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MICROBIOLOGY

Thermal comfort and photoperiod on the productive performance of sows and piglets

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ABSTRACT: *Pigs have difficulty in performing heat exchange and; therefore, it is important to consider the environmental factors that impact their productive performance. This study evaluated the effect of thermal comfort and photoperiod on the productive performance of sows during pregnancy and of nursery piglets. Zootechnical data were obtained from a commercial farm. The temperature–humidity index (THI) was used as the parameter to determine comfort or thermal stress of the sow. The parameters of the sows during pregnancy and nursery piglets were analyzed considering the criteria of comfort, stress, and four photoperiods. The correlation between photoperiod and THI was high and positive, which demonstrated the associated effect of these variables. More significant effects were observed under conditions of comfort and shorter photoperiods. In conclusion, thermal comfort and photoperiod influenced the parameters evaluated during pregnancy and in the nursery, and the strong association between THI and photoperiod suggested that environmental control favors productive parameters in commercial farms.*
Key words: *environment, THI, zootechnical parameters, pig farming.*

Conforto térmico e fotoperíodo sobre o desempenho produtivo de porcas e de leitões

RESUMO: *Os suínos são animais que apresentam dificuldade em realizar trocas de calor, por esse motivo é importante considerar os fatores ambientais que impactam seu desempenho produtivo. O objetivo do presente trabalho foi avaliar o efeito do conforto térmico e do fotoperíodo, sobre o desempenho produtivo das porcas na gestação e leitões na maternidade. Os dados zootécnicos foram obtidos de uma granja comercial. O índice de temperatura e umidade (ITU) foi utilizado como parâmetro para o conforto ou o estresse térmico da matriz. Foram analisados os parâmetros das fêmeas no período gestacional e dos leitões na maternidade, considerando os critérios de conforto, estresse e quatro faixas de fotoperíodos. A correlação entre o fotoperíodo e ITU foi alta e positiva, demonstrando efeito associado dessas variáveis. Foram observados mais efeitos significativos em situações de conforto e faixas de menor fotoperíodo. Em conclusão, o conforto térmico e o fotoperíodo influenciaram os parâmetros avaliados na gestação e na maternidade e a alta associação ITU e fotoperíodo sugere que o controle ambiental pode favorecer parâmetros produtivos em granjas comerciais.*
Palavras-chave: *ambiência, ITU, parâmetros zootécnicos, suinocultura.*

INTRODUCTION

The increase in productivity in recent decades in the Brazilian swine industry can be attributable to the progress achieved in several parameters, including nutrition, environment, health, management, breeding programs, and meeting the requirements imposed by consumer markets associated with animal welfare.

Temperature is a factor that reflects the quality of the environment and animal welfare, and it can lead to reduced food consumption, lower zootechnical performance, and even death. When outside the thermal comfort zone, animals require metabolic adaptations that increase energy expenditure to maintain their body temperature, which limits productive gain (BAUMGARD et al., 2012; DIAS et al., 2014). The metabolic mechanisms used by pigs to reduce heat production can also directly influence the reproductive parameters of females and males and it is thus important to consider environmental and climatic factors related to the facilities and the region where the pig production system is established.

It is imperative to consider environmental parameters, such as temperature and humidity, to establish criteria that characterize thermal comfort.

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THOM (1959) developed the temperature/humidity Index (THI), which can be used to determine the thermal comfort index in animals and humans. SALES et al. (2006) studied pigs in a commercial farm and concluded that a THI of > 69 corresponded to discomfort and thermal stress for both sows and piglets. A THI between 61 and 65 provided the best comfort for the sows and their litters.

High temperatures in summer have a direct effect on productive and reproductive performance because pigs are not physiologically and anatomically adapted to the tropical climate, as the swine breeds used in Brazil come from populations selected in temperate regions. Reproductive and productive factors such as reduced weight gain, disuniformity, and nursery piglet mortality may be affected by the decrease in feed consumption by sows during lactation, which may be related to thermal stress, especially in summer (SOBESTIANSKY, 2012; TUMMARUK et al., 2010).

