INTERNATIONAL JOURNAL FOR INNOVATION EDUCATION AND RESEARCH
ISSN: 2411-2933

Journal URL: https://scholarsjournal.net/index.php/ijier

DOI: https://doi.org/10.31686/ijier.vol10.iss11.4005

Thermal Comfort in Swine: Basic Concepts for Better Production

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Abstract
With the growth of the consumer market, several countries have been developing more efficient and sustainable management technologies to reduce the harmful effects of heat stress on swine production, an even more important fact in countries with tropical climates like Brazil. The swine produced in Brazil is an animal that, in different ways, was imported from other relatively cold countries. Therefore, they were genetically adapted to the tropical climate. Thus, due to the harmful effects of high temperatures, improving the production environment is the most efficient way to mitigate heat stress. This review aims to address the main complications that heat stress can cause to swine and identify appropriate management approaches to reduce short-term susceptibility to discomfort. Such information seeks to encourage sound management practices aimed at the thermal comfort of the animals and consequent gain in productive efficiency.

Keywords: Animal Environment; Swine farming; Thermoregulation.

1. Introduction
Swine farming is practiced in several countries, representing the most significant animal protein production, surpassing beef production in the late 1970s, and currently occupying great global socioeconomic importance (Martins et al., 2019).

Brazil occupies an important position in the world market, being fourth in the ranking of pork production, with more than 3.9 million tons produced in 2019, showing an increase of 0.22% compared to 2018. The country is also the fourth largest exporter of pork, with 750 thousand tons exported in the same year, an increase of 16% compared to the previous year (USDA, 2021; EMBRAPA, 2020). The distribution of Brazilian production in the sector is well-defined, with 66% concentrated in the South, 18% in the Southeast, and 15% in the Center-West (IBGE, 2020).

Even with an excellent position in the pork export ranking, competition with China, the European Union, and the United States, respectively, continues to be an excellent challenge for Brazil due to the deficiency of factors that support Brazilian production, such as biosecurity, health, investment in labor and mainly promotion of animal welfare (Galvão et al., 2019)

World production has been growing at an average rate of 0.5% per year after experiencing a recession in 2018 due to African swine fever, which mainly affected Chinese and Romanian production. Therefore, this market currently has an enormous supply deficit, becoming increasingly demanding in searching for products of higher quality and origin. In this sense, ambience, nutrition, and management investments have become essential to keep products within the expected standards (Dawkins, 2016).

One of the significant challenges of modernizing poultry and swine farming is the need to balance the reduction or elimination of polluting effects of the environment with the growing demands for animal welfare, maintaining a profitable and economically viable business. Furthermore, food security has become a genuine concern for governments and the public (Costantini et al., 2020).

Thus, the objective of this study is to present the environmental characteristics that most influence the quality of pig farming, discuss the environment applied to production, the biological factors that must interact with the environment, and the main constructive improvements proposed to improve the production environment.

2. Environmental Characteristics for Swine Production in Brazil

According to IBGE data (2020), 66% of swine farming is concentrated in the South region of Brazil, with 18% in the Southeast region and 15% in the Center-West region. The South region has a subtropical climate with an average annual temperature of 18ºC, which explains its advantage in swine farming due to the animal's low resistance to hot climates (MAPA, 2019). However, over the years, there is the possibility of a considerable increase in breeding in the tropical regions of the country through proper management and breeding of animals with improved genetic potential. (Melz & Gastardelo, 2014).

In this context, there is a possibility of increasing production in Brazil, with 50% of pork consumption by 2050 (Saath & Fachinello, 2018). However, as the environment is often quite different from the conditions in which genetic selection occurs, in addition to climate change, a significant barrier to sustainably meeting the global need for this animal protein needs to be overcome (Mayorga et al., 2019).

