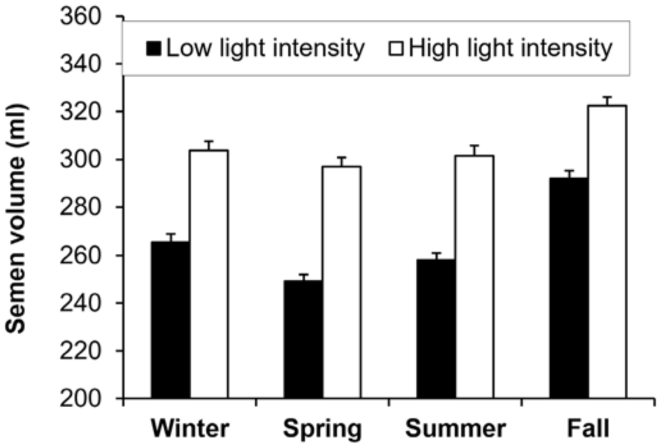

Figure 1. Semen volume (mean ± SEM) in Duroc boars kept under low and high light intensities in different seasons of the year

The total number of sperms was lower ($P < 0.01$) under the low light intensity than the high light intensity in the summer. It was not significantly different in other periods of the year (Figure 3). Under the low light intensity, the total number of sperms was lower in the summer than in other periods of the year ($P < 0.001$) and lower in the spring compared with winter ($P < 0.0001$). Under the high light intensity, the total number of sperms was lower in the spring and summer than in winter ($P < 0.05$).

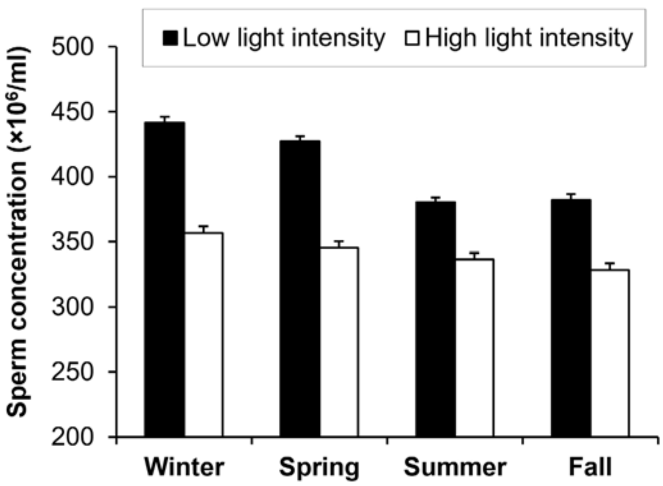

Figure 2. Sperm concentration (mean ± SEM) in Duroc boars kept under low and high light intensities in different seasons of the year

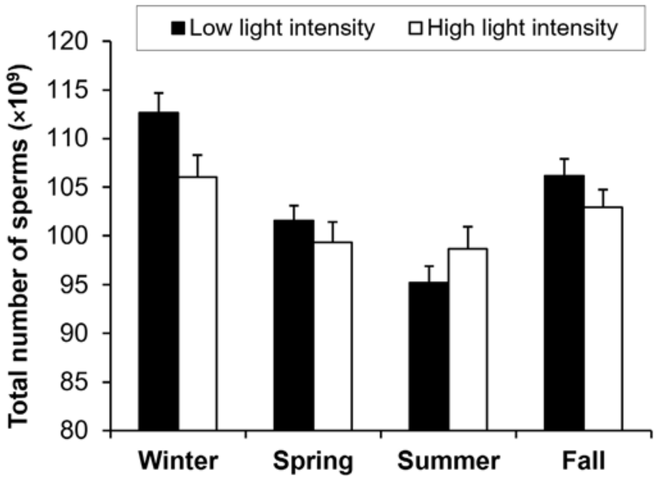

Figure 3. Total number of sperms (mean ± SEM) in Duroc boars kept under low and high light intensities in different seasons of the year

Sperm motility was not significantly different under the low light intensity compared with the high light intensity in all four seasons (Figure 4). Under the low light intensity, the sperm motility was higher ($P < 0.001$) in the spring compared with the summer and fall. Under the high light intensity, sperm motility was higher in spring than in summer and fall ($P < 0.01$).

