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Innovative strategies to minimize the negative impacts of autumn syndrome on sow reproduction

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INNOVATIVE STRATEGIES TO MINIMIZE THE NEGATIVE IMPACTS OF AUTUMN SYNDROME ON SOW REPRODUCTION

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Orientador: Prof. Dr. Leandro Batista Costa.

Coorientador: Dr. Marcos Soares Lopes.

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Aos vinte e sete dias do mês de fevereiro do ano de dois mil e vinte e três, às 9h, pela sala virtual do Google Meet, realizou-se a sessão pública de defesa de dissertação da mestranda Isabela Cristina Colaço Bez, intitulada: **"ESTRATÉGIAS INOVADORAS PARA MINIMIZAR OS IMPACTOS NEGATIVOS DA SÍNDROME DE OUTONO NA REPRODUÇÃO DE FÊMEAS SUÍNAS"**. A mestranda concluiu os créditos exigidos para obtenção do título de Mestre em Ciência Animal, Área de Concentração em Saúde, Tecnologia e Produção Animal, segundo os registros constantes na secretaria do Programa. Os trabalhos foram conduzidos pelo Professor orientador e Presidente da banca, Dr. Leandro Batista Costa (PUCPR), auxiliado pelos Professores Doutores Claudia Alejandra Sevillano del Aguila (Topigs Norsvin Research Center B.V.) e Frederico Márcio Corrêa Vieira (UTFPR - Campus Dois Vizinhos). Procedeu-se à exposição da Dissertação, seguida de sua arguição pública e defesa. Encerrada a fase, os examinadores expediram o parecer final sobre a Dissertação, que foi considerada aprovada.

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Assinatura ______________________________

Proclamado o resultado, o Presidente da Banca Examinadora encerrou os trabalhos, e para que tudo conste, eu Caroline Nocera Bertton, confiro e assino a presente ata juntamente com os membros da Banca Examinadora.

Curitiba, 27 de fevereiro de 2023.

Caroline Nocera Bertton

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Dedico essa dissertação
ao meu pai e mãe, quem sempre
me fizeram um cafezinho.

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SUMMARY

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LIST OF ABBREVIATIONS

WEI	*Weaning-to-estrus interval*
NPD	*Non-productive days*
FR	*Farrowing rate*
AAS	*Autumn abortion syndrome*
LH	*Luteal hormone*
INMET	*Instituto Nacional de Meteorologia*
UCT	*Upper critical temperature*
LCT	*Lower critical temperature*
lx	*Lux (unity of illuminance)*
RMSE	*Root mean squared error*
AIC	*Akaike Information Criterion*

DISSERTATION FORMAT

This dissertation is composed of four chapters. Chapter one presents a general introduction and contextualization to the topic of seasonal infertility, followed by the objectives of the present study. Chapter two presents a literature review covering all aspects of seasonal infertility (autumn syndrome) and the use of technological tools to solve this issue, as they are portrayed as the main problem in this study. Chapter three is a complete scientific article, formatted in the norms of the journal “Theriogenology”, to which the article will be submitted. Chapter four presents the impact and future perspectives of this study. This dissertation finishes with a brief conclusion. References of chapters one and four are presented at the end of chapter four.

ABSTRACT

Sows are animals that present natural seasonal reduction of reproduction performance to maximize the survival of their born offspring. With the advance of breeding and reproduction management, sows became well-adapted to temperature changes, however, a decrease in reproduction performance still can occur in modern pig production systems in some seasons of the year, especially in late summer and autumn. This decrease in reproduction performance due to seasonal infertility syndromes is also known as autumn syndrome and is influenced for several factors, such as failures in the nutrition program, healthy status, inappropriate environment and ambience, and poor handling of animals. In order to reduce this issue in modern pig production systems all these factors should be studied to seek strategies that can solve or minimize this problem. This study aimed to assess the influence of temperature, photoperiod, and luminosity on the farrowing rate of sows through a statistical model. Reproduction data of purebred Large White sows together with temperature, photoperiod, and luminosity information from four farms collected in 2020 and 2021 were evaluated in this study. In total, five treatments were evaluated in this study: non-corrected farrowing rate (T1), farrowing rate with temperature correction (T2), farrowing rate with temperature and photoperiod correction (T3), farrowing rate with luminosity correction (T4), and farrowing rate with temperature and luminosity correction (T5). For the first year (2020), temperature information were obtained from meteorological stations of the Instituto Nacional de Meteorologia (INMET - Brazil). Photoperiod was modelled by taking the sine of the day of the first insemination within a year. The treatments evaluated for this year were T1, T2 e T3, as luminosity information is not available at INMET. In 2021, after the installation of technological devices (*data logger*) in each farm, temperature and luminosity information were also collected and the treatments for this year were T1, T2, T3, T4 e T5. For both years, the maximum daily temperature was analyzed to estimate heat load. A linear model was built on the software R Studio to verify the influence of correct temperature, photoperiod, and luminosity on the farrowing rate of sows. The effect of changing luminosity on reproductive data was estimated based on root mean square error (RMSE) analysis. For the first and second years, only one of the farms did not show problems with autumn syndrome. The temperature and photoperiod correction (T3) yielded better farrowing rates for both years. These results indicate that temperature and photoperiod have an influence on the farrowing rate of sows, and that applying strategies that control these parameters could improve the reproduction performance of farms that present autumn syndrome and therefore a seasonal reduction in reproduction performance.

Keywords: farrowing rate; seasonal infertility; swine reproduction.

RESUMO GERAL

Fêmeas suínas são animais que apresentam redução sazonal natural do desempenho reprodutivo para maximizar a sobrevivência de sua prole nascida. Com o avanço da criação e manejo reprodutivo, essas fêmeas tornaram-se bem adaptadas às mudanças de temperatura. Porém, ainda é possível ocorrer uma queda no desempenho reprodutivo nos sistemas modernos de produção de suínos em algumas estações do ano, principalmente no final do verão e outono. Essa queda no desempenho reprodutivo acontece devido às síndromes sazonais de infertilidade, uma delas sendo conhecida como síndrome do outono, influenciada por diversos fatores como falhas no programa de nutrição, estado de saúde, ambiente e ambiência inadequados e manejo inadequado dos animais. Para diminuir esse problema nos sistemas modernos de produção de suínos, todos esses fatores devem ser estudados a fim de buscar estratégias que possam resolver ou minimizar esse problema. Este estudo teve como objetivo avaliar a influência da temperatura, fotoperíodo e luminosidade na taxa de parto de fêmeas suínas por meio de um modelo estatístico. Neste estudo foram avaliados dados reprodutivos de fêmeas da raça Large White juntamente com informações de temperatura, fotoperíodo e luminosidade de quatro granjas coletadas em 2020 e 2021. No total, cinco tratamentos foram avaliados neste estudo: taxa de parto não corrigida (T1), taxa de parto com correção de temperatura (T2), taxa de parto com correção de temperatura e fotoperíodo (T3), taxa de parto com correção de luminosidade (T4) e taxa de parto com correção de temperatura e luminosidade (T5). Para o primeiro ano (2020), as informações de temperatura foram obtidas de estações meteorológicas do Instituto Nacional de Meteorologia (INMET - Brasil). O fotoperíodo foi modelado tomando o seno do dia da primeira inseminação dentro de um ano. Os tratamentos avaliados para este ano foram T1, T2 e T3, pois informações de luminosidade não estão disponíveis no INMET. Em 2021, após a instalação de dispositivos tecnológicos (*data logger*) em cada granja, também foram coletadas informações de temperatura e luminosidade, e os tratamentos para este ano foram T1, T2, T3, T4 e T5. Para ambos os anos, a temperatura máxima diária foi analisada para estimar a carga de calor. Um modelo linear foi construído no software R Studio para verificar a influência da temperatura correta, fotoperíodo e luminosidade na taxa de parto das fêmeas. O efeito da mudança de luminosidade nos dados reprodutivos foi estimado com base na análise da raiz quadrática média do erro

(RMSE). Para o primeiro e segundo anos, apenas uma das granjas não apresentou problemas com a síndrome do outono. A correção de temperatura e fotoperíodo (T3) proporcionou melhores taxas de parto em ambos os anos. Estes resultados indicam que a temperatura e o fotoperíodo influenciam a taxa de parto das fêmeas suínas, e que a aplicação de estratégias que controlem esses parâmetros pode melhorar o desempenho reprodutivo de produções que apresentam síndrome do outono e, portanto, uma redução sazonal no desempenho reprodutivo.

Palavras-chave: infertilidade sazonal; reprodução suína; taxa de parto.

CHAPTER ONE

INTRODUCTION AND CONTEXT

Pork production has achieved remarkable developments worldwide in the last decades. Brazil encounters a highlighted position in this market, as it is the world's fourth-largest pig producer, being surpassed only by China, the European Union, and the United States of America. Brazil is also the world's fourth-largest pork exporter, behind the European Union, United States and Canada (USDA, 2021). According to the Brazilian Association of Animal Protein (2023), in 2022 there was a 6,5% increase in production compared to 2021, surpassing the growth expectation of 4%. More than 4,9 million tons of pork were produced in Brazil in 2022. The projection for 2023 is a 4% growth compared to 2022, aiming to reach more than 5 million tons of pork produced. Annual pork consumption per capita was 16.7 kg in 2022, 3% higher than in 2021. The export statistics indicate that the export volume reached 1,137 million tons in 2022, a 7.5% growth compared to 2021.

Although growth in production and export of pork has been observed in the last years, to increase its position in worldwide pig production, the Brazilian pork industry must seek for technological solutions to improve the efficiency and sustainability of their products, making the Brazilian market even more competitive. These alternatives can be applied in various sector categories, such as health, nutrition, animal handling, and breeding (ABRA, 2019).

The improvement in the amount of pigs available in the market is of significant importance, and investments in genetics and breeding have been robust and intensified in recent decades. The genetic improvement focusses mainly on the development of the animals placed on the top of the pig breeding pyramid. Those animals are purebred animals, and they are placed in nucleus farms with high health status, management, and dedicated nutrition schemes. The developments obtained on the nucleus farms will transfer one level down in the pyramid to the multiplication farms where F1 sows will be produced most of the time by crossing two different purebred maternal lines. The F1 sows will be crossed with a terminal sire line to produce the finishers that are at the bottom of the pyramid and represent the majority of the pigs slaughtered in the market (EMBRAPA, 2003; Oldenbroek e van der Waaij, 2015). Besides genetic improvement, current breeding programs aim at resilience against many problems, such as environmental sensitivity (Berghof et al., 2018), which can have more significant economic impact on producers (Utrera, 2008).

Failures in the reproduction performance of sows are frequent on farms, which shows the importance of raising awareness and finding ways to improve the health of these animals (Beuron e Brito, 2016). Return to estrus, abortions, longer weaning-to-estrus intervals (WEI), longer non-productive days (NPD), lower farrowing rates (FR) and stillbirths are the most known reproductive problems. It is essential to mention that these clinical signs, although associated with diseases, can be caused by several factors, infectious and non-infectious (Vanderhaeghe et al., 2013; Bortoletto et al., 2014). Among the non-infectious factors, seasonal infertility is characterized by decreased breeding and farrowing performances in swine, usually occurring in late-summer and early fall (Hughes e Wettere, 2010). However, due to the different areas of pig production and the territorial climatic diversity in Brazil, researchers have no consensus on how the reproductive performance of swine herds has behaved regarding seasonal influence (Silveira e Amaral, 2009). During the autumn, for example, the so-called autumn syndrome is known to affect a large part of the reproductive herd and has no specific cause but is mainly attributed to various climatic factors such as temperature and photoperiod (Bertoldo et al., 2009). For this reason, further studies in this area are essential.

Knowing the importance of reproduction performance for the growth of the Brazilian pig industry, and recognizing the problems of seasonal infertility as a hurdle to such development, accepting the need for technology to increase the market competitively, the objective of the present study was to assess, through the implantation of a technological device, the effect of temperature and photoperiod on the farrowing rate of sows from four different farms by correcting the evaluated traits by those factors in a statistical model. The final goal of this study was to seek opportunities to minimize the impacts of the autumn syndrome on the reproduction performance of sows.

CHAPTER TWO

LITERATURE REVIEW

2.1 Seasonal infertility and autumn syndrome

Sows' reproductive problems are responsible for up to 60% of production's discards, mainly causing economic losses to producers (Silveira e Amaral, 2009; Sobestiansky et al., 2007). Among these problems, there is seasonal infertility, shown to occur in different production systems, levels of performance, and environmental conditions. These complications are mainly influenced by the period of the year (Auvigne et al., 2010). During this period, the season affects different stages of sows' reproduction. Numerous parameters are reported to influence this infertility, including temperature and photoperiod (Auvigne et al., 2010; Iida and Koketsu, 2013; Sevillano et al., 2016), hormonal changes (Bertoldo et al., 2011; Am-in et al., 2021), boar handling (Andersson et al., 1998; Quesnel et al., 2005), nutrition (Bertoldo et al., 2009; de Rensis et al., 2017; Ross et al., 2017; Langendijk, 2021), vaccinal reactions (Bortoletto et al., 2014) and genetic and ancestral factors (Tast et al., 2002). This establishes the multifactorial origin of seasonal infertility problems and their syndromes.