The subtropical climate occurs only in the southern region of Brazil. The annual temperature averages are around 18°C, with high thermal amplitude. The rains are well distributed, and the pluviometric indexes exceed 1,250 mm yearly. The tropical climate prevails in the rest of the country. Generally, temperatures are high most of the year, with an average of 24°C, and the temperature range varies between 5°C and 6°C per year. The amount of rainfall is around 1,500 mm per year, with two well-defined seasons: a dry season (May to September) and a rainy season (October to April) (Mendonça & Danni-Oliveira, 2017).

Several studies have been carried out to understand better heat stress's impact on the zootechnical results of swine. Generally, the indicators used to measure welfare can be found in animals and the environment (Galvão et al., 2019).

According to Wankar et al. (2021), animal welfare is directly influenced by thermal stress and the fact that most producers are in hot climates and have excessive expenses with their production. If climate change related to global warming continues, hog production will be directly affected. In addition to changes in facilities aimed at better housing conditions, nutritional and genetic strategies will also be intensified, especially in the hot months of the year, to satisfy the demand for quality pork.

3. Well-Being and Environment in Swine

Swine comfort has been widely researched, with the concept of "welfare" directly linked to production, productivity, and reproduction.

According to the FAWC (Farm Animal Welfare Council), the five freedoms for sustainable production must be adopted (Ludtke et al., 2012), namely:

- Free from feeling thirsty and hungry;
- Freedom to feel comfort/discomfort;

- Freedom to feel pain, injury, and illness;
- Freedom to express their normal behavior;
- Free from feeling fear and stress.

According to the Novo Dicionário Aurélio (Ferreira, 2004), ambience represents "the physical, aesthetic or psychological environment specially prepared for human and animal activities. In other words, the ambience (the sum of the physical and biological factors that act in the space where the animal performs its activities) will significantly influence its degree of adaptation. Thus, systems that somehow promote an environment capable of mitigating heat stress can favor the homeothermic control of animals and improve their weight, reproductive, and health performance.

4. Biological Difference Between Swine from Brazil and Other Countries

The pigs, after being brought to Brazil in the period of their discovery, started reproducing without specific direction, and after a few centuries, they formed the local, native, or naturalized breeds (Melz & Gastardelo, 2014). The best-known native breeds are Piau, Nilo, Canastra, Canastrão, and Caruncho. The creation of these breeds, which traditionally had as their primary purpose the use of lard for food preservation, has been disused as vegetable oils and refrigeration equipment have replaced lard. Another decisive point is the low performance of native breeds concerning exotic or commercial ones (Formenton et al., 2019).

One factor that reduced the genetic variability of the swine lines present in the country is the introduction of exotic breeds with better zootechnical performances. Currently, 90% of commercial breeds produced in Brazil are a combination of Landrace (imported from Denmark), Large White (origin in northern England), Duroc (from the United States), and Pietrain (imported from Belgium).

4.1. Internal Thermal Regulation

If there are temperature differences between the animal and the environment, heat exchange can be performed latently or sensitively. When the ambient temperature is above the critical upper temperature of the animal, heat exchange occurs latently by evaporation. Already, they are forms of heat exchange sensitive to conduction, convection and radiation. Body heat exchanges with the environment occur as the ambient temperature increases, and the animals activate their thermoregulatory mechanisms to maintain homeothermy (Zhang et al., 2021).

Swine have few functional sweat glands and a thick layer of subcutaneous adipose tissue, hindering their thermoregulatory capacity. If efforts to lose heat are not enough, they may even have a change in diet among their strategies, aiming to regulate the internal temperature to approach the comfort region (Robbins et al., 2021).

4.2. Changes in Food and Growth

Usually, one of the first adaptations of an animal subjected to heat stress is the change in food intake. Thus, if the ambient temperature is above the maximum considered comfortable, the pig reduces feed consumption to produce less heat and mitigate its thermal stress, especially during the afternoon and evening (Cervantes et al., 2018).

A consequence of decreased nutrient intake is decreased average daily weight gain during heat stress. The reduction in feed efficiency is mainly reported in finishing pigs kept at a temperature above 30°C. Therefore, there is no doubt that heat stress reduces productive operational efficiency, as it significantly increases the time an animal takes to reach slaughter weight (Robbins et al., 2021).