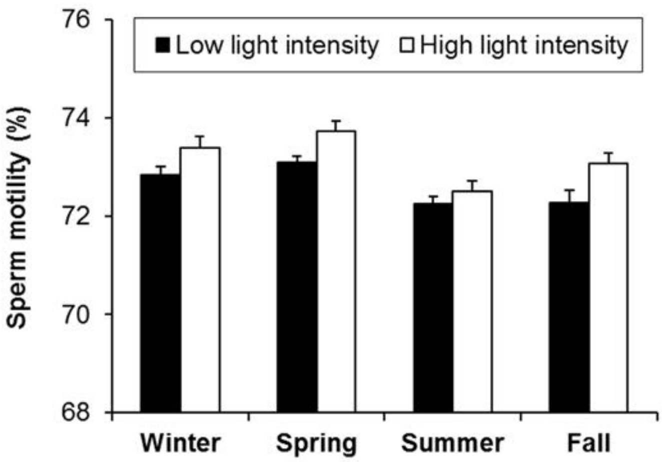

Figure 4. Sperm motility (mean ± SEM) in Duroc boars kept under low and high light intensities in different seasons of the year

The percentage of sperms with an abnormal morphology was lower ($P < 0.01$) under the low light intensity than the high light intensity in all four seasons (Figure 5). Under the low light intensity, the percentage of sperms with an abnormal morphology was higher in the fall than in the winter ($P < 0.0001$). Under the high light intensity, the rate of sperms with an abnormal morphology was higher in the winter ($P < 0.0001$) and fall ($P < 0.0001$) compared with the spring and summer.

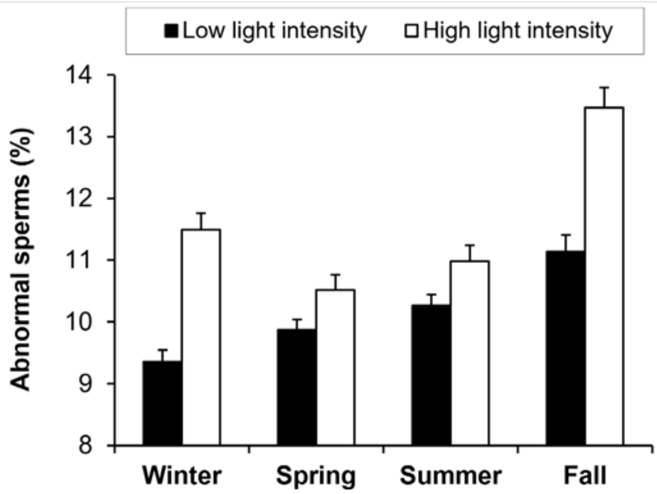

Figure 5. Sperm with abnormal morphology (mean ± SEM) in Duroc boars kept under low and high light intensities in different seasons of the year

Under the low light intensity (Table 1), the average number of insemination doses from one ejaculate was lower in the summer than in other periods of the year ($P < 0.001$) and lower in the spring compared with winter ($P < 0.001$). Under the high light intensity, the average number of insemination doses from one ejaculation was lower in the summer than in winter ($P < 0.05$).

Effect of the period from the beginning of the use of boars for semen collection on their sperm parameters when they were housed under two light intensities

Semen volume was lower ($P < 0.0001$) under the low light intensity than the high light intensity in all three years from the first semen collection (Figure 6). Under low light intensity, the semen volume gradually increased from the first to the third year of the first semen collection ($P < 0.0001$). Under the high light intensity, the semen volume increased from the first to the second year of the first semen collection ($P < 0.0001$). It was not significantly different among the second and third years from the first semen collection.

Table 1. The average number of insemination doses from one ejaculate in Duroc boars kept under low and high light intensities in different seasons of the year

Light intensity	Winter	Spring	Summer	Fall
Low	49,58	44,60	41,15	45,44
High	45,92	43,67	42,46	43,37

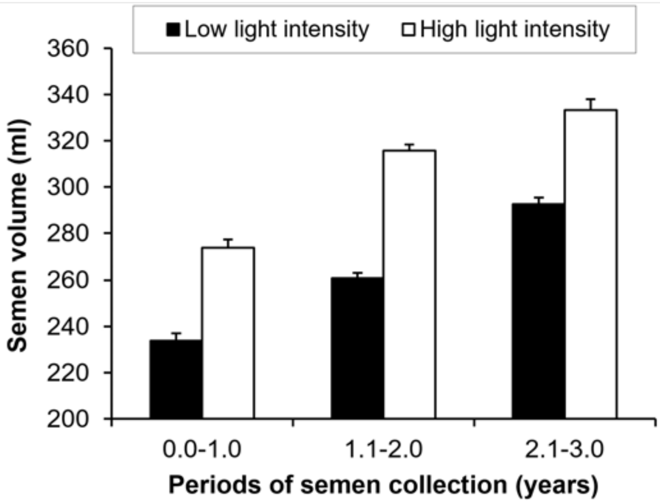

Figure 6. Semen volume (mean ± SEM) in Duroc boars kept under low and high light intensities in different periods from the first semen collection

The sperm concentration was higher ($P < 0.0001$) under the low light intensity than the high light intensity in all three years from the first semen collection (Figure 7).