It is well known that in autumn, reproductive losses tend to increase by 3 to 5% compared to other seasons (Holyoake, 2005). In this context, the autumn syndrome, or autumn abortion syndrome (AAS), began to be researched and has been reported in several studies (Bertoldo et al., 2009; Bertoldo et al., 2011; Bertoldo at al., 2012; Arend et al., 2019; Kirkwood et al., 2021). Its main flaws are the continuous return to estrus (Almond e Bilkei, 2005), which may be related to the size of the follicles at weaning (Lopes et al., 2014); delay in female puberty, mainly associated with gonadotropin secretion (Peltoniemi e Virolainen, 2006; de Rensis et al., 2017); anestrus, due to hormonal changes (Iida e Koketsu, 2013); the lower number of piglets at birth (Wegner et al., 2016), mainly related to heat stress (Hansen et al., 2001); and abortion, which varies from 30 to 110 days of gestation (Pescador, 2008). These clinical signs worry producers and companies in the field, mainly because they result in economic losses directly related to non-productive days (NPD) and lower farrowing rate (FR) of these females (Tast et al., 2002; Bortoletto et al., 2014).

2.2. Factors related to seasonal infertility and autumn syndrome

As previously stated, seasonal infertility is related to many causes. Reviews refer to temperature as one of the main problems associated with the autumn syndrome. Pigs control their body temperature in the form of sensible and latent heat. Conduction, convection, and radiation are the primary mechanisms through which sensible heat loss occurs, and each requires a temperature gradient between the animal and its environment (Collier e Gebremedhin, 2015). According to Mayorga et al. (2019), external environmental factors tend to produce internal variations in the animal's thermal control, influencing the amount of energy exchanged between both, with the need for physiological adjustments for the occurrence of heat balance. As ambient temperature increases, redistribution of blood towards the skin occurs to expand radiant heat loss. If the temperature is high, gradient between the environment and animal becomes smaller or even negative, and the transfer of heat decreases. The amount of heat generated by the pig depends mainly on its size, the metabolizable energy ingested and the efficiency of energy use contained in the feed, called heat increase, when energy is released as heat because of inefficiencies in the metabolism of nutrients (Holden et al., 2008; Barros et al., 2010). Variations in breed, body weight and composition, and diet management can affect the thermoregulatory ability (Renaudeau et al., 2004), which is further complicated by a thick subcutaneous adipose tissue layer impedes sensible heat loss (Collier e Gebremedhin, 2015).

Nowadays, thermal control can currently be executed through mechanisms in the facilities, such as the handling of curtains, or the use of technological equipment (e.g., industrial fans) present in modern pig production; consequently, animals become more sensitive to an uncontrolled temperature (de Rensis et al., 2017). Several studies have sought to understand which temperatures are considered the baseline for sows, concluding that temperatures above 20º C, or varying between 27º C to 30º C (evaporative critical temperature), characterize reproductive problems (Prunier et al., 1997; Auvigne et al., 2010). Heat stress can occur if sows are not found in an environment conducive to dissipating heat (Gourdine et al., 2021; Kasani et al., 2021). Other studies showed that female pigs respond immediately to heat stress by increasing rectal, skin, and mammary gland temperature and breathing more frequently to increase evaporative heat loss (Ross et al., 2015; Johnson et al., 2018; Brandt et al., 2021). According to Boni (2019), the intensity and duration of heat stress are associated with the difficulty of fertilization and can affect embryonic development, especially in the initial phase of pregnancy. It can also cause decreased uterine blood flow, maternal hyperthermia, alterations in the endocrine metabolism of females, higher rates of return to estrus, and lower farrowing rate and litter size (Nardone et al., 2006; He et al., 2019).

As pigs on heat stress depend more on the respiratory methods for heat dissipation (Collier e Gebremedhin, 2015), the main sign to identify if sows are suffering from heat stress is their breathing. Respiratory rate can be monitored when animals are resting. Regular respiration rates for pigs are between 15 and 25 breaths per minute, but when exceeding 40, it's possible they are entering heat stress. If respiration rates rise above 60, the pigs will likely suffer from heat stress (de Oliveira et al., 2018; Mayorga et al., 2019), this will lead to a respiratory alkalosis, condition that affects pigs and is caused by an increase in the pH of the blood due to an excessive loss of carbon dioxide from the body because of the hyperventilation (Engelking, 2015; Cotrell et al., 2020). Other clinical signs in females suffering from temperatures above their thermal comfort zone are an increase in water consumption, a decrease in feed consumption and, as pregnancy progresses, more significant weight losses (Williams et al., 2013); all these factors are directly related to gestation complications.

However, Tummaruk et al. (2010) showed that sows that farrow in warmer seasons of the year, that is, the entire gestation period occurred in the milder temperature season, have larger litter sizes when compared to those that farrow in the cold seasons. This can be explained by the findings of Spencer et al. (2003), which demonstrated that when high heat exposure is made for an extended period, the animals show a physiological adjustment suggestive of an acclimatization process. Considering that there are no changes in reproductive rates only associated with temperature, and knowing that season infertility is a multifactorial problem, other parameters must also be explored to find solutions.

In tropical and subtropical environments, the determining factor for reproduction losses is thought to be heat stress (de Rensis et al., 2017). Even so, researchers stated that seasonal infertility can occur independently of annual environmental temperatures and is more influenced by photoperiod. Studies by Auvigne et al. (2010), carried out in different regions of France, observed that seasonal infertility was a problem even in areas that had an average maximum temperature of 21°C. In Brazil, the problem with temperature varies within the different areas. During the most part of the year, the midwest and southeast regions have the hottest temperatures. The southern part, despite being colder, has a temperate climate, and even so, producers report infertility, leading researchers to assume that the photoperiod may have a strong influence on the problem (Silveira et al., 2006). Both studies corroborate the theory that the effect of the photoperiod is as vital as that of temperature.

Pigs are seasonal breeding animals; that is, they have an endogenous circannual rhythm, which allows the species' reproductive period to occur in short-day seasons (Peltoniemi et al., 2000; Hälli et al., 2008). Melatonin, the hormone responsible for guiding this rhythm, is synthesized and secreted when no light is inhibited in daylight (Haldar and Ahmad, 2010). Thus, when there is a change in day length, from a long to a short day, the animal's organism is signaled by this hormone (Hälli et al., 2008). As pigs convert changes in light duration into a hormonal signal (via melatonin secretion by the pineal gland, modulating gonadotropin secretion), this explains the environmental light effect surpassing temperature and its adaptation process (Peltoniemi and Virolainen, 2006).

Yet, the lightning regimen did not receive sufficient attention in swine production activities compared to other environmental parameters, and it is significantly related to hormone excretion. An extended photoperiod, 16 h light/d, during farrowing and lactation has been used to increase sow milk production, piglet weaning weight, and survival compared with 8 h light/d. An even longer photoperiod, 20 h light/d, positively affected piglet activity and creep feed intake without affecting sow nursing activity (Mabry et al., 1983; Simitzis et al., 2013). Halli et al. (2008) evaluated the effect of short and long days on the reproductive performance of females. They found that, even under an artificial light regimen, even with photoperiod control, females still reacted to changes in seasons, presenting lower farrowing rates during the summer months compared to the winter months. In other hand, Liu et al. (2022) found that illuminance of heat lamps was sufficient to stimulate reproductive and maternal sow activity. Therefore, further studies involving the photoperiod are needed to conclude its effect.

Besides environmental factors, physiological factors can be addressed. Researchers exemplify that exogenous hormones that support follicular development and help maintain pregnancy are already considered an alternative for the syndrome (de Rensis et al., 2017). One example is the use of melatonin. The increase of this hormone stimulates GnRH pulses and, consequently, the secretion of gonadotropins (Ferrari et al., 2012). A study by Arend et al. (2019) showed that melatonin as a supplement in the feed increased the number of follicles in sows but did not show significant changes in other reproductive parameters, reducing estrus in first-farrowing females. The authors recommended further research and proposed that better results can be obtained if melatonin is associated with other factors that influence seasonal infertility.

According to Auvigne et al. (2010), the mechanisms involved in the number of abortions during seasonal infertility represent an interaction between the hypothalamic-pituitary axis, seasonal effects, and the underestimated need to control the environment in which the sows live. Although not yet fully estimated, these interactions are fundamental and directly contribute to the early interruption of gestation during the highest incidence of high temperatures.

Hormonal changes are also directly linked to nutrition. Prunier et al. (1994) reported that reduced nutrient intake during the lactation period is directly related to infertility, as it corroborates with a pre-ovulatory luteinizing hormone (LH) rise, which decreases the quality of follicle luteinization (Likszo et al., 2019). Lower excretion of this same hormone in primiparous and gestating sows decreases the excretion of progesterone from the corpus luteum, affecting reproductive performance (de Rensis et al., 2017). According to Sobestiansky & Barcellos (2007), nutritional problems are increasingly involved with reproductive failures in swine. Factors already mentioned, such as heat stress and long photoperiods during the warmer season, can cause a reduction in feed intake and, with it, an imbalance of the hypothalamic-pituitary-ovarian axis (de Rensis et al., 2017).

Furthermore, nutritional infertility is common in sows due to the high dietary requirements of a complete reproductive cycle, including ovulation, gestation, farrowing and lactation. In many cases, this occurs due to an inadequate nutritional plan established during the formation of gilts, resulting in reproductive problems throughout the animal's life (Anil et al., 2006). Tummaruk et al. (2007) and Bloemhof et al. (2013) reported in their research that this syndrome is more likely to occur in primiparous females due to their lower appetite, endorsing the fact that they still do not have the body score of a sow. Using more energetic feed, such as 'flushing', becomes a solution for these situations, increasing and improving the ovulation rate through high LH peaks, consequently increasing the number of births. However, knowing the best time to adapt the feed of these animals is essential, as research conducted by Mallmann et al. (2020) showed that providing 'flushing' to gilts before insemination after pubertal estrus improved ovulation rate and potential litter size.

Besides melatonin, other hormones should be taken into consideration. Leptin, a hormone produced by adipose tissue, is a mediator between feeding and reproduction, being related to a positive energy balance in the long term; a dietary restriction can lead to a rapid reduction of leptin, bringing reproductive problems (Smith et al., 2006). Insulin, a hormone produced in the pancreas, may also be related, as it acts directly on the ovaries, allowing greater cell nutrition. IGF1, which stimulates cells in the granulosa, works in the production of estradiol, in addition to the formation and functionality of the corpus luteum, being of paramount importance for reproduction (Green et al., 1995; Peltoniemi et al., 2021).

Deficiency of nutrients and non-involving hormones is also a parameter to be aware of. According to González and Silva (2019), vitamin A, iron, zinc, selenium, and calcium deficiency can lead to abortions, infertility, and placental retention. Zile (2001) reported that the retinol-binding protein, which depends on the vitamin A level, is essential in establishing and maintaining pregnancy and embryonic and fetal development. It can also affect sows' milk content, preventing future piglets' development (Amavizca-Nazar et al., 2019). Mahan (2006) mentioned that if the sow's diet does not have adequate levels of minerals to meet their reproductive requirements, they will mobilize their body reserves before lactation, which may cause abortion.

Regarding genetics, seasonal infertility is mainly related to the pig's ancestry, as infertility is observed simultaneously as the European wild sow enters on full anestrus to avoid farrowing during the winter (Tast et al., 2001; Almond and Bilkei, 2005).

Genetics and breeding companies aim to provide females with constant fertility, despite the seasonal variation, to bring profits to producers. Implementing genetic selection in breeders tolerant to changes in photoperiod and ambient temperature is necessary to determine the magnitude of genetic variation in response to these factors (Sevillano et al., 2106; Ross et al., 2017). Bloemhof et al. (2012) showed genetic variation in the farrowing rate in response to ambient temperature variation. However, farrowing rate heritability could be higher in stressed and non-stressed environments, making genetic selection difficult to support seasonal environmental changes. This means that, besides genetic selection, it is necessary to work on environmental parameters to minimize seasonal aspects (Sevillano et al., 2016). According to Brown-Brandl et al. (2001), pigs with high protein deposition, for example, are prone to produce additional heat, which increases the difficulty in maintaining homeothermy in environments with high air temperature. This difficulty makes new heat-stressed breeds. Recently, the percentage of heat production in pigs has increased by around 15% due to the increase in lean meat in the new lines (Oliveira & Formigoni, 2018; Rauw et al., 2020). Bloemhof et al. (2008) found different higher critical temperatures for matrices of two lineages. According to their finding, at temperatures above 25ºC, the Large White pure line has superior reproductive performance, indicating a precise genotype x environment interaction.

