THE SCIENCE OF SWINE VISION

LED Lighting Programs for Enhancement of Swine Performance

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ABSTRACT:

Light is a key environmental factor that influences and directs physiological processes in all animals. In domestic boars, research has shown that there is seasonality in sperm production related to the light in the animal's environment. Light exposure mediates the level of melatonin secretion, which ultimately affects the quality and quantity of the boar's reproductive products.

Past research on pig photosensitivity and boar performance under different lighting treatments has provided us with rudimentary background information on lighting programs for AI units, but the results of many of these studies are limited in their application.

However, because of newly developed LED technologies, more comprehensive lighting programs are now possible for farmed animals. More specifically, LED light programs can be created for boar holding units that incorporate, modulate and synchronize the three characteristics of light (intensity, wavelength and duration).

The following article is a review of the research that supports the use of comprehensive lighting programs in the swine industry, particularly in boar-holding facilities.

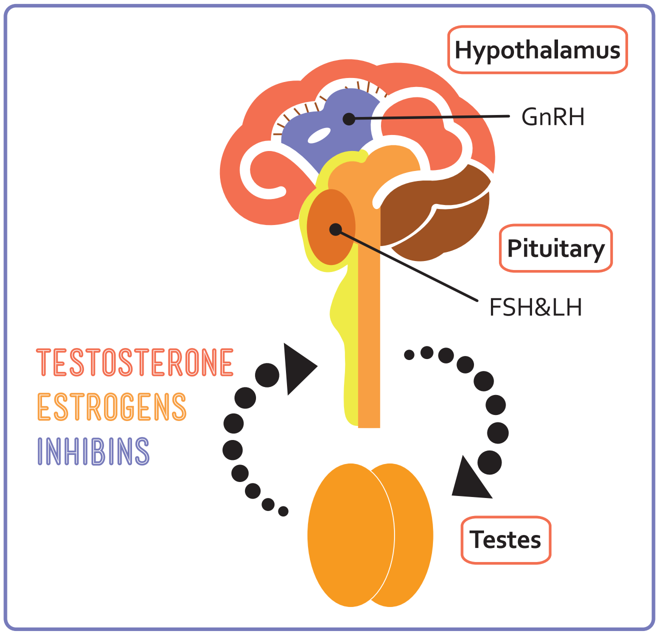
IMPORTANCE OF ARTIFICIAL LIGHTING PROGRAMS IN BOAR HOLDING UNITS

Environmental lighting affects a boar's biological clock and therefore has an influence on boar physiology. Specifically, it has been found that lighting affects seasonality in the production of domestic boar semen (Andersson et al., 1998; Claus et al., 1985; Tast et al. 2001a). The presence of this seasonality is somewhat surprising since domestic boars, different from their ancestors, breed and sire offspring all year round (Andersson, 2000; Smital, 2009) and are held in light-tight holding units.

In swine farming overall, temperature and light are viewed as major environmental factors affecting animal physiology (Andersson et al., 1998; Rivera et al., 2005) with temperature being considered the most important factor. However, when temperature is kept relatively constant, as is done in modern boar-holding units, and only light exposure varies, seasonal changes in pig physiology still occur (Sancho, 2006); thus indicating the importance of artificial lighting programs.

Light in the boar stud's environment affects the hypothalamus-pituitary-gonadal axis regulation of sperm production and epididymis maturation in the testes (FIGURE 1). It is believed this occurs via melatonin secretions from the pineal gland in the animal's brain (Andersson, 2000). Notably, both natural and artificial light sources are effective in influencing this physiological response in domestic pigs (Diekman & Green, 1997; Fredriksen et al., 2006; Mahone et al., 1979; Sancho et al., 2004, 2006).

Figure 1: The hypothalamus-pituitary-gonadal axis in boars mediated by melatonin secretions from the brain's pineal gland (modified from Knox, 2003).