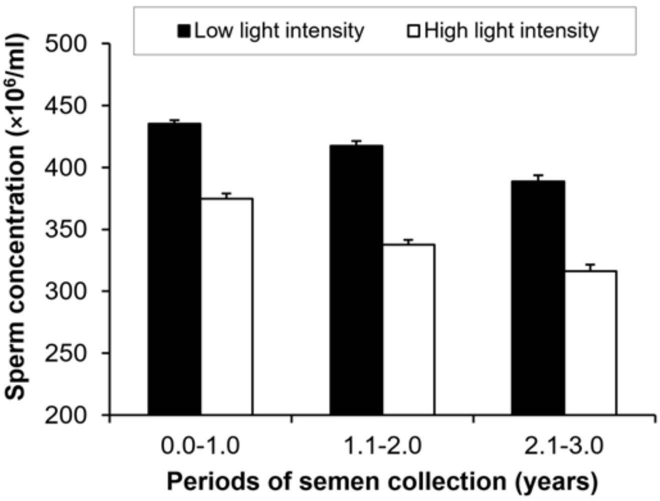

Figure 7. Sperm concentration (mean ± SEM) in Duroc boars kept under low and high light intensities in different periods from the first semen collection

Under low light intensity, the sperm concentration gradually decreased from the first to the third year of the first semen collection ($P < 0.0001$). Under the high light intensity, the sperm concentration steadily reduced from the first to the third year of the first semen collection ($P < 0.001$).

The total number of sperms under the low light intensity and high light intensity was not significantly different in all three periods from the first semen collection (Figure 8).

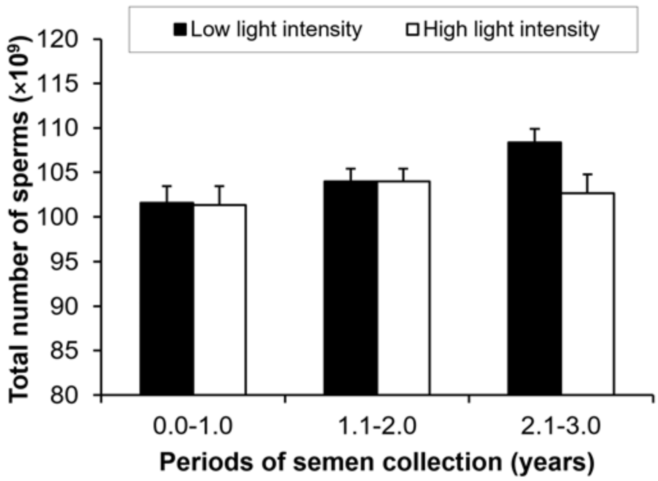

Figure 8. A total number of sperms (mean ± SEM) in Duroc boars kept under low and high light intensities in different periods from the first semen collection

Sperm motility was not significantly different under the low light intensity compared with the high light intensity in the first and second years of the first semen collection and was lower in the third year from the first semen collection ($P < 0.01$) (Figure 9). Under the low light intensity; the sperm motility decreased from the first to the second year from the first semen collection ($P < 0.01$). Under the high light intensity, sperm motility decreased from the first to the second year from the first semen collection ($P < 0.01$) and increased during the third year from the first semen collection ($P < 0.01$).

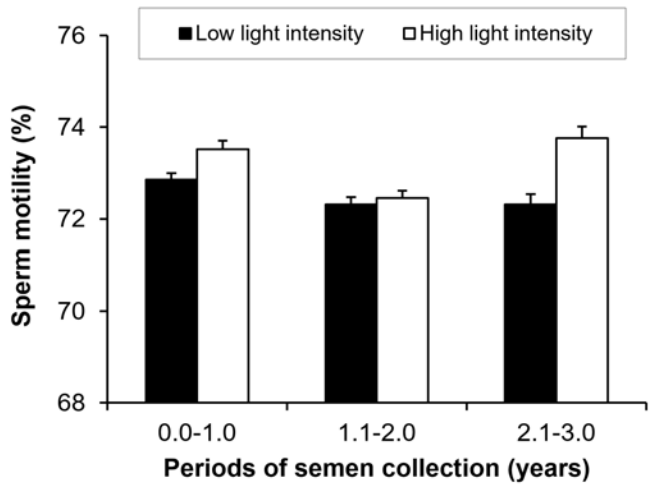

Figure 9. Sperm motility (mean ± SEM) in Duroc boars kept under low and high light intensities in different periods from the first semen collection

The percentage of sperms with an abnormal morphology was lower ($P < 0.05$) under the low light intensity than the high light intensity from the second to the third year of the first semen collection (Figure 10).