Another hypothesis that needs to be more commonly studied is the male influence on seasonal infertility. The act of walking the teaser boar to identify the estrus of sows is handling performed in numerous productions; it is considered in estrus the female that remains immobile with the 'back-pressure test' (Weng and Ndwandwe, 2020). This method has a positive response because the pheromone that this animal exhales stimulates the appearance of estrus in the female swine (Bortolozzo & Wentz, 2004). In the study report by King (2017), it is understood that increasing contact between females and males, paying particular attention to estrus detection procedures during the seasonal period of infertility, helps reduce its effects. However, comparative studies regarding this management in seasonality still need to be conducted. The syndrome also affects male pigs intrinsically because when born from a sow with fertility problems, changes in their puberty time and semen quality will possibly occur, resulting in decreases both in sperm motility and quantity, increasing the proportion of abnormal sperms (Almond & Bilkei, 2005; King, 2017).

The multifactorial nature of this syndrome is evident. Although many authors believe that the main factor influencing it is hormonal changes, several other parameters related to temperature, photoperiod, handling, and sows' health must be controlled. With this review, the need for a study that associates the factors above and evaluates whether, with the help of technologies and handling instructions already offered in pig production, the effects of seasonal infertility can be reduced or ceased.

REFERENCES

Almond, P. K.; Bilkei, G. Seasonal infertility in large pig production units in an Eastern-European climate. Australian Veterinary Journal. 2005; 83 (6): 344-346.

Amavizca-Nazar, A.; Montalvo-Corral, M.; González-Rios, H.; Pinelli-Saavedra, A. Hot environment on reproductive performance, immunoglobulins, vitamin E, and vitamin A status in sows and their progeny under commercial husbandry. Journal of Animal Science and Technology. 2019; 61 (6): 340-351.

Am-In, N; Techakumphu, M.; Kirkwood, R. N. Effect of altering the ratio of exogenous gonadotropins on reproductive performance of primiparous sows during the seasonal infertility period. Canadian Journal of Animal Science. 2019; 99: 202-205.

Andersson, H.; Rydhmerac, L.; Lundström, L.; Wallgren, M.; Andersson, K.; Forsberg, M. F. Influence of artificial light regimens on sexual maturation and boar taint in entire male pigs. Animal Reproduction Science. 1998; 51: 31-43.

Anil, S. S.; Anil, L.; Deen, J. Association of inadequate feed intake during lactation with removal of sows from the breeding herd. Journal of Swine Health Production. 2006; 14 (6): 296–301.

Arend, L. S.; Knox, R. V.; Greiner, L. L.; Graham, A. B.; Connor, J. F. Effects of feeding melatonin during proestrus and early gestation to gilts and parity 1 sows to minimize effects of seasonal infertility. Journal of Animal Science. 2019; 4635–4646.

Auvigne, V.; Leneveu, B.; Jehannin, C.; Peltoniemi, O.; Salle, E. Seasonal infertility in sows: A five year field study to analyze the relative roles of heat stress and photoperiod. Theriogenology. 2010; 74: 60–66.

Barros, P. C.; Oliveira, V.; Chambó, E. D.; Souza, L. C. Aspectos práticos da termorregulação em suínos. Revista Nutritime. 2010; 7 (3): 1248-1253.

Bertoldo, M. J.; Grupen, C. G.; Thomson, P. C.; Evans, G.; Holyoake, P. K. Identification of sow-specific risk factors for late pregnancy loss during the seasonal infertility period in pigs. Theriogenology. 2009; 72 (3): 393-400.

Bertoldo, M. J.; Holyoake, P. K.; Evans, G.; Grupen, C. G. Seasonal effects on oocyte developmental competence in sows experiencing pregnancy loss. Animal Reproduction Science. 2011; 124: 104-111.

Bertoldo, M. J.; Holyoake, P. K.; Evans, G.; Grupen, C. G. Seasonal variation in the ovarian function of sows. Reproduction, fertility, and development. 2012; 24 (6): 822-834.

Bloemhof, S.; Kause, A.; Knol, E. F.; Van Arendon, J. A. M.; Misztal, I. Heat stress effects on farrowing rate in sows: Genetic parameter estimation using within-line and crossbred models. Journal of Animal Science. 2012; 90: 2109–2119.

Bloemhof, S.; Mathur, P. K.; Knol, E. F.; Van Der Waaii, E. H. Effect of daily environmental temperature on farrowing rate and total born in dam line sows. Journal of Animal Science. 2013; 91: 2667–2679.

Bloemhof, S.; Van Der Waaij, E.H.; Merks, J.W.M.; Knol, E.F. Sow line differences in heat stress tolerance expressed in reproductive performance traits. Journal of Animal Science. 2008; 86: 3330-3337.

Boni, R. Heat stress, a serious threat to reproductive function in animals and humans. Molecular Reproduction and Development. 2019; 86 (10): 1307-1323.

Bortoletto, C.; Ferreira, G. F.; Gasser, B.; Nakamura, A. M.; Almeira, H. M. De S.; de Oliveira, L. G. Principais causas de problemas reprodutivos em porcas. Revista Científica de Medicina Veterinária. 2014; 23.

Bortolozzo, F.; Wentz, I. Intervalo desmame-estro e anestro pós lactacional em suínos. Editora Pallotti. 2004.

Brandt, P.; Bjerga, B.; Pedersen, P.; Sørensenc, K. B. S.; Rongd, L.; Huangd, T.; Zhangd, G. The effect of air temperature, velocity and humidity on respiration rate and rectal temperature as an expression of heat stress in gestating sows. Journal of Thermal Biology. 2022; 104.

Brown-Brandl, T.; Eigenberg, R. A.; Nienaber. J. A.; Kachman, S. D. Thermoregulatory profile of a newer genetic line of pigs. Livestock Production Science. 2001; 253-260.

Collier, R. J.; Gebremedhin, K. G. Thermal Biology of Domestic Animals. Annual Review of Animal Biosciences. 2015; 3: 10-20.

Cottrell, J.J.; Furness, J.B.; Wijesiriwardana, U.A.; Ringuet, M.; Liu, F.; DiGiacomo, K.; Leury, B.J.; Clarke, I.J.; Dunshea, F.R. The Effect of Heat Stress on Respiratory Alkalosis and Insulin Sensitivity in Cinnamon Supplemented Pigs. Animals. 2020; 10: 690.

De Oliveira, R. F.; Ferreira, R. A.; Abreu, L. H. P.; Tadayuki, Y.; Lourençoni, D. Estimation of respiratory frequency and rectal temperature on pigs in heat stress by fuzzy logic. Engenharia Agrícola. 2018; 38 (4): 457-470.

De Rensis, F.; Ziecik, A. J.; Kirkwood, R. N. Seasonal infertility in gilts and sows: aetiology, clinical implications and treatments. Theriogenology. 2017; 96: 111-117.

Engblom, L.; Lundeheim, N.; Dalin, A.; Andersson, K. Sow removal in Swendish commercial herds. Livestock Science. 2007; 106: 76–86.

Engelking, L. R. Chapter 91 - Respiratory Alkalosis. Textbook of Veterinary Physiological Chemistry (Third Edition), Academic Press. 2015; 590-595.

Ferrari, C. V.; Bardella, P. E.; Bortolozzo, F. P.; Wentz, I. Infertilidade sazonal associada ao estresse pelo calor em fêmeas suínas: impactos produtivos e medidas de controle. A Hora Veterinária. 2012; 32 (188): 44-47.

González, F. H. D.; Silva, S. C. Minerais e vitaminas no metabolismo animal. Laboratório de Análises Clínicas Veterinárias, Universidade Federal do Rio Grande do Sul. 2019.

Gourdine, J. L.; Rauw, W. M.; Gilbert, H.; Poullet, N. The Genetics of Thermoregulation in Pigs: A Review. Frontiers in Veterinary Science. 2021; 13 (8).

Green, M. L.; Simmen, R. C. M.; Simmen, F. A. Developmental regulation of steroidogenic enzyme gene expression in the periimplantation porcine conceptus: a paracrine role for insulin-like growth factor-I. Endocrinology. 1995; 136: 3961–3970.

Haldar, C.; Ahmad, R. Haldar, R. Photoimmunomodulation and melatonin. Journal of Photochemistry and Photobiology. 2010; 98: 107-117.

Hälli, O.; Tast, A.; Heinonen, M.; Munsterhjelm, C.; Valros, A.; Peltoniemi, O. A. T. Short or long day light regimes may not affect reproductive performance in the sow. Reproduction in Domestic Animals. 2008; 43(6): 643-770.

Hansen, P. J.; Drost, M.; Rivera, R. M.; Paula-Lopes, F. F.; Al-Katanani, Y. M.; Krininger, C. E. Adverse impact of heat stress on embryo production: causes and strategies for mitigation. Theriogenology. 2001; 55: 91-103.

He, J.; Zheng, W.; Lu, M.; Yang, X.; Xue, Y.; Yao, W. A Controlled heat stress during late gestation affects thermoregulation, productive performance, and metabolite profiles of primiparous sow. Journal Of Thermal Biology. 2019; 81: 33-40.

Holden, J. P.; Shurson, G. C.; Ewan, R. C. Dietary Energy for Swine. Pork Industry Handbook: U.S. Pork Center of Excellence. 2006.

Holyoake, T. What do we know of pregnancy loss during seasonal infertility? Proceedings of the Australian Association of Pig Veterinarians Gold Coast. 2005; 13-17.

Iida, R.; Koketsu, Y. Delayed age of gilts at first mating associated with photoperiod and number of hot days in humid subtropical areas. Animal Reproduction Science. 2013; 134: 115-120.

Johnson, J. S. Heat Stress: impact on livestock well-being and productivity and mitigation strategies to alleviate the negative effects. Animal Production Science. 2018; 58:1404–1413.

Kasani, P. H.; Oh, S. M.; Choi, Y. H.; Ha, S. H.; Jun, H.; Park, K. H.; Ko, H. S.; Kim, J. E.; Choi, J. W.; Cho, E. S.; Kim, J. S. A computer vision-based approach for behavior recognition of gestating sows fed different fiber levels during high ambient temperature. Journal of Animal Science and Technology. 2021; 63 (2): 367-379.

King, R. H. Seasonal infertility in pigs: what have we achieved and where are we up to? Animal Production Science. 2017; 57: 2325–2330.

Kirkwood, R. N.; Aherne, F. X. Foxcroft, G. R. Effect of gonadotropin at weaning on reproductive performance of primiparous sows. Swine Health Production. 1998; 6: 51-55.

Langendijk, P. Latest Advances in Sow Nutrition during Early Gestation. Animals. 2021; 11.

Liu, K.; Liu, L.; Tai, M.; Ding, Q.; Yao, W.; Shen, M. Light from heat lamps affects sow behaviour and piglet salivary melatonin levels. Animal. 2022; 6 (6).

Likszo, P.; Skarzynski, D. J.; Jalali, B. M. Proteomic analysis of porcine pre-ovulatory follicle differentiation into corpus luteum. Frontiers in Endocrinology. 2019.

Lopes, T. P.; Sanchez-Osorio, J.; Bolarin, A.; Martinez, E. A.; Roca, J. Relevance of ovarian follicular development to the seasonal impairment of fertility in weaned sows. The Veterinary Journal. 2014; 199 (3): 382-386.

Mabry, J.W.; Coffey, M. T.; Seerley, R. W. A comparison of an 8- versus 16-hour photoperiod during lactation on suckling frequency of the baby pig and maternal performance of the sow. Journal of Animal Science. 1983; 57: 292-295.

Mahan, D. The Changing Mineral Status of High Producing Sows - What are their needs and when are the critical periods? Swine Nutrition Conference Proceeding. 2006; 17-27.

Mallmann, A. L.; Arend, L. S.; Oliveira, G. S.; Mellagi, A. P. G.; Ulguim, R. R.; Bernardi, M. L.; Bortolozzo, F. P.; Knox, R. V. Effects of flush feeding strategy before breeding on reproductive performance of modern replacement gilts: impacts on ovulation rate and litter traits. American Society of Animal Science. 2020.

Mayorga, E. J.; Renaudeau, D.; Ramirez, B. C.; Ross, J. W.; Baumgard, L. H. Heat stress adaptations in pigs. Animal Frontiers. 2019; 9 (1): 54–61.

Nardone, A.; Ronchi, B.; Lacetera, N.; Bernabucci, U. Climatic effects on productive traits in livestock. Veterinary Research Communications. 2006; 30: 75-81.

Oliveira, F. A.; Formigoni, A. S. Produção de calor em suínos e suas formas de determinação. ANAIS da XI Mostra Científica FAMEZ: UFMS. 2018.

Peltoniemi, O. A. T.; Tast, A.; Love, R. J. Factors effecting reproduction in the pig: seasonal effects and restricted feeding of the pregnant gilt and sow. Animal Reproduction Science. 2000; 60: 173-84.

Peltoniemi, O. A. T.; Virolainen, J. V. Seasonality of reproduction in gilts and sows. Reproduction Supplement. 2006; 62: 205-218.

Peltoniemi, O.; Yun, J.; Björkman, S.; Han, T. Coping with large litters: the management of neonatal piglets and sow reproduction. Journal of Animal Science and Technology. 2021; 63 (1): 1-15.

Pescador, C. A. Causas infecciosas de abortos e natimortalidade de suínos no sul do Brasil. Tese. Universidade Federal do Rio Grande do Sul. 2008.