5. Rural Buildings and Thermal Stress Mitigation

Engineering has acted in different ways to avoid the stress caused by thermal variations, proposing strategies for environmental modification and making it more comfortable. The changes range from the design to the functioning of the mechanisms installed in the buildings. Buildings designed with a critical eye on the ambience provide a suitable place for sustainable production, focusing on well-being and restricted effects of the impacts caused by heat stress (Maes et al., 2020).

5.1. Control of Solar Radiation

For free-range pigs, providing shaded areas is a simple and inexpensive task. To reduce direct insolation, trees or plant barriers can be used. It should be considered a minimum requirement of a project, aiming at thermal comfort, shed orientation, construction material and ceiling height (Mayoral, 1999).

In the case of housed animals, there is rarely exposed to direct solar radiation. However, the breeding site can heat up indirectly, inducing a more significant infrared radiative load (longwave radiation) (Mayorga et al., 2019). Thus, ceiling insulation effectively reduces indoor surface temperature and heat build-up.

5.2. Sprinkling or Dripping

The simple and economical method consists of Sprinkling or dripping in finishing pigs in slatted floor pens. The animals are refrigerated and not in the housing environment (Parois et al., 2018). Adding water to pig skin can increase heat loss and, if combined with high air velocities, becomes a powerful stress-relieving tool. The animal's heat is transferred to the water, which evaporates. This thermal energy transfer lowers body temperature and increases well-being (Driessen et al., 2020).

5.3. Nebulization

Fogging systems reduce air temperature by evaporating water. As all refrigeration systems utilize water evaporation, the rate of evaporation and subsequent heat removal is limited by the amount of moisture in the air. (Maes et al., 2020)

The positive effect of targeted cooling on the skin of pigs can also be found during transport to a slaughterhouse. The misting of the animals before transport and later unloading reflected in meats with lower lactate content and higher pH value (Driessen et al., 2020).

Evaporative cooling works well when atmospheric conditions are relatively dry (dew point temperature below 10°C). As the moisture content in the atmosphere increases, the effectiveness of evaporative cooling decreases. When dew point temperatures are above 15°C, the performance of evaporative cooling systems begins to degrade. If the ambient air moving over the pig is almost saturated, the water in its skin will evaporate very little, and only a tiny amount of heat will be removed (Rioja-Lang et al., 2019).

5.4. Evaporative Plates / Climatized

It takes approximately 2425 kJ per kg of H2O at 32°C for water to change from liquid to vapor. As outside air enters an evaporative cooler, energy is removed from the wet hive/cushion, and the air as the water evaporates, thus lowering the air temperature (Figure 1). This application combines air conditioners and exhaust fans in confined rearing (Rong et al., 2017; Fidaros et al., 2018; Sultan et al., 2019). It is essential to mention that evaporative cooling systems can be low-cost options, even more so in case of dry weather.

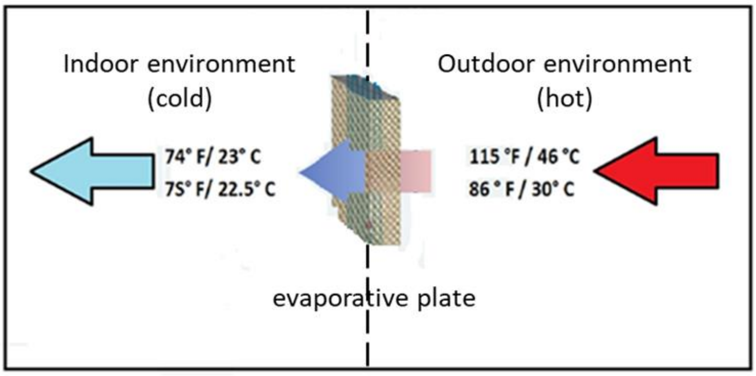

Figure 1. Model of Evaporative System

5.5. Increase in Air Speed

Raising air velocity is one of the most effective ways to improve an animal's heat loss. In swine facilities, systems can be installed to cool the animals in a specific region (e.g., snout cooling), or high air velocity over the animal can be achieved throughout the farm area (e.g., by ventilation in the tunnel) (Godyń et al., 2020).