KNECHT et al. (2013) demonstrated that the effect of the season on fertility is related to temperature and photoperiod variation. Hormonal behavior in pigs according to varying photoperiods (controlled or not) remains unknown because no behavior pattern has been determined (BORTOLOZZO et al., 2011; HÄLLI et al., 2008; KNOX et al., 2019).

Based on the above, the present study evaluated the effect of photoperiod and thermal comfort (defined by the THI) on the productive performance of sows and their piglets reared in a commercial facility.

MATERIALS AND METHODS

The zootechnical data were provided by a full-cycle commercial farm, through the management program S2, of the company Agriness. The farm is located in the municipality of Cascavel, state of Paraná with coordinates 25°08'14''S and 53°27'31''W, at an altitude of 526 m. The facilities are located along a longitudinal axis facing east and west. They are covered with clay tiles and have varied lengths and standard width and height of 10 m and 3.5 m respectively. The data presented herein are relative to the period from September 2012 to February 2018. The technological level of the environmental control of the facilities is low.

Data on 738 sows of three commercial breeds housed in individual pens were used. Heat detection was performed twice daily, starting on the day of weaning (established by management as close to 23 days), using a breeding male. The semen was provided by the semen collection center of the farm itself. A weekly collection was performed per breeder (rotating among the available males) on the day of insemination.

The daily climate data of mean temperature (Tm) and relative humidity (RH) were obtained by the Meteorological System of Paraná (SIMEPAR) from the meteorological station of the city of Cascavel, in the State of Paraná, located 30 kilometers from the farm (latitude 24°53'4.20"S, longitude 53°33'16.92"W, and altitude 671 m).

To evaluate the effect of thermal comfort and photoperiod on sow pregnancy, the following four gestational periods were considered from the date of mating: first period, day 1–30 of gestation; second period, day 31–60 of gestation; third period, day 61–90 of gestation; and fourth period, day 91 to the date of delivery. A single period was considered for the evaluations performed in the nursery.

The THI was used as a parameter to express the thermal comfort of the animals, according to the method described by THOM (1959) and the THI classification criterion proposed by SALES et al. (2006), which indicates that environments with an index of ≤ 68 are considered to provide thermal comfort to animals and an index of > 68 reflects thermal stress. The duration of the photoperiod was expressed in hours between sunrise and sunset. The duration of the day (Td) was determined according to the location of the farm and the day of the year was determined using the equation mentioned below, adapted from the equations described by BORGES (2019).

$$Td = (\frac{2}{15} arcos(-tan\emptyset * tan(23{,}45 * \text{sen}$$

$$(\frac{365}{360}(284 + \text{N})) + ((\lambda - 45) * 60/15/100)$$

Where: $\emptyset$ is the latitude of the location, N is the sequential day of the year, and λ is the longitude of the location.

To determine the effect of the photoperiod on performance, the duration of light was expressed in hours and corrected for longitude to determine the amount of light received each day in the different periods of pregnancy. The following four photoperiods were defined according to the duration of light: 11 hours - daylight duration between 10:30 and 11:29; 12 hours - between 11:30 and 12:29; 13

hours - between 12:30 and 13:29; and 14 hours - between 13:30 and 14:29.

The parameters evaluated during the gestation period were the following: total number of piglets born (TOTAL), number of piglets born alive (LIVE), and losses in pregnancy (PG) (the sum of stillborn piglets, piglets who died at birth, and mummified piglets). In the nursery, the parameters evaluated were as follows: number of weaned piglets (WEAN), weaning age of piglets (WAP), total weight of the litter at weaning (TWW), mean weight of piglets at weaning (MWW), mean weight gain of nursery piglets (WGN), and mean daily weight gain in the nursery (DWG).

The data were analyzed using the least square method with ANOVA, test of means, and the correlation coefficient. The SAS 9.0 software was used for the analyses. The statistical model evaluated zootechnical performance as a function of thermal comfort and photoperiod. The Tukey test was used to compare the means at 5% probability.