Prunier, A.; De Bragança, M. M.; Dividich, J. Influence of high ambient temperature on performance of reproductive sows. Livestock Production Science. 1997; 52 (2): 123-133.

Prunier, A.; Dourmad, J. Y.; Etienne, M. Effect of light regimen under various temperatures on sow and litter performance. Journal of Animal Science. 1994; 72: 1461-1466.

Quesnel, H.; Boulot, S.; Cozler, L. E. Les variations saisonnières des performances de reproduction chez la truie. INRA Production Animale. 2005; 18 (2): 101-110.

Rauw, W. M.; de la Peña, E.; Gomez-Raya, L.; Cortés, L. A. G.; Ciruelos, J. J.; Izquierdo, E. G. Impact of environmental temperature on production traits in pigs. Scientific Reports. 2020; 10 (1): 2106.

Renaudeau, D.; Mandonnet, N.; Tixier-Boichard, M.; Noblet, J.; Bidanel, J. Attenuate the effects of high ambient temperature on pig performance: the genetic selection. Productions Animales. 2004; 17(2): 93-108.

Renaudeau, D.; Quiniou, N.; Noblet, J. Effects of exposure to high ambient temperature and dietary protein level on performance of multiparous lactating sows. Journal of Animal Science. 2001; 79 (5): 1240-1249.

Ross, J. W.; Hale, B. J.; Gabler, N. K.; Rhoads, R. P.; Keating, A. F.; Baumhard, L. H. Physiological consequences of heat stress in pigs. Animal Production Science. 2015; 55:1381–1390.

Ross, J. W.; Hale, B. J.; Seibert, J. T.; Romoser, M. R.; Adur, M. K.; Keating, K. A.; Baumgard, L. H. Physiological mechanisms through which heat stress compromises reproduction in pigs. Molecular Reproduction and Development. 2017; 84:934–945.

Sevillano, C. A.; Mulder, H. A.; Rashidi, H.; Mathur, P. K.; Knol, E. F. Genetic variation for farrowing rate in pigs in response to change in photoperiod and ambient temperature. Journal of Animal Science. 2016; 3185-3197.

Silveira, P. R. S.; Amaral, A. Análise dos fatores mais comuns relacionados com falhas reprodutivas em modernos rebanhos suínos. Revista Brasileira de Reprodução Animal. 2009; 6: 187-193.

Silveira, P. R.; Mendes, A.; Coldebella, A. Variações Sazonais no Desempenho Reprodutivo de Porcas. EMBRAPA. 2006.

Simitzis, P.E.; Veis, D.; Demiris, N.; Charismiadou, M. A.; Ayoutanti, A.; Deligeorgis, S. G. The effects of the light regimen imposed during lactation on the performance and behaviour of sows and their litters. Applied Animal Behaviour Science. 2013; 144: 116-120.

Sobestiansky, J.; Barcellos, D. Doenças dos Suínos. Cânone Editorial. 2007.

Spencer, J. D.; Boyd, R. D.; Cabrera, R. Early weaning to reduce tissue mobilization in lactating sows and milk supplementation to enhance pigs weaning weight during extreme heat stress. Journal of Animal Science. 2003; 81 (8): 2041-2052.

Tast, A.; Peltoniemi, O. A. T.; Virolainen, J. V.; Love, R. J. Early disruption of pregnancy as a manifestation of seasonal infertility in pigs. Animal Reproduction Science. 2002; 74: 75–86.

Tummaruk, P.; Tantasuparuk, W.; Techakumphu, M.; Kunavongkrit, A. Age, body weight and backfat thickness at first observed oestrus in crossbred

Landrace×Yorkshire gilts, seasonal variations and their influence on subsequence reproductive performance. Animal Reproduction Science. 2007; 99: 167-181.

Tummaruk, P.; Tantasuparuk, W.; Techakumphu, M.; Kunavongkrit, A. Seasonal influences on the litter size at birth of pigs are more pronounced in the gilt than sow litters. Journal of Agricultural Science. 2010; 148: 421–432.

Wegner, K.; Lambertz, C.; Das, G.; Reiner, G.; Gauly, M. Effects of temperature and temperature-humidity index on the reproductive performance of sows during summer months under a temperate climate. Animal Science Journal. 2016; 11: 1334-1339.

Weng, R. C.; Ndwandwe, S. B. Application of modern estrus detection protocols in small scale Hybrid Black pig production systems. Journal of Agricultural and Crop Research. 2020; 8 (6): 120-131.

Williams, A. M.; Safranski, T. J.; Spiers, D. E.; Eichen, P. A.; Coate, E. A.; Lucy, M. C. Effects of a controlled heat stress during late gestation, lactation, and after weaning on thermoregulation, metabolism, and reproduction of primiparous sows. Journal of Animal Science. 2013; 91: 2700-2714.

Zile, M. H. Function of vitamin A in vertebrate embryonic development. The Journal of Nutrition. 2001; 3 (3): 705–708.

CHAPTER THREE

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Strategies to minimize the negative impact of autumn syndrome on sow reproduction performance

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Abstract

Achieving high levels of reproduction performance under different climate conditions is one of the concerns in modern pig production worldwide. One of its challenges is to maintain a constant temperature, avoiding intensive heat or low temperature in the barns that can negatively affect the reproduction performance of the herd. Although modern sows have been bred to adapt to temperature changes through the year, a decrease in reproduction performance can occur in certain seasons, especially in late summer and early autumn, which is known as autumn syndrome. To increase the production efficiency of pig systems, it is necessary to search for alternatives that can eliminate or mitigate the seasonal reduction in reproduction performance of sows. This study aimed to assess the influence of temperature, photoperiod, and luminosity on the farrowing rate of sows through a statistical model. Reproduction data of purebred Large White sows together with temperature, photoperiod, and luminosity information from four farms collected in 2020 and 2021 were evaluated in this study. In total, five treatments were evaluated in this study: non-corrected farrowing rate (T1), farrowing rate with temperature correction (T2), farrowing rate with temperature and photoperiod correction (T3), farrowing rate with luminosity correction (T4), and farrowing rate with temperature and luminosity correction (T5). For the first year (2020), temperature information were obtained from meteorological stations of the Instituto Nacional de Meteorologia (INMET - Brazil). Photoperiod was modelled by taking the sine of the day of the first insemination within a year. The treatments evaluated for this year were T1, T2 e T3, as luminosity information is not available at INMET. In 2021, after the installation of technological devices (*data logger*) in each farm, temperature and luminosity information were also collected and the treatments for this year were T1, T2, T3, T4 e T5. For both years, the maximum daily temperature was analyzed to estimate heat load. A linear model was built on the software R Studio to verify the influence of correct temperature, photoperiod, and luminosity on the farrowing rate of sows. The effect of changing luminosity on reproductive data was estimated based on root means square error (RMSE) analysis. For the first and second years, only one of the farms did not show problems with autumn syndrome. The temperature and photoperiod correction (T3) yielded better farrowing rates for both years. These results indicate that temperature and photoperiod have an influence on the farrowing rate of sows, and that applying strategies that control these parameters could improve the reproduction performance of farms that present autumn syndrome and therefore a seasonal reduction in reproduction performance.

Keywords: farrowing rate; seasonal infertility; swine reproduction.

1. Introduction

Pork production has achieved remarkable developments worldwide in the last decades. Brazil encounters a highlighted position in this market, as it ranks as the world’s fourth-largest producer and exporter of pork [1]. Aiming to keep increasing the worldwide pig production, the pig industry needs to search for technological alternatives to improve their products' efficiency, sustainability and rentability. The use of state-of-the-art technology in genetics and breeding, nutrition, housing, and handling of pigs improves performance and, consequently, increases pork production with high-quality standards [2].

Genetics are one of the main parameters when assessing pigs’ development. Nowadays, genetic companies aim to breed robust females that are able to achieve high reproduction performance despite the seasonal variation or other challenges that may happen at the herds.

With this, genetic companies aim to bring profit to producers while creating resilience against many problems, such as environmental sensitivity [3, 4]. Failures in the reproduction performance of sows are frequent on farms, which shows the importance of promoting consciousness and solutions to the reproductive performance of these animals [5]. Return to estrus, abortions, longer weaning-to-estrus intervals (WEI), longer non-productive days (NPD), lower farrowing rates and stillbirths are the most known reproductive problems. It is essential to mention that these clinical signs, although associated with diseases, can be caused by several factors, infectious and non-infectious [6, 7].

As one of the non-infectious factors, seasonal infertility is a critical known reproductive problem characterized by a considerable reduction in farrowing rate [8]. This infertility is associated with many conditions, such as environment [9, 10], hormonal changes, unhealthy animals [11, 12], nutrition and genetics [13]. In Brazil, one of the main challenges to sows' reproduction is the climate, which can directly influence the sector's productivity. Added to this, the ineffective thermoregulation system of pigs stands out, responsible for the difficulty in keeping their temperature constant, causing a decrease in their reproductive performance [14, 15]. Pigs need milder temperatures to be under thermal comfort. The range known as the thermoneutrality zone (temperature range in which the animal is in thermal comfort) is determined by the lower critical temperature (LCT), below 12 °C, and upper critical temperature (UCT), above 22 °C [12, 16]. If the temperature on barn is over the female's UCT, they find themselves under heat stress. Heat stress is directly associated with the difficulty of fertilization and can affect embryonic development, especially in the initial phase of pregnancy. It can also cause decreased uterine blood flow, maternal hyperthermia, alterations in the endocrine metabolism of females, higher rates of return to estrus, and lower farrowing rate and litter size [17, 18]. Another critical parameter to consider is the photoperiod. As pigs are seasonal animals, that is, they have an endogenous circannual rhythm, which allows the species' reproductive period to occur in short-day seasons [19, 20]; the change in the duration of sunlight exposure, which regulates hormonal activity, is reduced in the period between summer and autumn [21, 22]. This infertility period is an autumn or autumn abortion syndrome (AAS) [22, 23].

Striving to mitigate problems in reproduction involving seasonal infertility, new technologies are being implemented, such as automatic recorders of temperature and light through sensors (*data loggers*), the use of artificial lamps in barns, which guarantee the ideal period of the morning for sows, and exhaust fans, for better control of temperature. Knowing the importance of reproduction for the growth of the pig industry and recognizing the problems of seasonal infertility as a hurdle to such development, we aimed to assess the influence of temperature, photoperiod, and luminosity on the farrowing rate of sows through a statistical model in order to minimize the impacts of the autumn syndrome in pig herds.

2. Materials and methods

2.1 Data set

Data from four farms located in different states of Brazil were evaluated in this study. Two farms were located in the state of Paraná and one in Santa Catarina, both in the south region of Brazil, while one farm was located in the state of Goiás, in the middle-west region. The number of sows per farm ranged from 200 to 3000.

Primary temperature data were collected from January 2020 to December 2020 on the website of the Instituto Nacional de Meteorologia (INMET) from meteorological stations located near farms selected for the study (with the closest being 2.5 km and the farthest being 126 km) to obtain maximum daily temperature data for that year. Subsequently, reproductive records available from Topigs Norsvin farms were accessed. Each reproductive history collected included: sow identification number, farrowing order, date of first insemination, date of successful insemination, boar ID, date of farrowing, duration of pregnancy, farrowing rate, litter size, weaning to first insemination interval, first to last insemination interval and weaning to positive gestation interval. To detect the influence of seasonal infertility, reproduction parameters were evaluated using Sevillano et al.'s previous methodology [10]. Treatments considered for this year were:

- T1: non-corrected farrowing rate.
- T2: farrowing rate with temperature correction.
- T3: farrowing rate with temperature and photoperiod correction.

After evaluation, the facilities and handling of the respective farms were changed (described below) to improve these reproductive indexes. From January 2021 to December 2021, new records were collected for further evaluation. Treatments evaluated this year were T1, T2, T3 and:

- T4: farrowing rate with luminosity correction.
- T5: farrowing rate with temperature and luminosity correction.

2.2 Facilities changes

2.2.1 Ambient temperature

Seeking precision, easier handling and better access in obtaining and evaluating temperature data, the company chose to use a technological device, installing a *data logger* (HOBO MX1104 – Onset Computer Corporation – Bourne, MA) in the four farms. This device captures the temperature and relative humidity on the farm and stores its records in a cloud system chosen by the company.

Following the methodology of Bloemhof et al. [16], for farrowing rate, the maximum daily temperature of the 21st day before the first insemination of a sow was utilized for the evaluation or temperature influence, as this specific day can be used as a predictive measure of heat stress in commercial breeder farms. Ambient temperatures were used to estimate heat load, defined as the amount of thermal energy needed to be added to a space to keep the temperature within an acceptable range. The heat load is used to prevent the local temperature from exceeding the sows' upper critical temperature (UCT), which is responsible for the onset of thermal stress. A UCT of 19.2°C was used for reproductive data, following the methodologies of Bloemhof et al. [27] and Sevillano et al. [10]. Each farm's average maximum temperature for each month was calculated to compare exceptions related to UCT.