In a cross-flow ventilation system (air flows the entire length of the house), the air velocity at the animal level varies from 0.25 to 0.50 m/s. With tunnel ventilation, the aim is to achieve an air velocity of 1.0 to 2.5 m/s over the animals. However, tunnel ventilation is not recommended for younger and more sensitive animals as the effect of wind chill can be stressful (Medojević et al., 2017).

Air movement over the animal affects heat loss through convection and evaporation. The typical skin temperature of pigs varies between 32 and 36°C. Thus, if the ambient temperature approaches skin temperature, the effectiveness of ventilation (without using evaporative cooling) is minimized (Parois et al., 2018).

Several studies have been carried out with hybrid ventilation and cooling, that is, a mixture of mechanical ventilation, cross ventilation, and nebulization, among others, to promote different solutions depending on the characteristics of each region (Vitali et al., 2021). Thus, using heat exchangers allows better indoor air circulation and contributes significantly to increasing animal comfort.

5.6. Air Conditioning in Swine's Production

The air temperature can be reduced using an air conditioning unit consisting of a mechanical system with circulating refrigerant gas. However, considering the cost of installation and operation, equipment longevity, and electricity consumption, it is generally considered unfeasible for swine applications (Wankar et al., 2021).

5.7. Floor with Cooling Conductive

There is sensible heat exchange between the pigs and a floor with a lower temperature in order to reduce the animal's skin temperature and improve its comfort level. It is predominantly achieved by circulating cold water through their housed floor. Lactating sows spend most of the day lying down, and this behavior allows the refrigerated boards to be more effective. For the finishing phase, the concrete floor can contain a pipe that allows the circulation and cooling of the water. Economic feasibility is limited as installation and operating costs can be substantial, along with the technical feasibility of having a chilled water source and pipe distribution network (Godyń et al., 2020).

6. Qualitative Comparison of Cost

Given the above, the costs of refrigeration systems for sheds can be divided between the initial installation of the system and the operational for its maintenance. Table 1 qualitatively lists the relative values of various components presented in this article on a scale of 1 to 5.

Table 1. Qualitative values related to the comparison of refrigeration systems

Refrigeration system	Installation cost*	Cost of operation*	Simplicity of Installation*	Electric power consumption*	Reliability*
Sprinkling or dripping	1	1	2	2	3
Nebulization	1	2	3	2	3
Evaporative plates / Air conditioning	2	2	1	1	3
Air speed rise	1	1	1	2	2
Air conditioning	4	4	3	4	5
Floor with Conductive Cooling	4	3	3	2	2
Solar or geothermal cooling	5	3	5	1	1

*scale of 1 to 5.

Source: Medojević et al. (2017) and Robbins et al. (2021), adapted.

Having seen so far the main points that heat stress can affect in swine and having addressed the main techniques of proper handling to reduce discomfort, this material serves as a roadmap of good practices to assist in sustainable production with a view to the swine production thermal comfort, others animals production and consequent gain in productive efficiency.

7. Acknowledgement

The authors would like to acknowledge the contribution of Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-Brasil (CAPES) and Universidade Federal da Grande Dourados (UFGD) in the structural and financial support for the development of the present study.

8. References

1. Cervantes, M., Antoine, D., Valle, J. A., Vásquez, N., Camacho, R. L., Bernal, H., & Morales, A. (2018). Effect of feed intake level on the body temperature of pigs exposed to heat stress conditions. *Journal of thermal biology*, 76, 1-7. https://doi.org/10.1016/j.jtherbio.2018.06.010

2. Costantini, M., Bacenetti, J., Coppola, G., Orsi, L., Ganzaroli, A., & Guarino, M. (2020). Improvement of human health and environmental costs in the European Union by air scrubbers in intensive pig farming. *Journal of Cleaner Production*, 275, 124007. https://doi.org/10.1016/j.jclepro.2020.124007