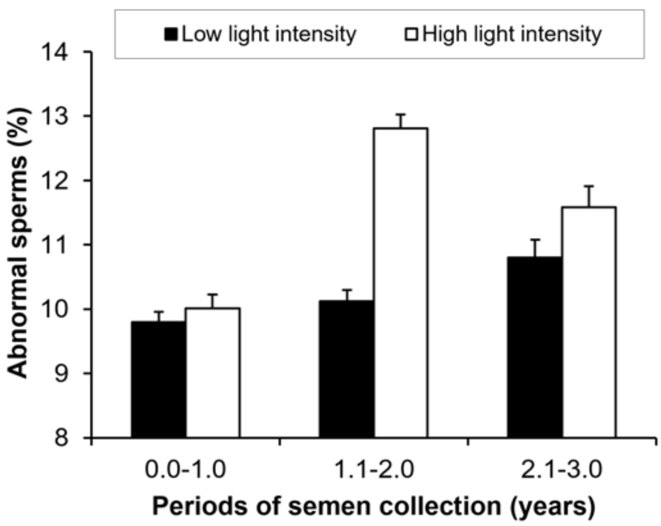

Figure 10. Sperm with abnormal morphology (mean ± SEM) in Duroc boars kept under low and high light intensities in different periods from the first semen collection

Under low light intensity, the percentage of sperms with an abnormal morphology gradually increased from the first to the third year of the first semen collection ($P < 0.0001$). Under the high light intensity, the percentage of sperms with an abnormal morphology was lower in the first year compared to other years from the first semen collection ($P < 0.0001$) and higher during the second year compared to the third year from the first semen collection ($P < 0.01$).

The number of insemination doses from one ejaculate under the low light intensity and high light intensity was not significantly different in all three periods from the first semen collection.

Table 2. The average number of insemination doses from one ejaculate in Duroc boars kept under low and high light intensities in different periods from the first semen collection

	Periods from the first semen collection (years)		
Light intensity	0–1,0	1,1-2	2,1-3
Low	48,63	48,86	50,53
High	49,28	47,59	49,38