2.2.2 Photoperiod and luminosity

Before changes, photoperiod management was controlled only by natural light and curtain handling, with no possibility of capturing daily lighting intensity, time, and the number of hours of light. For the first year's evaluation (2020), December 21 was the longest day of the year, and September 21 was the Spring equinox for the Southern Hemisphere, adapted from methodology by Bergsma and Hermesch [28]. For the second year (2021), with the *data logger* and the temperature, the device measured the luminosity of each barn on the farms through daily Lux (lx) quantity.

2.3 Statistical analysis

Statistical analyses were performed in R Software version 4.1.0 (R Foundation for Statistical Computing – Vienna, Austria). A linear model was built using package 'lma4' to verify the influence of correct temperature and photoperiod on the farrowing rate of sows. For the first year, daylight was modelled based on the sine of the amount of lux from the first insemination day of each female, following the methodology of Sevillano et al. [10]. For the second year, as sows can recognize and adapt to changes in photoperiod, and consequently luminosity [29], the effect of changing lux on reproductive data was estimated based on mean root square (RSME) analysis for each day. For other parameters, packages ‘reshape2’, ‘dplyr’, and ‘labelling’ were used to organize, summarize, and visualize data. Akaike Information Criterion (AIC) was used to compare the models, regarding the temperature parameter (measured in ^{o} C), applied with INMET and data logger parameters.

3. Results

For both years, the farrowing rate with correct temperature and luminosity above 1, when presented in graphs, is an artefact of the statistical model used. Farrowing Rate (FR) is a binary characteristic; in this model, it was considered linear. This detail did not change the parameter evaluation, as it was possible to observe equally how the heat load and the variation in luminosity impact the FR. Regarding the AIC, when the model used INMET parameters for temperature data, it presented a value of 142.4151, and when using the data logger parameters, 1065.42.

The figures below descriptively present the influence of temperature and daylight compared to the non-corrected farrowing rate for 2020. It is important to emphasize that, as the autumn syndrome effects are being considered, only the months related to the syndrome were evaluated (January to June). Table 1 presents the percentage rates of farrow losses on each farm.

Table 1 - Percentage rates of farrow losses on farms 1, 2, 3 and 4 in 2020.

Months	Farms											
	1 (n=550)			2 (n=700)			3 (n=200)			4 (n=3000)		
	T	L	%	T	L	%	T	L	%	T	L	%
1	119	10	8.40%	148	16	10.81%	27	14	51.85%	579	91	15.72%
2	120	7	5.83%	176	11	6.25%	41	21	51.22%	490	65	13.27%
3	137	6	4.38%	167	19	11.38%	36	11	30.56%	519	77	14.84%
4	115	7	6.09%	167	3	1.80%	28	0	0.00%	474	54	11.39%
5	129	6	4.65%	169	8	4.73%	25	3	12.00%	586	74	12.63%
6	126	4	3.17%	168	10	5.95%	25	3	12.00%	477	64	13.42%
7	114	3	2.63%	160	9	5.63%	22	4	18.18%	561	67	11.94%
8	117	4	3.42%	180	23	12.78%	33	3	9.09%	516	74	14.34%
9	123	8	6.50%	161	21	13.04%	31	5	16.13%	496	58	11.69%

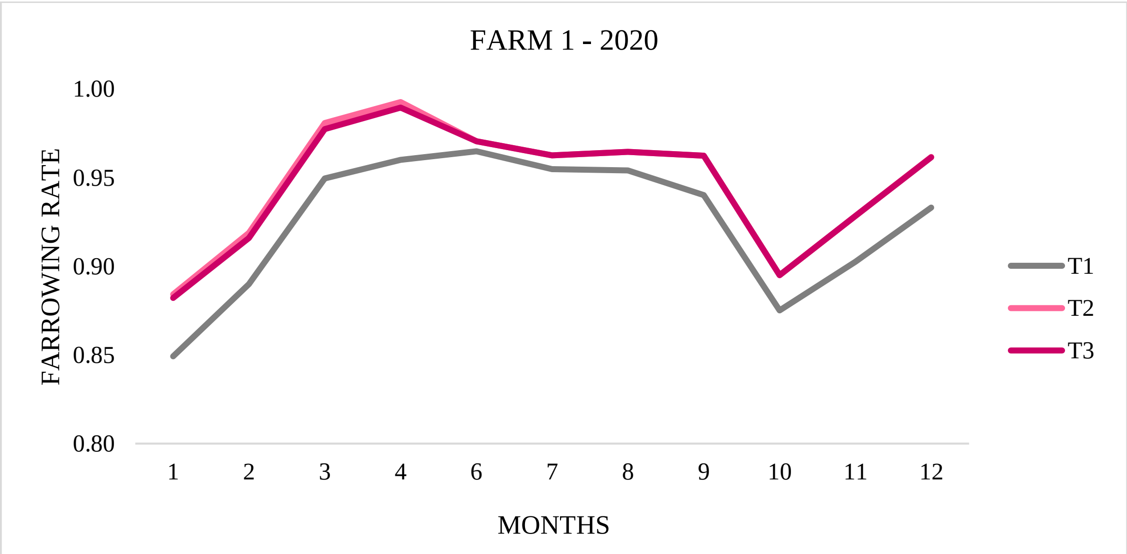
10	117	9	7.69%	165	13	7.88%	25	4	16.00%	562	52	9.25%
11	136	9	6.62%	173	11	6.36%	21	2	9.52%	548	64	11.68%
12	117	7	5.98%	154	15	9.74%	21	1	4.76%	516	78	15.12%

n: total number of sows on each farm.
T: a total of inseminated sows in that month.
L: a total of return-to-estrus sows (non-functional insemination/reproduction loss).
%: percentage of L compared to T.

It is important to note that, for all graphs, the percentage of losses from Table 1 differs from T1, which is the non-corrected farrowing rate, as T1 has a phenotypical correction related to cycle number, gestation length, sow lineage and service sire from the model.

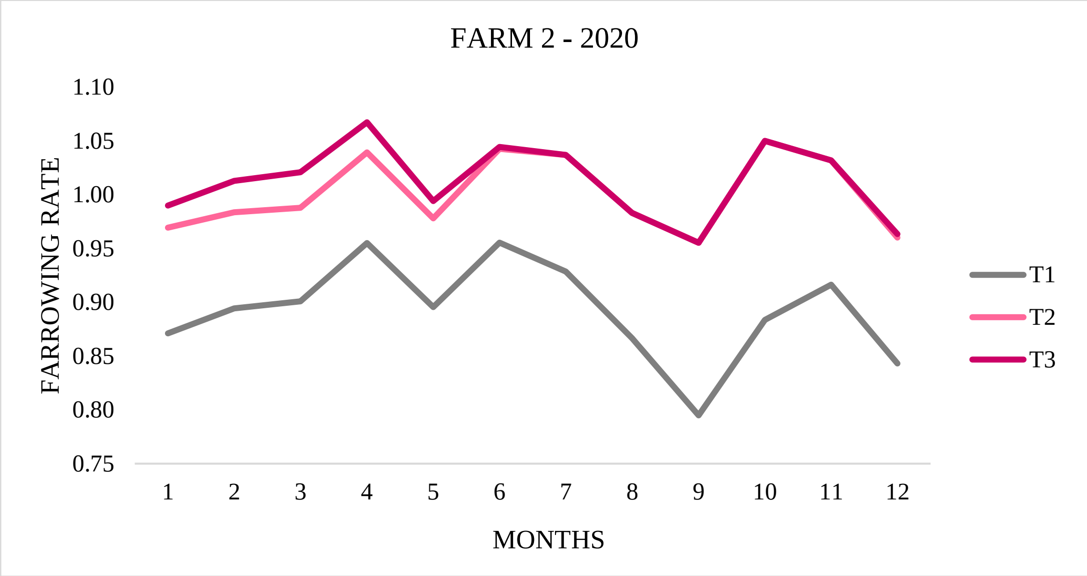
Farm 1 (figure 1), considered a model farm, shows that T2 and T3 behave similarly, having better farrowing rates when compared to the non-corrected farrowing rate (T1). May was not evaluated for this farm as there needed to be more sufficient data. Farm 2 presented a greater than 10% farrowing rate loss during January and March (table 1), and treatments T2 and T3 had greater FR levels than T1 (figure 2). Farm 3 presented a greater than 10% loss rate during all the summer to autumn months (table 1), and T3 had had greater FR levels when compared to T1 and T2 (figure 3). As for farm 4 (figure 4), there was a high rate of greater than 10% losses all year (table 1). For the autumn syndrome months, T2 presented better rates than T1 and T3.

Figure 1 – Correction of temperature and daylight on the farrowing rate of farm 1 during 2020.



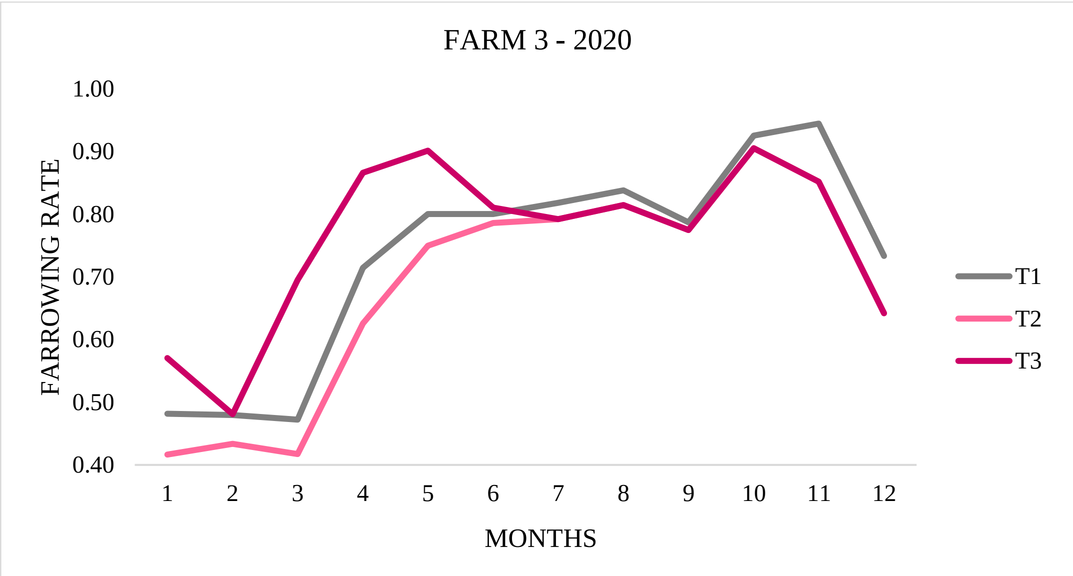
T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction.

Figure 2 - Correction of temperature and daylight on the farrowing rate of farm 2 in 2020.



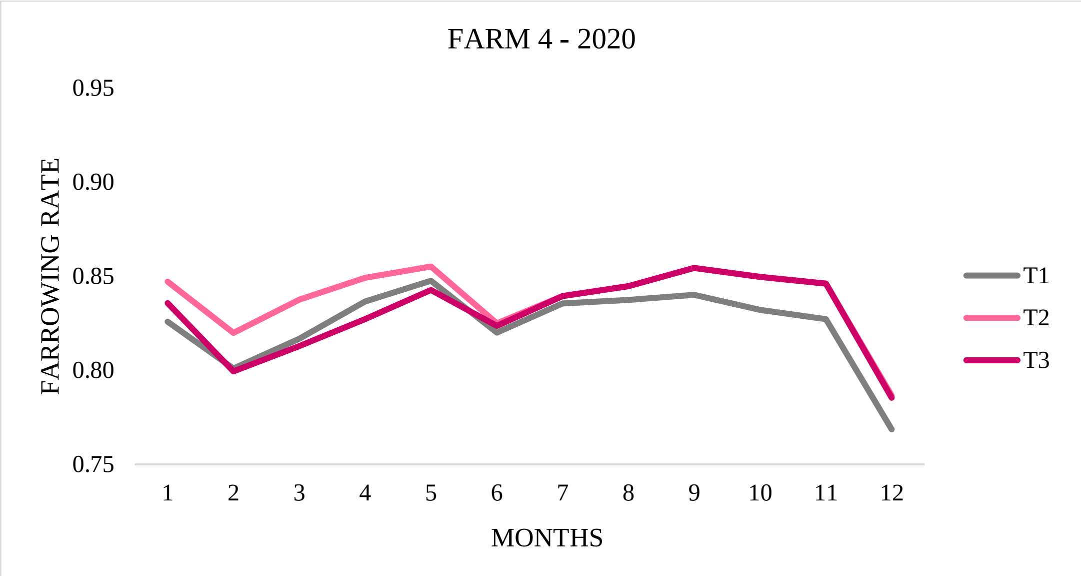
T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction.

Figure 3 - Correction of temperature and daylight on the farrowing rate of farm 3 during the year 2020.



T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction.