Over the past three decades, the scientific perspective of lighting effects on boar physiology has changed. In early research on pig melatonin levels, there were reports that there was no endocrine response in pigs to different light exposures (McConnell & Ellendorf, 1987; Minton et al., 1981) and it was presumed (Diekman et al., 1992; Green et al., 1997) that this lack of response was due to impaired melatonin production. However, later research indicated that melatonin shifts do occur in boars and that there is a definite pattern in response to light/dark cycles (Andersson, 2000, 2001). Early researchers did not find this melatonin secretion pattern because melatonin shifts experienced by pigs are of lower amplitude than those observed in other mammals (Andersson, 2000, 2001). It was only in later studies, using new and more sensitive assays, that researchers were able to successfully measure these endocrinological shifts (Andersson, 2000; Tast et al., 2002). These later studies demonstrated that melatonin secretions in pigs were directly linked to reproductive performance (Knecht, 2013; Tast, 2002).

LIGHT EXPOSURE AND WHAT IT MEANS

Before discussing artificial lighting programs, it is important to understand what is meant by the term "light exposure". "Light exposure" involves three characteristics of artificial lighting programs: spectrum (color), intensity and photoperiod. Photoperiod, the third characteristic, can be further separated into three components: 1) length of time of illumination (sometimes termed duration), 2) the rate of change of this illumination (in time increments) over a specific period of time (daily or weekly), and 3) the direction of this rate of change (whether increasing or decreasing) during the illumination period.

For example, an artificial lighting program may initially use lamps emitting green spectrum (545 to 565 nm wavelength) at an intensity of 40 lux (measured at the animal's eye level) for 12 hours a day. This program would keep the light color and intensity remaining the same over time, but every week the illumination time would decrease by one hour until it reached 8 hours of lighting a day. The full description of this lighting program would be 12 hours of 545 to 565 nm at 40 lux, declining by one hour per week to final light exposure of 8 hours.

Past research on pig photosensitivity and boar performance under different lighting conditions has provided rudimentary background information on lighting programs for AI units. However, these past studies were often deficient in fully describing the light programs used and therefore their application is extremely limited and their results not easily compared to other studies.

THE SIGNIFICANCE OF LIGHT SPECTRUM (COLOR) IN BOAR LIGHTING PROGRAMS

Pigs have dichromatic vision; in the pig's eye there are two sets of cones that give the animal peak wavelength sensitivity at 439 nm (blue color) and 556 nm (green color). The photoreceptors in a pig's eye cannot detect the color red (>650 nm) (Neitz & Jacobs, 1989; Taylor, 2006).

The natural habitat of wild pigs is covered foliage and in natural settings, pigs are termed "crepuscular" in behavior -- being active in the early morning and late evening (Lewis & Southern, 2001).

In consideration of the animal's ancestral habitat, Taylor (2010) described for domestic pigs a "pig forest light" which has a relatively smooth spectral distribution curve with maximum output around 550 nm.

Past research indicates that in order to get a physiological response from domestic pigs, the light exposure for "daylight" should be within the light spectrum of 380 to 580 nm (Tast, 2002 ; Taylor, 2006).

THE SIGNIFICANCE OF LIGHT INTENSITY IN BOAR LIGHTING PROGRAMS

European (EU) rules for light intensity in swine buildings define a minimum day standard of at least 40 lux (Costa et al., 2009; Pannekoek, 2010; Taylor 2010). This level of intensity is also the minimum required by the Canadian and New Zealand governments with respect to animal welfare considerations.

In the United States, the 2002 edition of the Swine Care Handbook recommended the following lighting levels for practicing good husbandry, inspecting the pigs adequately, maintaining their well-being and working safely in pig holding areas:

- 20 foot-candles (200 lux) for special inspection areas;
- 15 foot-candles (150 lux) for breeding, gestation and farrowing areas;
- 10 foot-candles (100 lux) for nurseries; and
- 5 foot-candles (50 lux) for growing and finishing areas (MWPS, 1983).

Research by Tast et al. (2002) found in pigs there was a melatonin response to light at intensity as low as 40 lux. When changing abruptly from short to long days however, Tast suggested higher intensities (> 240 lux) be used to suppress the established melatonin rhythms. It is important to note that Tast's scotophase (levels of light during the night phase) was 7 lux , since light during the night phase must also be considered in lighting programs for boars.