DISCUSSION

The total number of sperms was not significantly different between these two light intensities during the year, except for the summer when it was higher at the high light intensity. In all four seasons, the semen volume was higher, whereas the sperm concentration was lower when boars were exposed to the high light intensity than the low light intensity. This suggests that in the summer in a temperate zone, the high light intensity in boars stimulates the production of seminal plasma by accessory glands and sperm production by seminiferous tubules. Still, in other seasons, only the production of seminal plasma is stimulated. The effects of supplementary lighting on hormonal and fertility indicators in developing and adult boars have been reported. Additional lighting can contribute to earlier sexual maturity and thus to the first collection of sperm at a younger age of boars (Colenbrander and Kemp, 1990). The opinion on the effect of supplementary lighting on adult boars' reproductive functions appears inconsistent. Short-day length increased total sperm output, which differed from boars exposed to a long-day length (Sancho et al., 2004; Rivera et al., 2005). Published works presented the results of experiments with an increase in the number of sperms in ejaculate, libido, and hormone production in boars with a reversed lighting regimen. Experimental boars were bred in conditions with an increased intensity of light in the fall and a decrease of light in the spring. These studies suggest that the change in the photoperiod during the summer and fall may be the main cause of seasonality and, in modern swine breeds, is likely related to a genetic vestige of the European wild boar, a seasonal breeder (Bertoldo et al., 2012). Semen volume, sperm concentration, and the total number of sperms under both light intensities displayed seasonal changes. However, the annual pattern of all three parameters was not parallel. Under both light intensities, semen volume was highest in the fall, and sperm concentration and the total number of sperms were highest in the winter; semen volume was lowest in the spring, the total number of sperms was lowest in the summer, and sperm concentration was lowest in the fall. Seasonal changes in semen parameters under natural light were also reported by Smital (2009) and Fraser et al. (2016). When exposed to continuous light, the semen volume of boars increased at first but then decreased in the third month of exposure, whereas absolute darkness did not affect this variable (Sancho et al., 2006). Their findings also showed that light affects the overall accessory sex gland production much more than the composition of the secretions. At the low light intensity, the total number of sperms decreased from the winter to the summer and increased in the fall. Similar changes in the total number of sperms were reported by Smital (2010) in boars housed under natural light. Since pigs are distinctly seasonal breeders, seasonal mechanisms of wild ancestors likely still influence semen characteristics of boars, especially semen volume and the number of sperms in the ejaculate (Ciereszko et al., 2000). Compared to the low light intensity, the high light intensity in our study reduced the seasonal changes in semen volume, sperm concentration, and the total number of sperms. Consistent with seasonal changes, semen volume in all three years from the first semen collection was higher. In contrast, sperm concentration was lower when boars were exposed to the high light intensity than the low light intensity. However, the total number of sperms did not differ between these two light intensities in any of all three years of semen collection. This shows that the high light intensity affected the production of seminal plasma by accessory glands but not sperm production by seminiferous tubules in all three years of semen collection. Semen volume increased from the first to the third year of semen collection for the low light intensity and from the first to the second year of semen collection for the high light intensity. In contrast, sperm concentration decreased during all three years from the first semen collection for both light intensities. This suggests that earlier exposure of boars to high light intensity ended the increase in semen volume but not the decrease in sperm concentration. The increase in semen volume with the increase in boar age was consistent with studies under natural light (Wolf and Smital, 2009; Kondracki et al., 2013). The total number of sperms in boars exposed to low and high light intensities was highest in the second and third years of the first semen collection, respectively. Consistently, boar sperm production under natural light tended to increase up to an age of 2.5 years (Knecht et al., 2017), 3 years (Huang et al., 2010) and 3.5 years (Smital, 2010). The growth of sperm production capacity dependent on age may be connected with boars' increasing live weight and testicular weight during their development (Wolf and Smital, 2009). Sperm motility was not significantly different between boars exposed to low or high light intensities in all seasons. Under both light intensities, sperm motility decreased in the summer and fall. Reduced sperm motility in these seasons was also reported in boars housed under natural light (Murase et al., 2007; Ibanescu et al., 2018). This coincides with reduced fertility occurring during the summer months and in early autumn in gilts and sows (Kraeling and Webel, 2015). Age-related changes in semen volume, sperm concentration, and the total number of sperm were not accompanied by alterations in sperm motility. This shows that sperm motility does not undergo parallel age-related changes with these parameters of the boar ejaculate. The occurrence of sperms with an abnormal morphology was increased in boars exposed to the high light intensity compared with the low light intensity in all four seasons. This shows that the high light intensity may deteriorate this parameter of sperm quality. It is possible to consider that high-intensity lighting has a stressful effect. Under the low light intensity, the percentage of sperms with an abnormal morphology increased from the winter to the fall, while under the high light intensity, the percentage of sperms with an abnormal morphology was higher in the winter and fall than in the spring and summer. Murase et al. (2007) found that the highest percentage of sperms with an abnormal morphology was in August–September. Sancho et al. (2004) reported that the frequency of immature and aberrant sperms was similar under increasing and decreasing photoperiods. The above shows that the effects of season on sperm abnormal morphology in boars are still controversial among authors (Argenti et al., 2018; Schulze et al., 2014; Suriyasomboon et al., 2005), despite the marked seasonal oscillations in serum hormones (Trudeau and Sanford, 1986, 1990). The percentage of sperms with an abnormal morphology was higher at the high light intensity than at the low light intensity from the second to the third year of the first semen collection. This suggests that the high light intensity may deteriorate this parameter of sperm quality in older boars, while in the youngest boars, it has no effect.

CONCLUSION

In conclusion, light intensity inversely affected semen volume and sperm concentration. A high intensity increased semen volume and decreased sperm concentration over the year and in all age groups of boars. The light intensity did not affect the total number of sperms, except in the summer, when the high light intensity increased this parameter. Simultaneously, this intensity increased the number of abnormal sperms in all age groups except for the youngest boars. The lowest numbers of seminal doses were obtained from ejaculates of boars collected in summer in natural light conditions. The number of insemination doses from one ejaculation in Duroc boars kept under the high light intensity fluctuated less during the year, which is advantageous from a commercial point of view.

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