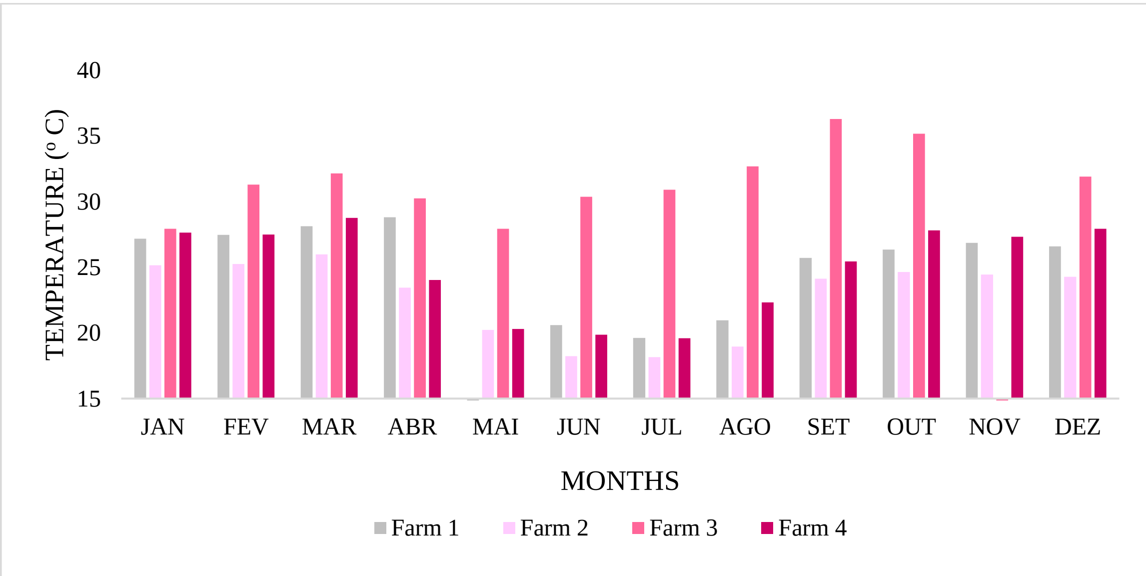
Figure 4 - Correction of temperature and daylight on the farrowing rate of farm 4 during 2020.



T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction.

The average maximum temperatures for each month of 2020 show that the UCT of 19.2 ºC was mainly not reached, and temperatures from January to June remained above ideal. For farm 1, May had no temperature data from INMET.

Figure 5 – Average maximum temperature for farms 1, 2, 3 and 4 during 2020.



After the first year of evaluation, technological enhancements were applied to farms (described above). Following the same evaluated months (January to June), the figures below descriptively present the influence of correct temperature and luminosity compared to the non-corrected farrowing rate for 2021. Table 2 shows the percentage rates of farrow losses on each farm.

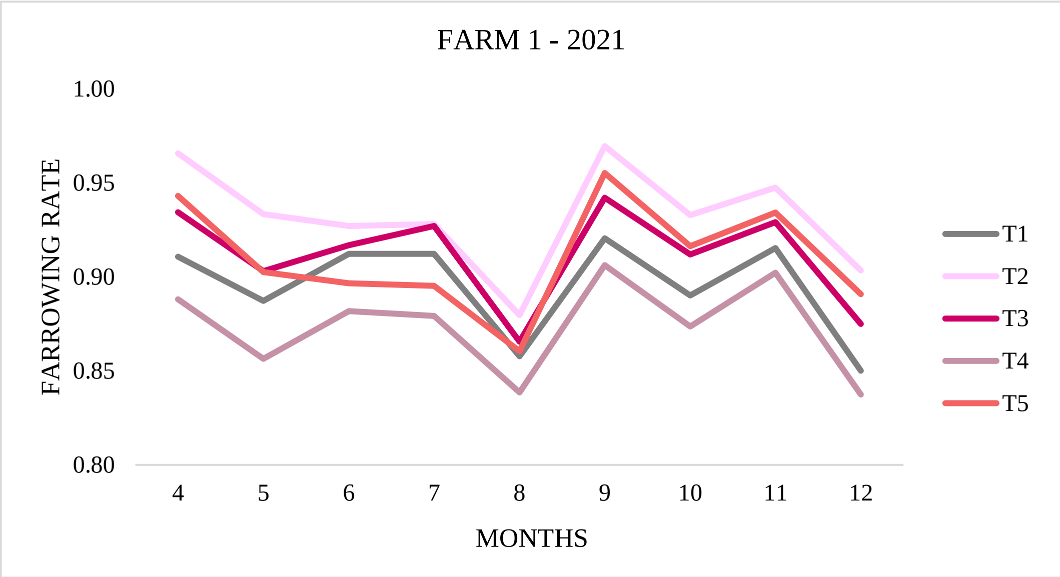
Table 2 - Percentage rates of farrow losses on farms 1, 2, 3 and 4 in the year 2021.

Months	**Farms**											
	1 (n=550)			**2 (n=700)**			**3 (n=200)**			**4 (n=3000)**		
	T	**L**	**%**	**T**	**L**	**%**	**T**	**L**	**%**	**T**	**L**	**%**
1	128	11	8.59%	168	12	7.14%	24	3	12.50%	569	83	14.59%
2	118	6	5.08%	154	10	6.49%	23	2	8.70%	513	93	18.13%
3	141	13	9.22%	165	17	10.30%	41	5	12.20%	573	104	18.15%
4	117	8	6.84%	155	8	5.16%	21	1	4.76%	558	115	20.61%
5	135	11	8.15%	178	16	8.99%	22	1	4.55%	502	83	16.53%
6	121	9	7.44%	145	10	6.90%	22	3	13.64%	479	65	13.57%
7	119	5	4.20%	165	18	10.91%	22	0	0.00%	627	69	11.00%
8	145	19	13.10%	185	17	9.19%	22	0	0.00%	525	43	8.19%
9	117	5	4.27%	147	7	4.76%	22	0	0.00%	511	55	10.76%
10	135	11	8.15%	167	14	8.38%	22	1	4.55%	555	52	9.37%
11	128	11	8.59%	167	20	11.98%	23	0	0.00%	477	50	10.48%
12	119	13	10.92%	161	10	6.21%	24	2	8.33%	540	49	9.07%

n: total number of sows on each farm.
T: a total of inseminated sows in that month.
L: a total of return-to-estrus sows (non-functional insemination/reproduction loss).
%: percentage of L compared to T.

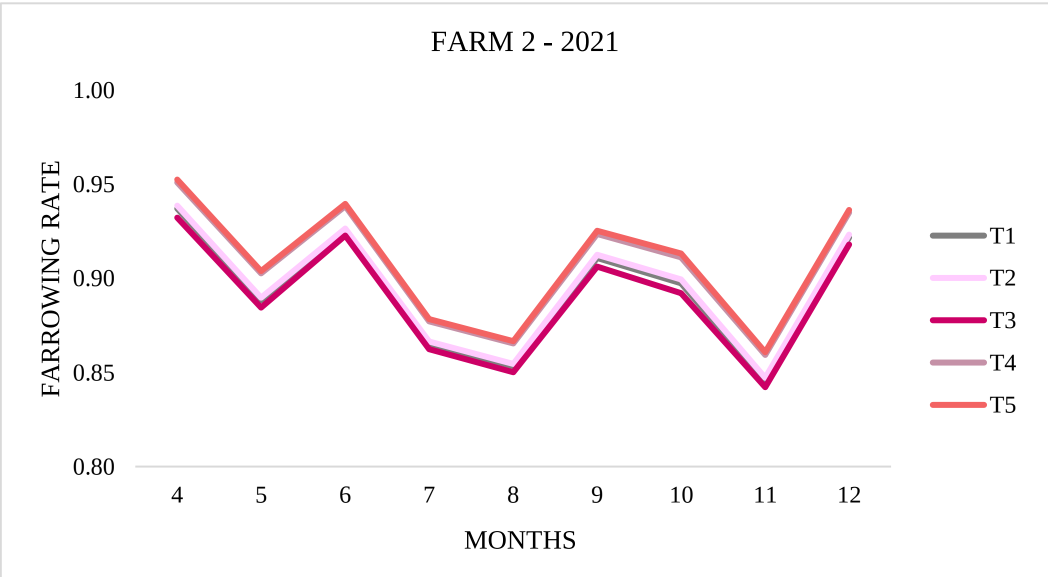
Farm 1 (figure 6) presented all treatments T2 and T3 with better rates than non-corrected FR. No rates on farrowing losses for this farm were above 10% (table 2). Farm 2 (figure 7) showed better rates for T5. March was the only month with higher than 10% farrowing losses (table 2), but it could not be represented on the model as there was no sufficient ambient data. For both farms with data loggers, only April, May and June were evaluated.

Figure 6 – Correction of temperature and lux on the farrowing rate of farm 1 during the year 2021, utilizing data logger data.



T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction;
T4: farrowing rate with luminosity correction;
T5: farrowing rate with temperature and luminosity correction.

Figure 7 – Correction of temperature and luminosity on the farrowing rate of farm 2 during the year 2021, utilizing data logger data.



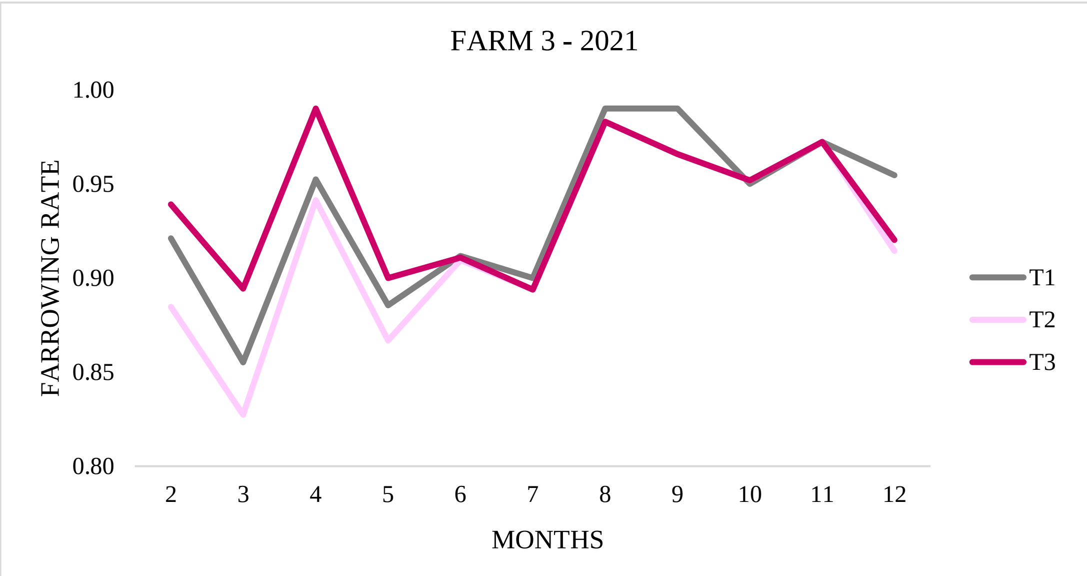
T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;

T3: farrowing rate with temperature and photoperiod correction;
T4: farrowing rate with luminosity correction;
T5: farrowing rate with temperature and luminosity correction.

For farms 3 and 4, the data logger had technical issues. As there was not enough data in the cloud to evaluate the year, the influence of correct temperature and photoperiod was assessed through INMET data.

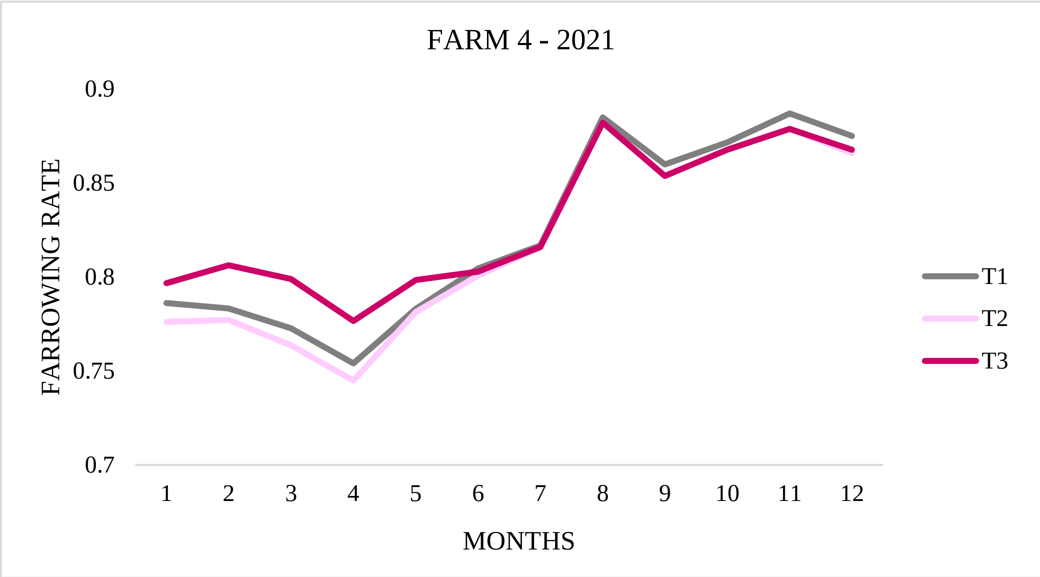
Farm 3 (figure 8) presented a lower farrowing rate during March and May, and T3 overcame other treatments during autumn syndrome related period. January was not evaluated as there needed to be more INMET available data. Farm 4 (figure 9) presented T3 with better rates than other treatments and lower rates during April.