THE SIGNIFICANCE OF PHOTOPERIOD IN BOAR LIGHTING PROGRAMS

In the past, manipulation of the natural photoperiod through artificial lighting was not a common practice in AI units because it was believed that supplemental lighting did not change semen quality of postpubertal boars. As stated by Rivera et al. (2005), "[...]variations of photoperiod do not induce substantial changes in overall semen-quality parameters." However, new research strongly contradicts this position. There is now reason to believe that photoperiod manipulation can be a useful tool for enhancing semen production (Knecht et al., 2013 ; Sancho, 2005).

As mentioned earlier, photoperiods can be separated into three components 1) length of time there is illumination in a 24- hour cycle (photoperiod length); 2) the direction (increasing or decreasing) of change over time in the illumination period; and 3) the time increments involved in the change of illumination over a specific time. For example, an "increasing photoperiod" would be a daily increase of illumination of 15 minutes added to the 24-hour photoperiod cycle so that at day 1 the illumination period was 8 hours and the following day the illumination period was 8 hours plus 15 minutes, and so on.

1) Photoperiod length (hours of illumination)

An 8-hour photoperiod for animal welfare purposes is prescribed by a number of different government regulations (United States, European Union, Canada, New Zealand) as the minimum length of time lighting should be available in piggeries. These 8 hours do not have to be consecutive. Specifically for boars, the 2013 edition of the Pig Improvement Company (PIC) Boar Stud Manual recommended illumination in the boar holding units be less than 16 hours and limited to a minimum of 8 hours of darkness.

2) A static or changing photoperiod

There is some confusion in the literature when describing photoperiods. This confusion arises when it is not clearly stated whether or not there is any change within the illumination time over a treatment. Photoperiods are sometimes described as short days, decreasing photoperiods, short photoperiods, or autumn/winter photoperiods-. Each description refers to different photoperiod applications but are often discussed and compared as if they were the same. The ability to differentiate between the descriptors is very important.

A photoperiod of short days commonly refers to a static (not changing) 8 hours of illumination and 16 hours of dark cycle. This is the description of a short photoperiod. However, a decreasing photoperiod or an autumn/winter photoperiod refers to a light exposure over time, whereby the starting photoperiod has a longer daily light exposure than the final photoperiod. An example of this is a photoperiod starting point of 16 hours of illumination decreasing over time to an end point of 8 hours of illumination in a 24 hour cycle.

3) Why change in direction of the photoperiod is important

A review of past research indicates a photoperiod, where the light exposure time is incrementally decreasing in time, has a significant effect on boar performance. Researchers found that semen volume and semen concentration show a seasonality with the highest levels associated with decreasing photoperiods. Kennedy and Wilkins (1984) claimed, after examining 12,000 ejaculates from AI boars, that "in these data, semen volume increased almost linearly from June to December, coincident with decreasing day length."
Anderson (2000), Kunavongkrit et al., (2005), Sancho (2006) and Taylor (2010) commented on the rate of change in the photoperiod being a significant factor in physiological response.

In 1985, Claus et al. used a "reversed photoperiod strategy", subjecting boars to an artificial light environment that was opposite to ambient seasonal lighting. He found a significant difference in the performance of boars held under an artificial lighting program simulating a decreasing autumn photoperiod. Most notably "with the light reverse program there was a maximum of sperm production under decreasing light condition in summer, the same season when in the daylight (control) boars a lower production was observed."

Studies Finding Seasonality in Industrial Settings

Rutten et al. (2000) examined boar production in AI units in the United States. They reported boars were most productive in fall and winter and least productive in spring and summer.

Wolf and Smittal (2009) examined 150,000 ejaculates from 2000 AI boars during a 7-year period, with the animals maintained under a variety of holding conditions. They reported "semen volume had the greatest values from October to December and was least in March and April. Sperm concentration was greatest in winter and early spring (December to April) and least in late summer and early autumn."

Knecht et al. (2013) studied the effects of photoperiod on selected parameters of boar semen and found a statistically proven effect of photoperiod on semen volume and semen concentration. This research noted that "boar reaction to photoperiod was breed-dependent" but regardless of breed, "during increasing photoperiod there was a decrease in the number of insemination doses."

Thus, light programs with a decreasing photoperiod (autumn/winter) have shown the greatest impact on enhancing boar reproductive performance.

Other Noteworthy Considerations in Boar Lighting Programs

Separate from the different characteristics of lighting programs, there are other factors that must be considered when establishing scientific protocols for lighting programs for boars and assessing the results of these programs.