For the statistical model, the fixed effects were the four photoperiods (11, 12, 13, and 14 hours of daylight), thermal comfort (comfort and thermal stress), the four gestational periods (P1, P2, P3, and P4), and the interaction pertinent to each analyzed variable. The models adopted were as follows:

$$Y_{ijl} = PG_i + CT_j + PG * CT_{ij} + e_{ijl};$$

$$Y_{jl} = CT_j + e_{jl};\ Y_{il} = PG_i + e_{il};$$

$$Y_{ikl} = PG_i + FP_k + PG * FP_{ik} + e_{ikl};Y_{jl} = FP_j + e_{jl}$$

Where: $Y_{...l}$ represents the variables that receive the evaluated effects for each repetition "*l*". PG_i represents the effect of the gestation period i. CT_j represents the effect of thermal comfort j. FP_k represents the effect of photoperiod k. *e*... represents random error associated with each observation.

RESULTS AND DISCUSSION

The environmental variables and TWW are shown in figure 1. The results of zootechnical performance considering the factors comfort and stress are presented in table 1 and those considering the photoperiod are shown in table 2.

The correlation between thermal comfort (THI) and photoperiod was 0.82 (82%), i.e., high and positive, which demonstrates a strong association between the two variables. The farm's facilities have little control over the environment, which makes it difficult to manage light, wind speed, humidity, and temperature; this has a negative impact on the thermal comfort provided to the animals.

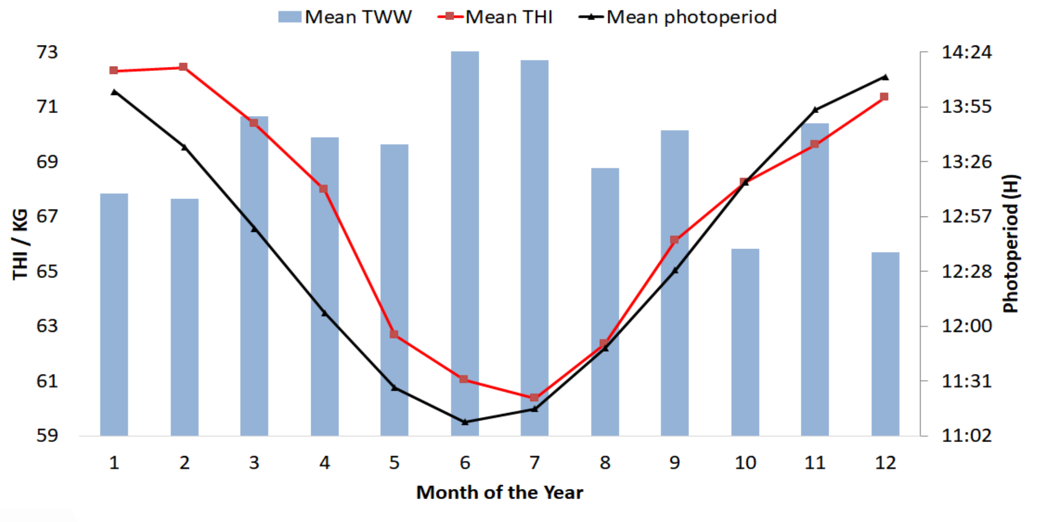

Figure 1 - Mean total weaning weight (TWW) per delivery, temperature and humidity index (THI), and photoperiod according to the month of the year during the nursery period.

Table 1 - Mean reproductive performance of sows at each gestation period (P) and mean productive performance of nursery piglets according to thermal comfort zone.

Gestation Periods	THI Zone	TOTAL (piglets)	LIVE (piglets)	LP (piglets)
First	Comfort (n = 1094)	15.24A	13.72	1.52a
	Stress (n = 1065)	14.90b	13.64	1.26B
Second	Comfort (n = 1089)	15.16	13.77	1.40
	Stress (n = 1070)	14.98	13.59	1.39
Third	Comfort (n = 1072)	15.06	13.75	1.30b
	Stress (n = 1087)	15.09	13.61	1.48a
Fourth	Comfort (n = 1076)	15.01	13.79A	1.21b
	Stress (n = 1083)	15.14	13.57b	1.57a

----------Nursery----------

THI Zone	WEAN (piglets)	WAP (days)	TWW (kg)	MWW (kg)	WGN (kg)	DWG (kg)
Comfort (n = 1015)	11.09	23.46a	69.76A	6.34A	4.88a	0.208
Stress (n = 1053)	11.06	22.95b	68.04b	6.19B	4.73B	0.207

The means followed by different letters (columns) in the same gestation period differ statistically from each other by the Tukey test at 5%.
TOTAL: Total piglets born / LIVE: piglets born alive / LP: Losses in pregnancy / WEAN: Weaned / WAP: Weaning age of piglets / TWW: Total weight at weaning / MWW: Mean weight at weaning / WGN: Weight gain in nursery / DWG: Daily weight gain in nursery / N: number of animals.