Figure 8 - Correction of temperature and daylight on the farrowing rate of farm 3 during the year 2021, utilizing INMET data.



T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction.

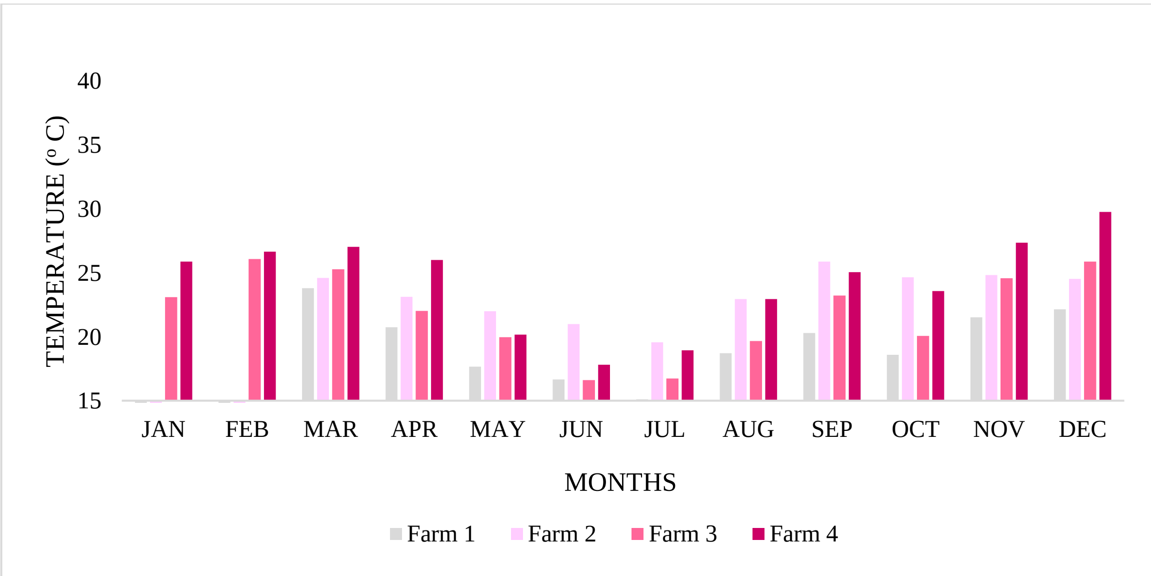
Figure 9 - Correction of temperature and daylight on the farrowing rate of farm 4 during the year 2021, utilizing INMET data.



T1: non-corrected farrowing rate;
T2: farrowing rate with temperature correction;
T3: farrowing rate with temperature and photoperiod correction.

The average maximum temperatures for each month of 2021 show that the UCT of 19.2º C was mainly not reached. Although having lower temperatures than in 2020 (figure 5), January to June remained above ideal. For farms 1 and 2, January and February had no temperature data retrieved from the data logger.

Figure 10 – Average maximum temperature for farms 1, 2, 3 and 4 during 2021.



4. Discussion

For the two years, the months evaluated and considered relevant for this project were from January to June (1 to 6), and the discussion will be based on these. January was comprised because some dates 21 days before the first insemination of February included that month.

Regarding the first year of evaluated data, farms 2, 3 and 4 were affected by seasonal infertility, presenting lower farrowing rates during selected months. March was the most affected month for the three farms, which can be related to the fact that it was the hottest month of 2020 among those evaluated. Farm 1 had suitable temperature and lighting control, with environmental parameters influencing their already reasonable farrowing rate. We can associate these positive results with the farm's location in the country's southern region, where temperatures follow its tropical climate and mild temperatures throughout the year, as shown in figure 5. The distance from the meteorological stations did not influence the results, as Freitas et al. [33] estimated a correlation of 0.9 between on-farm weather data and weather station data, with 300 km being the farthest station from the farm.

In the second year, farms 2, 3 and 4 presented lower farrowing rates in months 1 to 6 but at better rates than in 2020. March was also the most affected month this year. This result may be associated with the fact that 2020 was recorded as one of the hottest years in recent times [34], making it more difficult to control heat load even during autumn, so in 2021, sows suffered less from temperature effects, although still present. Also, March again is the month with the highest temperatures for all farms. As stated by Wegner et al. [35], increased climatic values at the time of farrowing will negatively affect the reproductive performance of the sows, expecting that in the hottest month the temperature correction has more effect. But, while heat stress varies from year to year according to climate fluctuations, majorly affecting sows when higher than usual, the photoperiod also has its variation and influence on sow reproduction.

We can see with the research results that farms that showed lower farrowing rates in the summer to autumn months (figures 2, 3, 8 and 9), and farms with no lower rates (figures 1), T3 (correct temperature and photoperiod) was the treatment with more influence; the corrected temperature has a better effect if the daylight amount is correct too. The yearly number of hours of sunshine varies significantly from year to year [9]. These impact the length and quantity of daylight per day per year and only sometimes reach eight hours or above, which is the photoperiod recommended for sows [10]. Longer than expected, photoperiod can also have consequences, such as a decrease in GnRH [29]. Still, this factor was controlled in the statistical model used in the present research, not influencing the farrowing rate. In the second year, for farms 1 and 2, the data logger had greater accuracy of the actual temperature and luminosity; it was possible to observe that for the farm in the south region (1), with a more tropical climate, a correction in temperature only was more influential than luminosity; animals are used to the mild climate, and 2020 has been such a hot year, the temperature correction highlighted other factors. As for the farm in the middle-west region (2), the climate of the area has high temperatures all year round, the animals are used to this temperature, and the light regimen becomes more influential, requiring the correct hours of bright light, but also of the dark period, for hormone production to occur correctly. Auvigne et al. [9] found that obtaining data on the microclimate within the barns can present more reliable results on the influence of temperature and photoperiod, such as in this case. The correction offered by the model becomes visible as each farm depends on a different factor to improve its farrowing rate.

Our results match the findings by Sevillano et al. [10], which, although operated their research in Europe, showed that during the syndrome period, FR dropped when the photoperiod decreased and raised when the photoperiod increased. Whilst temperature influences FR, photoperiod and luminosity tends to excel in it. This change in photoperiod and its more significant influence on farrowing rates may be related to LH secretion, which is reduced in the summer–autumn period [19]. When given the correct amount of light to sows (above 40 lx per day), hormonal secretion and reproduction rates should not be affected. A possible solution for the light problem is the installation of artificial lights in barns, offering the amount of light necessary for the reproduction of these females, as stated by King [36], who presented research alternatives for seasonal infertility.

However, despite this more significant photoperiod influence, it is possible to observe that the affected months in farms that presented seasonal infertility continue to show lower farrowing rates, even with temperature and photoperiod correction. As seasonal infertility is known to be multifactorial, the lower rates may be linked to other parameters that were not included in the current project, such as handling, housing condition, ovarian health, general health status, hormonal changes, and feeding and nutrition [21, 37, 38].

The data logger was essential to the research regarding the use of technologies to recognize and correct seasonal infertility. Farms, where its data was collected and evaluated, showed different results on where to apply corrections best to avoid the syndrome. Having easy access to ambient temperature and the amount of daily light on each farm can make producers aware of the problem of seasonal infertility earlier in their productions and, with that, think about alternatives to cease this problem before its consequences. However, in addition to technology, the innovative linear model built and assessed to estimate the influence of environmental factors had an important addition. Based on the AIC, the model evaluated with INMET data had a better fit and could be considered more likely results. This could be related to the fact that AIC scores are a probabilistic ranking of the models that are likely to minimize the information loss (best fit the data), and since the *data logger* gathers a major number of data, in this case, temperature for each 10 minutes throughout the whole day, the score was higher. Even so, both models presented relatable results where it was possible to observe that correcting ambient parameters causes significant changes to the reproduction of sows.

With better accuracy of temperature and luminosity inside the farm, a good prediction model, and correction of these factors combined with previously mentioned factors (handling, housing, nutrition, and others), we can reach the best possible effective result, preventing autumn syndrome and season infertility from happening.

5. Conclusion

These results indicate that temperature and photoperiod have an influence on the farrowing rate of sows, and that applying strategies that control these parameters could improve the reproduction performance of breeding sows from farms that present autumn syndrome and therefore a seasonal reduction in reproduction performance.

Conflicts of interest

The authors confirm that there are no known conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

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References

[1] USDA. Livestock and Poultry: World Markets and Trade. United States Department of Agriculture Foreign Agricultural Service. 2021.

[2] Ferreira, A. H., Carraro, B., Dallanora, D., Machado, G., Machado, I. P., Pinheiro, R., Rohr, S. Produção de suínos: teoria e prática. Coordenação editorial: Associação Brasileira de Criadores de Suínos; Coordenação Integral Soluções em Produção Animal. 2014.

[3] Utreta, V. Impacto econômico das doenças na produção de suínos. Suínos & Cia. 2008; 28: 26-31.

[4] Berghof, T. V., Poppe, M., Mulder, H. A. Opportunities to Improve Resilience in Animal Breeding Programs. Frontiers in genetics. 2018; 9.

[5] Beuron, M. P.; Brito, D. C. Principais Afecções Reprodutivas Em Fêmeas Suínas. Anuário Pesquisa e Extensão UNOESC São Miguel Do Oeste. 2016.

[6] Vanderhaeghe, C.; Dewulf, J.; de Kruif, A.; Maes, D. Non-infectious factors associated with stillbirth in pigs: a review. Animal Reproduction Science. 2013; 139 (1-4): 76-88.

[7] Bortoletto, C.; Ferreira, G. F.; Gasser, B.; Nakamura, A. M.; Almeira, H. M. De S.; De Oliveira, L. G. Principais causas de problemas reprodutivos em porcas. Revista Científica de Medicina Veterinária. 2014; 23.

[8] Bertoldo, M. J.; Grupen, C. G.; Thomson, P. C.; Evans, G.; Holyoake, P. K. Identification of sow-specific risk factors for late pregnancy loss during the seasonal infertility period in pigs. Theriogenology. 2009; 72 (3): 393-400.

[9] Auvigne, V.; Leneveu, B.; Jehannin, C.; Peltoniemi, O.; Salle, E. Seasonal infertility in sows: A five year field study to analyze the relative roles of heat stress and photoperiod. Theriogenology. 2010; 74: 60–66.

[10] Sevillano, C. A.; Mulder, H. A.; Rashidi, H.; Mathur, P. K.; Knol, E. F. Genetic variation for farrowing rate in pigs in response to change in photoperiod and ambient temperature. Journal of Animal Science. 2016; 3185-3197.

[11] Bertoldo, M. J.; Holyoake, P. K.; Evans, G.; Grupen, C. G. Seasonal effects on oocyte developmental competence in sows experiencing pregnancy loss. Animal Reproduction Science. 2011; 124: 104-111.

[12] Tast, A.; Peltoniemi, O. A. T.; Virolainen, J. V.; Love, R. J. Early disruption of pregnancy as a manifestation of seasonal infertility in pigs. Animal Reproduction Science. 2002; 74: 75–86.

[13] de Rensis, F.; Ziecik, A. J.; Kirkwood, R. N. Seasonal infertility in gilts and sows: aetiology, clinical implications and treatments. Theriogenology. 2017; 96: 111-117.

[14] Souza, F. A. Análise de fatores ambientais na criação de suínos em camas sobrepostas e produção de biogás. Thesis. Universidade Federal de Lavras. 2014.

[15] Mayorga, E. J.; Renaudeau, D.; Ramirez, B. C.; Ross, J. W.; Baumgard, L. H. Heat stress adaptations in pigs. Animal Frontiers. 2019; 9 (1): 54–61.

[16] Bloemhof, S.; Mathur, P. K.; Knol, E. F.; Van Der Waaii, E. H. Effect of daily environmental temperature on farrowing rate and total born in dam line sows. Journal of Animal Science. 2013; 91: 2667–2679.

[17] Nardone, A.; Ronchi, B.; Lacetera, N.; Bernabucci, U. Climatic effects on productive traits in livestock. Veterinary Research Communications. 2006; 30: 75-81.

[18] He, J.; Zheng, W.; Lu, M.; Yang, X.; Xue, Y.; Yao, W. A Controlled heat stress during late gestation affects thermoregulation, productive performance, and metabolite profiles of primiparous sow. Journal Of Thermal Biology. 2019; 81: 33-40.

[19] Peltoniemi, O. A. T.; Tast, A.; Love, R. J. Factors effecting reproduction in the pig: seasonal effects and restricted feeding of the pregnant gilt and sow. Animal Reproduction Science. 2000; 60: 173-84.

[20] Hälli, O.; Tast, A.; Heinonen, M.; Munsterhjelm, C.; Valros, A.; Peltoniemi, O. A. T. Short or long day light regimes may not affect reproductive performance in the sow. Reproduction in Domestic Animals. 2008; 43(6): 643-770.