Researchers (Andersson, 2000; Taylor, 2010) recognized the importance of pretreatment conditions and acclimatization time as factors influencing results reported on boar performance. Tast et al. (2001b) specifically investigated the capability of pigs to respond to abrupt changes in lighting conditions and concluded that the pigs subjected to change from short days to long days needed two weeks to reach full adjustment. This acclimatization time must be accounted for when prescribing lighting programs and analyzing their effects.

Taylor (2010) talked about "night lighting" in piggeries. For husbandry reasons, this is sometime necessary, but it must be applied judiciously since studies on circadian rhythms in mammals have shown "even minor deviations in the intensity and duration of environmental light at a given time of day can alter or disrupt various chronobiologic rhythms" (Brainard, 1989). Similarly, it must be understood that night lighting can disrupt hormonal cycles. As Evans et al. (2007) observed in mammals "completely dark nights are not functionally equivalent to dimly lit nights, even when nighttime illumination is below putative thresholds for the circadian visual system [….] dim light markedly alters the behavior of the free-running circadian pacemaker." In addition, Dauchy et al. (2010) found, in their research on night light contamination in mammals and its effect on melatonin levels, that the specific wavelength 459 to 520 nm (blue-green) was the most potent contaminant in the dark-phase of photoperiodism.

Therefore, if night lighting is deemed necessary for security and safety issues in AI units, it should be of the red spectrum (>650 nm) only.

TIMELINES FOR LIGHTING PROGRAMS

In the domestic boar, it takes approximately 45 days (7 weeks) from the onset of sperm cell development to the time it appears in the ejaculate product (Knox, 2003). An AI unit will contain boars that are in different stages of the spermatogenesis cycle. Any light program focused on delivering a specific light treatment must take this variation into account. At the start of a light treatment some animals in the test population will be at the onset of spermatogenesis, some will be in the middle of the cycle and others while be a the end of the cycle.

Therefore, a light treatment should at least extend over a period of time where all animals in the test population will have had full exposure time to the treatment. The length of time a treatment is applied will depend on the number of animals in the population and the variance among the population in status with respect to spermatogenesis.

MEASURING THE IMPACT OF A LIGHTING PROGRAM ON BOAR PERFORMANCE

Clause et al. (1985) examined hormone production in boars and reported an average one-month lag time between increased steroid concentrations and improved sperm counts. Thus, the effects of a lighting program in terms of performance enhancement may not be immediately apparent. In addition, other environmental parameters (particularly room temperature) must be closely monitored during light program studies since research has shown that adverse variants in these can have an impact on sperm quality for up to two months (Knox, 2003).

High variability in the response of an individual pig to light exposure is another important consideration when measuring the effects of a lighting program (Andersson, 2000; Smital, 2009). Research has shown that this variability has a genetic component and is evident between siblings as well as among different breeds (lines) and age of animals (Knecht, 2013).

Separate from the biological considerations in measuring performance, there is also the question of what instruments are used to measure and monitor the three individual characteristics of a particular lighting program. Not all light meters measure the same light source the same way. There are large differences in light meter readings not only due to the capabilities of the instrument itself, but also where the readings are taken (i.e. at pig eye level) and under what conditions in the barn (light tight, with unshaded windows, etc). For researchers it is quite difficult to compare results from different lighting programs unless the measurement method and instruments used to measure the light are identified. Lighting program studies need to comprehensively document all three of the lighting system's characteristics, specify location and height of the light meter when taking readings and report on confounding light conditions in the environment.

IN SUMMARY:

Artificial lighting programs in stud boar holdings can be useful tools in manipulating the pig's environment and thus influencing certain desirable physiological responses, most specifically enhancing boar performance. New developments in LED lighting systems can now provide customized light intensity, spectrum and photoperiod control for swine rearing environments. However, artificial lighting programs must be applied judiciously, with a thorough understanding of the animal's physiological response to light and the significance of the different characteristics of light incorporated in such lighting programs.

ONCE Inc. is currently conducting research on performance enhancement in the swine industry using their animal-specific lighting systems. This research is in conjunction with New Fashion Pork, an integrated pork producer in the United States with operations in Minnesota, Indiana, Iowa, Illinois, South Dakota, and Wyoming.