In this study, the sows remained in their thermal comfort zone (THI < 69) between months 4 and 9, which was the period with the shortest photoperiod, comprising autumn and winter in southern hemisphere (Figure 1). The highest TWW of piglets (TOTAL) was observed in months 6 and 7, coinciding with the lowest means of THI and photoperiod. These findings are in line with those of other studies in which females in thermal comfort exhibit higher feed intake and milk production, which translates into higher TWW (MCGLONE et al., 1988; RIBEIRO et al., 2018)

Sows in thermal comfort in the initial period of pregnancy had a higher number of piglets (TOTAL) than those under stress conditions (Table 1). A worse performance under stress conditions may be associated with the difficulty pigs have in losing heat, which can cause a decrease in the ovulation rate of the sows, a decrease in the quality of the males' semen, and affect the number of viable embryos (EDWARDS et al., 1967; HAGAN & ETIM, 2019; TOMPKINS et al., 1967), which all result in fewer piglets being born. No effect was observed in subsequent phases of pregnancy, which shows the importance of thermal comfort in the first 30 days of pregnancy, when embryonic implantation occurs.

With regard to parameter LIVE, a difference was observed in the 4th period: the mean number of live-born piglets was higher among females in comfort than among females under stress. Males also play an important role in the number of TOTAL and LIVE, because they exhibit a reduction in sperm quantity and quality when exposed to thermal stress, and the use of semen in these conditions may lead to a reduced number of embryos (WETTEMANN et al., 1976). This indicated the importance of thermal comfort in males and the opportunity to conduct studies with these animals at the farm.

Females in comfort had higher LP in the first gestation period, but there was no difference in the number of LIVE and the difference in TOTAL was maintained; this may be an opportunity for a higher number of LIVE if there is lower PG in the initial period. Females under stress had higher LP in periods 3 and 4; the negative effect of thermal stress on sows in the final phase of pregnancy was also observed by KNECHT & DUZINSKI (2014) and OMTVEDT et al. (1971). In this phase there is a natural increase in the growth and development of the fetuses, which promotes the caloric increase in sows that already have difficulty in heat exchange, leading to increasing metabolic difficulties and potential gestational losses.

There was no effect on WEAN ($P > 0.05$), a result similar to that obtained by RIBEIRO et al., 2018 and SALES et al., 2006. With regard to WAP, it

Table 2 - Mean reproductive performance of sows at each gestation period (P) and of piglets according to the photoperiod.

Gestation Periods	PHOTOPERIOD	TOTAL (piglets)	LIVE (piglets)	LP (piglets)
First	F11h (n = 697)	15.10ab	13.76a	1.34
	F12h (n = 477)	15.23a	13.76a	1.46
	F13h (n = 528)	15.19a	13.77a	1.42
	F14h (n = 457)	14.73b	13.36b	1.37
Second	F11h (n = 691)	14.98	13.74ab	1.24B
	F12h (n = 454)	15.20	13.88a	1.32ab
	F13h (n = 552)	15.13	13.58ab	1.55a
	F14h (n = 462)	15.02	13.50b	1.51a
Third	F11h (n = 662)	14.76b	13.70	1.06c
	F12h (n = 490)	15.13ab	13.80	1.32B
	F13h (n = 529)	15.33a	13.73	1.60a
	F14h (n = 478)	15.16ab	13.47	1.69a
Fourth	F11h (n = 666)	14.88	13.85	1.03c
	F12h (n = 492)	14.93	13.62	1.31b
	F13h (n = 536)	15.25	13.65	1.60a
	F14h (n = 465)	15.28	13.52	1.76A

---Nursery---

Photoperiod	WEAN (piglets)	WAP (days)	TWW (kg)	MWW (kg)	WGN (kg)	DWG (kg)
F11h (n = 599)	10.98	23.76A	70.62A	6.47A	5.00a	0.211A
F12h (n = 488)	11.15	22.99b	69.43ab	6.27B	4.81B	0.209ab
F13h (n = 536)	11.01	22.97b	67.41b	6.17bc	4.70B	0.205ab
F14h (n = 445)	11.18	22.94b	67.71b	6.09c	4.65B	0.203b

The means followed by different letters (columns) in the same gestation period differ statistically from each other by the Tukey test at 5%.