[21] Hälli, O., Peltoniemi, O.A.T., Tast, A., Virolainen, J.V., Munsterhjelm, C., Valros, A. & Heinonen, M. Photoperiod and luteinising hormone secretion in domestic and wild pigs. Animal Reproduction Science. 2008; 103: 99- 106.

[22] Bertoldo, M. J.; Holyoake, P. K.; Evans, G.; Grupen, C. G. Seasonal variation in the ovarian function of sows. Reproduction, fertility, and development. 2012; 24 (6): 822-834.

[23] Arend, L. S.; Knox, R. V.; Greiner, L. L.; Graham, A. B.; Connor, J. F. Effects of feeding melatonin during proestrus and early gestation to gilts and parity 1 sows to minimize effects of seasonal infertility. Journal of Animal Science. 2019; 4635–4646.

[24] Rodrigues. T. R. Aspectos de produção e ambiência de suínos criados em diferentes sistemas de produção. Universidade Estadual de Goiás. 2015.

[25] Theil, P.; Akechi, B. V.; Rodrigues, D. C.; Andrade, M. F; Tedeschi, L.; Filardi, R. S. Desempenho de marrãs da raça Moura mantidas em diferentes sistemas de alojamento durante a fase de gestação. Faculdade de Engenharia - Campus de Ilha Solteira – UNESP. 2010.

[26] Costa, A. N. Impactos das demandas fisiológicas e metabólicas sobre a reprodução e o bem estar das matrizes suínas. Acta Veterinária Brasílica. 2014; 8 (2): 305-308.

[27] Bloemhof, S.; Van Der Waaij, E.H.; Merks, J.W.M.; Knol, E.F. Sow line differences in heat stress tolerance expressed in reproductive performance traits. Journal of Animal Science. 2008; 86: 3330-3337.

[28] Bergsma, R.; S. Hermesch. Exploring breeding opportunities for reduced thermal sensitivity of feed intake in the lactating sow. Journal of Animal Science. 2012; 90: 85-98.

[29] Tast, A.; Love, R. J.; Clarke, I. J.; Evans, G. Effects of active and passive gonadotrophin-releasing hormone immunization on recognition and establishment of pregnancy in pigs. Reproduction, fertility, and development. 2000; 12: 277–282.

[30] Williams, A. M.; Safranski, T. J.; Spiers, D. E.; Eichen, P. A.; Coate, E. A.; Lucy, M.C. Effects of a controlled heat stress during late gestation, lactation, and after weaning on

thermoregulation, metabolism, and reproduction of primiparous sows. Journal of Animal Science. 2013; 91 (6): 2700-20714.

[31] Stevenson, J.S.; Pollmann, D.S.; Davis, D.L.; Murphy, J.P. Influence of supplemental light on sow performance during and after lactation. Journal of Animal Science. 1983; 56: 1282-1286.

[32] McGlone, J.J.; Wayne, F.S.; Leland, F.T.; Morrow, J.L. Photoperiod and heat stress influence on lactating sow performance and photoperiod effects on nursery pig performance. Journal of Animal Science. 1988; 66: 1915-1919.

[33] Freitas, M.S.I.; Misztal, J. B.; West, J. 2006. Utility of on-and off-farm weather records for studies in genetics of heat tolerance. Livestock Science. 2006; 105: 223–228.

[34] National Oceanic and Atmospheric Administration. 2020 was Earth's 2nd-hottest year, just behind 2016, https://www.noaa.gov/news/2020-was-earth-s-2nd-hottest-year-just-behind-2016; 2021 [accessed 16 November 2022].

[35] Wegner, K.; Lambertz, C.; Das, G.; Reiner, G.; Gauly, M. Climatic effects on sow fertility and piglet survival under influence of a moderate climate. Animal. 2014; 8 (9): 1526-1533.

[36] King, R. H. Seasonal infertility in pigs: what have we achieved and where are we up to? Animal Production Science. 2017; 57: 2325–2330.

[37] Am-In, N.; Techakumphu, M.; Kirkwood, R. N. Effect of altering the ratio of exogenous gonadotropins on reproductive performance of primiparous sows during the seasonal infertility period. Canadian Journal of Animal Science. 2019; 99: 202-205.

[38] Lopes, T. P.; Sanchez-Osorio, J.; Bolarin, A.; Martinez, E. A.; Roca, J. Relevance of ovarian follicular development to the seasonal impairment of fertility in weaned sows. The Veterinary Journal. 2014; 199 (3): 382-386.

CHAPTER FOUR

IMPACT AND FUTURE PERSPECTIVES

The results obtained in this research can contribute substantially to pig farming in general, as it promotes knowledge on one of the concerns presented in the production. As there is still much room for the expansion of technology in pig production, seeking alternatives that will improve pure lines, such as the one presented in this project, will bring economic gains to the entire pig sector, as the core farms, from which sows were evaluated in this project, are the basis of pig production. With the data logger, for example, it is possible to have better control of temperature and lightning, which affect seasonal infertility. Working its data with the linear model built for this research, it is possible to recognize the problem early and see its correction's importance. Interconnected with other factors, finding a solution is a small step towards better genetic lines for the future, hoping a decrease in problems related to seasonal infertility will occur. In addition, these animals make up the genetic basis of many herds due to their higher productivity and prolificacy. Less expense with fertility issues or any other animal health issues will generate profit for companies and producers in the future. This profit can be invested in other areas of pig production, consequently improving the Brazilian market.

CONCLUSION

In conclusion, studying the effect of temperature, photoperiod, and luminosity on the farrowing rate of sows brought positive aspects to the area of pig research. The results of this study showed the importance of using technology to evaluate a specific parameter concerning the autumn syndrome. It also encourages future studies involving other parameters, to find even more answers about this reproductive problem, seeking to cease it.

REFERENCES

ABPA. Relatório Anual 2021. Associação Brasileira de Proteína Animal. 2022.

ABPA. Relatório Anual 2022. Associação Brasileira de Proteína Animal. 2023.

ABRA. A suinocultura brasileira e seus destaques. Associação Brasileira de Reciclagem Animal. 2019.

Berghof, T. V., Poppe, M., Mulder, H. A. Opportunities to Improve Resilience in Animal Breeding Programs. Frontiers in genetics. 2018; 9.

Bertoldo, M. J.; Grupen, C. G.; Thomson, P. C.; Evans, G.; Holyoake, P. K. Identification of sow-specific risk factors for late pregnancy loss during the seasonal infertility period in pigs. Theriogenology. 2009; 72 (3): 393-400.

Beuron, M. P.; Brito, D. C. Principais Afecções Reprodutivas Em Fêmeas Suínas. Anuário Pesquisa e Extensão UNOESC São Miguel Do Oeste. 2016.

Bortoletto, C.; Ferreira, G. F.; Gasser, B.; Nakamura, A. M.; Almeira, H. M. De S.; de Oliveira, L. G. Principais causas de problemas reprodutivos em porcas. Revista Científica de Medicina Veterinária. 2014; 23.

EMBRAPA. Sistemas de Produção: Produção de Suínos. Embrapa Suínos e Aves. 2003.

Filha, W. S. A.; Costa, M. S.; Bernardi, M. L.; Wentz, I.; Bortolozzo, F. P. Causas não infecciosas de abortamentos em suínos. I Simpósio UFRGS sobre produção, reprodução e sanidade suína. 2006.

Hughes, P.; van Wettere, W. Seasonal infertility in pigs. Porc CRC Australia. 2010.

Oldenbroek, K.; van der Waaij, L. Animal breeding and genetics for BSc students. Centre for Genetic Resources and Animal Breeding and Genomics Group. 2014.

Silveira, P. R. S.; Amaral, A. Análise dos fatores mais comuns relacionados com falhas reprodutivas em modernos rebanhos suínos. Revista Brasileira de Reprodução Animal. 2009; 6: 187-193.

Thornton, P. K. Livestock production: recent trends, prospects. Philosophical Transitions of the Royal Society. 2010; 365: 2853–2867.

USDA. Livestock and Poultry: World Markets and Trade. United States Department of Agriculture Foreign Agricultural Service. 2021.

Utreta, V. Impacto econômico das doenças na produção de suínos. Suínos & Cia. 2008; 28: 26-31.

Vanderhaeghe, C.; Dewulf, J.; de Kruif, A., Maes, D. Non-infectious factors associated with stillbirth in pigs: a review. Animal Reproduction Science. 2013; 139(1-4): 76-88.

ANNEXES

Normas do periódico escolhido para a submissão do artigo: https://www.elsevier.com/journals/theriogenology/0093-691X/guide-for-authors.

Pontifícia Universidade Católica do Paraná
Pró-Reitoria de Pesquisa, Pós-Graduação e Inovação
Comissão de Ética em Pesquisa no Uso de Animais

PARECER CONSUBSTANCIADO DA CEUA

TÍTULO DA PESQUISA	Estratégias inovadoras para minimizar os impactos negativos da síndrome de outono na reprodução de fêmeas suínas		
Nº DO PARECER / VERSÃO	022101		
PESQUISADOR RESPONSÁVEL	Leandro Batista Costa		
ESPECIE DO ANIMAL	*Sus scrofa domesticus*	**Nº DE ANIMAIS**	
NOME COMUM DO ANIMAL	suíno	**Nº SISBIO** (animais de vida livre)	*Não se aplica*
SEXO / IDADE / PESO	Femeas primíparas e multíparas de idade e pesos variados	**ATIVIDADES** (animais de vida livre)	*Não se aplica*
ORIGEM DO ANIMAL	Topigs Norsvin do Brasil	**GP TAXONÔMICOS** (animais de vida livre)	*Não se aplica*
DATA DE INICIO DA PESQUISA	Novembro 2022	**LOCAL (IS)** (animais de vida livre)	*Não se aplica*
DATA DE TÉRMINO DA PESQUISA	Fevereiro 2023	**Nº SISGEN**	*Não se aplica*
APRESENTAÇÃO DO PROJETO	-		
OBJETIVO DA PESQUISA	Objetiva-se com o presente estudo avaliar, por meio de estratégias inovadoras de manejo, o efeito da temperatura e da luminosidade na taxa de parto de fêmeas suínas, a fim de que minimizem os impactos da síndrome de outono. Específicos: • Coletar dados de temperatura e luminosidade de estações meteorológicas do Instituto Nacional de Meteorologia (INMET) próximas às granjas selecionadas para o estudo; • Interpretar e analisar a taxa de parto de fêmeas, durante um ano, das respectivas granjas, sob a influência de temperatura e luz do dia coletados pelo INMET; • Coletar dados de temperatura e luminosidade das granjas selecionadas utilizando um data logger; • Interpretar e analisar a taxa de parto de fêmeas, durante um ano, das respectivas granjas, sob a influência de temperatura e luz do dia coletados pelo data logger; • Verificar se há influência ou não da luminosidade e temperatura, ajustadas, sobre a taxa de parto de matrizes suínas das respectivas granjas.		
RISCOS E ATITUDES MITIGATÓRIAS	A coleta de dados ficará sob responsabilidade da empresa Topigs Norsvin. A empresa tem completo controle da sanidade e bem- estar de suas granjas, inclusive as envolvidas no projeto. Todos os funcionários da empresa são treinados para lidar com situações não-convencionais, e todos prezam pela saúde dos animais. Todos os funcionários trabalham com EPI's corretos para seus serviços. Como será feita apenas análise de dados via equipamentos eletrônicos (notebook), não existem riscos inerentes a equipe de pesquisadores do PPGCA.		
CONSIDERAÇÕES SOBRE A PESQUISA	Projeto muito relevante para a suinocultura.		
CONSIDERAÇÕES SOBRE OS TERMOS DE APRESENTAÇÃO OBRIGATÓRIA	Todos os termos de apresentação obrigatória foram submetidos e estão de acordo.		
RECOMENDAÇÕES	Não há recomendações.		
CONCLUSÕES OU PENDÊNCIAS E LISTA DE INADEQUAÇÕES	Nada a declarar.		
CONSIDERAÇÕES FINAIS	O colegiado da CEUA certifica que este protocolo que envolve a produção, manutenção e/ou utilização de animais pertencentes ao filo Chordata, subfilo Vertebrata (exceto homem), para fins de pesquisa cientifica, encontra-se de acordo com os preceitos da Lei nº 11.794/2018 e Decreto nº 6.899/2009, e com as normas editadas pelo CONCEA sendo aprovado pela CEUA -		

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	PUCPR em reunião de colegiado. Se houver mudança do protocolo o pesquisador deve enviar uma emenda á CEUA descrevendo de forma clara e sucinta, a parte do protocolo a ser modificado e as suas justificativas. Se a pesquisa, ou parte dela for realizada em outras instituições, cabe ao pesquisador não iniciar antes de receber a autorização formal para a sua realização.
SITUAÇÃO DO PARECER	**APROVADO**

CURITIBA 18 de novembro de 2022

PROF. DR. SÉRGIO LUIZ ROCHA

Coordenador CEUA-PUCPR

A validade deste documento pode ser confirmada pelo e-mail ceua@pucpr.br informando o número do parecer.