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REFERENCES

- Andersson, H., Rydhmer, L., Lundstrom, K., Wallgren, M., Andersson, K., Forsberg, M., 1998, Influence of artificial light regimens on sexual maturation and boar taint in entire male pigs. Animal Reproduction Science 51: 3-43.
- Andersson, H., Lillpers, K., Rydhmer, L., 2000. Influence of light environment on plasma melatonin and cortisol profiles in young domestic boars, comparing two commercial melatonin assays. Domestic Animal Endocrinology 19 (4): 261-274.
- Andersson, H. 2001. Plasma melatonin levels in relation to the light-dark cycle and parental background in domestic pigs. Acta vet. Scand 42, 287-294.
- Brainard, G.C. 1989. Illumination of laboratory animal quarters: participation of light irradiance and wavelength in the regulation of the neuroendocrine system, p 69–74: Guttman HN, Mench JA, Simmonds RC, editors. Science and animals: addressing contemporary issues. Bethesda (MD): Scientists Center for Animal Welfare.
- Claus, R., Schopper, D., Wagner, G.H., Weiler, U. 1985. Photoperiodic influences on reproduction of domestic boars 1. Light influences on testicular steroids in peripheral blood plasma and seminal ZBL.Vet.Med A, 32: 86-98.
- Costa, A., Van Brecht, A., Porro, M., Berckmans, D., Guarino, M. 2009. Quantification of three–dimensional light distribution in pig houses. Transactions of the ASABE. 52(5): 1677-1682.
- Dauchy, R., Dauchy, E., Tirrel, R., Hill, C., Davidson, L., Greene, M., Tirrell, P., Wu, J., Sauer, L., Blask, D. 2010. Dark-phase light contamination disrupts circadian rhythms in plasma measures of endocrine physiology and metabolism in rats. Comparative Medicine 60 (5): 348-356.
- Diekman M. A., Brandt, K.E., Green, M. L., Clapper, J. A., Malayer, J.R. 1992. Lack of a nocturanal rise of serum melatonin in prepubertal gilts Domestic Animal Endocrinolgy 9(2): 161-167.
- Evans, J. A., Elliott J.S., Gorman, M.R. 2007. Circadian effects of light no brighter than moonlight. J Biol Rhythms. 22(4): 356-67.
- Fredriksen, B., Nafstad, O., Lium, B.M., Marka, C.H., Dahl, E., Choinski, J.U. 2006. Artificial light programmes in entire male pig production – effects on androstenone, skatole and animal welfare. Acta Veterinaria Scandinavica 2006, 48 (Suppl 1):P3
- Green, M. L., Clapper, J. A., Andres, C. J., Diekman, M. A. 1997. Serum concentrations of melatonin in prebubertal gilts exposed to either constant or stepwise biweekly alteration in scotophase, Domestic Animal Endocrinology 13: 307-323.
- Kennedy, B. W., Wilkins, J. N. 1984. Boar, breed and environmental factors influencing semen characteristics of boars used in artificial insemination. Can. J. Anim. Sci. 64: 833-843.
- Knecht , D., S. Środoń, K. Szulc and K. Duziński. 2013. The effect of photoperiod on selected parameters of boar semen. Livestock Science 157: 364–371.
- Knox, R.. 2003. The Anatomy and Physiology of Sperm Production in Boars. http://www.e-bookspdf.org/view/ http://www.e-bookspdf.org/view aHR0cDovL3d3dy5saXZlc3RvY2t0cmFpbC5pbGxpbm9pcy5lZHUvc3dpbmVyZXByb25ldC9wdWJsaWNhdGlvbnMvZXh0ZW5zaW9uL0JvYXJBJlAucGRm/ VGhlIEFuYXRvbXkgJiBQaHlzaW9sb2d5IE9mIFNwZXJtIFByb2R1Y3Rpb24gSW4gQm9hcnM=,
- Kunavongkrit, A., Suriyasomboon, A., Lundeheim, N., Heard, T.W., Einarsson, S. 2005. Management and sperm production of boars under differing environmental conditions.Theriogenology 63(2): 657-67.
- Lewis, J. and L. Lee Southern (Editors). 2001. Swine Nutrition, Second Edition. CRC Press, Boca Raton, Florida