TOTAL: Total piglets born / LIVE: piglets born alive / PG: Losses in pregnancy / DESM: Weaned / WAP: Weaning age of piglets / TWW: Total weight at weaning / MWW: Mean weight at weaning / WGN: Weight gain in nursery / DWG: Daily weight gain in nursery / N: number of animals.

was found that piglets of females in comfort remained on average more days in the nursery than piglets of females under stress. WAP can directly influence weight gain and weight at weaning, because piglets remain in contact with the sow for longer, sucking and consuming feed in the nursey. This explains the higher TWW, because piglets in comfort weighed an extra 1.72 kg. The MWW was higher ($P < 0.05$) in the group in thermal comfort and the WGN of piglets of sows in comfort was 3.00% higher.

There were no differences in DWG ($P = 0.346$). The litters of females in comfort had a 3.07% higher WGN, even with the lactation time of these sows being 2.54% higher than that of females under stress, which demonstrates that DWG or its variation is little influenced by the THI. The environment can influence the performance of sows, which has an impact on the initial performance of piglets. A lower environmental control exposes the animals to external conditions, because for every 1 °C above the sows' thermal comfort zone (between 15 °C and 25 °C) there is a decrease in feed intake and milk production, resulting in a lower weight of piglets at weaning (RIBEIRO et al., 2018).

Table 2 presents the results according to the different photoperiod. The results of TOTAL were better in the first gestational period with up to 13 hours of light incidence, which may be related to shorter days because there is a higher release of melatonin, a hormone that acts directly on the ovaries and has antioxidant activity, thereby having a positive effect on fertility (KNOX et al., 2019; PATTERSON et al., 2010). The negative result in F14h coincides with the summer months (Figure 1), which may be related to partial embryonic death and decrease in ovulation rate (DOMINGUEZ et al., 1996). In the third period of gestation, the performance of females in the F11h range was 3.72% lower, i.e., shorter light duration negatively affected performance. From the F12h range, performance remained statistically stable, thus suggesting that photoperiod associated with temperature and thermal comfort positively affects the performance of the animals.

Shorter photoperiods exerted a positive influence ($P < 0.05$) on LIVE in the initial periods of gestation, which may also be related to the reproductive phase and the time of year because the date of service has an impact on reproductive performance and; consequently, on LIVE (KNECHT & DUZIŃSKI, 2014). Regarding LP, differences were detected ($P < 0.05$) from the second period onward, with lower LP in shorter photoperiods (F11h and F12h).

Considering the photoperiod during the nursery period (Table 2), no difference was observed ($P > 0.05$) in WEAN; however, there was a difference in WAP ($P < 0.05$), with piglets weaning later in F11h. This difference may have influenced the remaining parameters because TWW, MWW, WGN, and DWG of females that nursed in F11h were higher than those in females that nursed in F14h. The animals of the groups with higher TWW had higher MWW; the photoperiod affected these variables concomitantly, because sows were comfortable and provided better initial development for their piglets in the shorter photoperiods. There was a significant difference ($P < 0.05$) in DWG only between piglets whose mothers were in the F11h and F14h photoperiods, and the latter photoperiods did not differ from F12h and F13h. This demonstrated that exposure to photoperiod extremes affected piglet performance (DWG) but a change of ± 2 hours within the evaluated intervals was not sufficient to significantly affect piglet performance.

CONCLUSION

There was a considerable and positive association between photoperiod and thermal comfort (THI) in both pregnancy and nursery periods, which can negatively impact the performance of animals in facilities with low technological levels.

Thermal comfort and photoperiod exerted a significant influence during the pregnancy and the nursery periods, which suggested that environmental changes in the different gestational phases can improve the zootechnical parameters of sows and piglets.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

All authors contributed equally to the preparation of this article.

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