- Mahone, J.P., Berger, T., Clegg, E.D., Singleton, and W. L. 1979. Photoinduction of puberty in boars during naturally occurring short daylengths. J. Anim. Sci. 48:1159.
- McConnell, S.J. and Ellendorf, F. 1987. Absence of nocturnal plasma melatonin sure under long and short artificial photoperiods in the domestic sow. J. of Pineal Research 4: 201-210.
- Minton, J.E., Fent, R.W., Wettemann, R.P. 1981. Reproductive characteristics of young boars exposed to 8 or 16 hours of light daily. Animal Science Research Report, Oklahoma Agriculture Experiment Station.pp.1-4
- Mid-West Plan Service (MWPS) 1983. Swine Housing and Equipment Handbook. MWPS-8. Midwest Plan Service, Iowa State University, Ames, Iowa 50011.
- Neitz,J. and Jacobs, G.H., 1989. Spectral sensitivity of cones in an ungulate. Visual Neuroscience. 2: 97-100.
- Pannekoek, M., 2010. Melatonin release patterns in pigs kept under different light regimens Utrecht University, Faculty of Veterinary Medicine, Department of Farm Animal Health.
- Rivera. M.M., Quintero-Moreno, A., Barrera, X., Palomo, M.J., Rigau, T., Rodriguez-Gil, J.E. 2005. Natural mediterranean photoperiod does not affect the main parameters of boar-semen quality analysis. Theriogenology. 64: 934–946.
- Rutten, S., Morrison, R.B., Reicks , D. 2000. Boar stud production analysis. Swine Health and Production 8 (1): 11-14.
- Sancho, S,, Pinart ,E,, Briz ,M., Garcia-Gil, N,, Badia, E., Bassols, J., Kadar, E., Pruneda, A., Bussalleu, E., Yeste, M., Coll, M.G. and Bonet, S. 2004 Semen quality of postpubertal boars during increasing and decreasing natural photoperiods. Theriogenology. 62: 1271–1282.
- Sancho, S., Pinart, E., Briz, M., 2005. Study of boar semen quality during an artificial photoperiod of 24, 12 and 0 hours. Reproduction in Domestic Animals. 40 (4)
- Sancho S, Rodriguez-Gil J.E., Pinart, E., Briz, M., Garcia-Gil, N., Badia, E., Bassols, J., Pruneda, A., Bussalleu, E., Yeste, M., Casas, I., Palomo, M.J., Ramio, L., Bonet, S., 2006. Effects of exposing boars to different artificial light regimens on semen plasma markers and "in vivo" fertilizing capacity. Theriogenology 65: 317-331.
- Smital, J. 2009. Effects influencing boar semen. Animal Reproduction Science. 110: 335-346.
- Tast, A., Love, R.G., Evans, G., Andersson, H., Peltoniemi, O.A.T., Kennaway, D.J., 2001a. The photophase light intensity does not affect the scotophase melatonin response in the domestic pig. Animal Reproduction Science 65 (3-4): 283-290
- Tast, A., Love, R.G., Evans, G., Telsfer, S., Giles, R., Nicholls, P., Voultsios, A., Kennaway, D.J. 2001b. The pattern of melatonin secretion is rhythmic in the domestic pig and responds rapidly to changes in daylength. Journal of Pineal Research 31(4): 294-300.
- Tast, A., Halli, O., Ahlstrom, S., Andersson, H., Love , R.J. and O, Peltoniemi
  2001c. Seasonal alterations in circadian melatonin rhythms of the European wild boar and domestic gilt J. Pineal Res. 30:43–49
- Tast, A. 2002. Endocrinological basis of seasonal infertility in pigs. Doctoral Thesis. Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland.
- Taylor, N. 2010. Lighting for pig. Report compiled for British Pig Exporters.
- Taylor, N., Prescott, N., Perry, G., Potter, M., Le Sueur, C., Wathes, C.M. 2006. Preference of growing pigs for illuminance. Applied Animal Behaviour Science 96 (1-2): 19-31.
- Wolf, J. and J. Smittal. 2009. Quantification of factors affecting semen traits in artificial insemination boars from animal model analyses. J. Anim. Sci. 87: 1620–1627.