3. Dawkins, M. S. (2016). Animal welfare and efficient farming: is conflict inevitable?. *Animal Production Science*, 57(2), 201-208. https://doi.org/10.1071/AN15383

4. Driessen, B., Van Beirendonck, S., & Buyse, J. (2020). Effects of transport and lairage on the skin damage of pig carcasses. *Animals*, 10(4), 575. https://doi.org/10.3390/ani10040575

5. EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. Estatísticas - Portal Embrapa. (2020). Central de Inteligência de Aves e Suínos - CIAS. Available in: https://www.embrapa.br/suinos-e-aves/cias/estatisticas. Access in: October 2022.

6. Ferreira, A. B. de H. Novo dicionário Aurélio da língua portuguesa. (2004). pp. 2012–2012.

7. Formenton, B. D. K., Dallago, B. S. L., Braccini, J., Tanure, C. B. G., Peripolli, V., & McManus, C. (2019). Crescimento alométrico de suínos brasileiros naturalizados. *Ciência Animal Brasileira*, 20. https://doi.org/10.1590/1809-6891v20e-38449

8. Galvão, A. T., da Silva, A. D. S. L., Pires, A. P., de Morais, A. F. F., Neto, J. S. N. M., & de Azevedo, H. H. F. (2019). Bem-estar animal na suinocultura: Revisão. *Pubvet,* 13, 148. https://doi.org/10.31533/pubvet.v13n3a289.1-6

9. Godyń, D., Herbut, P., Angrecka, S., & Corrêa Vieira, F. M. (2020). Use of different cooling methods in pig facilities to alleviate the effects of heat stress - A review. *Animals*, 10(9), 1459. https://doi.org/10.3390/ani10091459

10. IBGE – Instituto Brasileiro de Geografia e Estatística. Portal do IBGE. (2020). Available in: https://www.ibge.gov.br/. Access in: July 2022.

11. Ludtke, C. B., Dalla Costa, O. A., Roça, R. D. O., Silveira, E. T. F., Athayde, N. B., Araújo, A. P. D., ... & Azambuja, N. C. D. (2012). Bem-estar animal no manejo pré-abate e a influência na qualidade da carne suína e nos parâmetros fisiológicos do estresse. *Ciência Rural*, 42, 532-537. https://doi.org/10.1590/S0103-84782012000300024

12. MAPA – Ministério da Agricultura Pecuária e Abastecimento. Projeções do Agronegócio 2018/2019 - 2028/2029. (2019). Available in: www.gov.br/agricultura/pt-br/assuntos/politica-agricola/todas-publicacoes-de-politica-agricola/projecoes-do-agronegocio/projecoes-do-agronegocio-2018-2019-2028-2029/view. Access in: July 2022.

13. Martins, F. M., Santos Filho, J. I., & Talamini, D. J. (2019). Conjuntura econômica da suinocultura brasileira. *Embrapa Suínos e Aves-Artigo de divulgação na mídia (INFOTECA-E)*, 291.

14. Maes, D. G., Dewulf, J., Piñeiro, C., Edwards, S., & Kyriazakis, I. (2020). A critical reflection on intensive pork production with an emphasis on animal health and welfare. *Journal of animal science*, 98(Supplement_1), S15-S26. https://doi.org/10.1093/jas/skz362

15. Mayoral, A. I., Dorado, M., Guillén, M. T., Robina, A., Vivo, J. M., Vázquez, C., & Ruiz, J. (1999). Development of meat and carcass quality characteristics in Iberian pigs reared outdoors. *Meat Science*, 52(3), 315-324. https://doi.org/10.1016/S0309-1740(99)00008-X

16. Mayorga, E. J., Renaudeau, D., Ramirez, B. C., Ross, J. W., & Baumgard, L. H. (2019). Heat stress adaptations in pigs. *Animal Frontiers*, 9(1), 54-61. https://doi.org/10.1093/af/vfy035

17. Medojević, M., Zong, C., Zhang, G., & Medić, N. (2017). The selection and design of the air conditioning system in the facilities for fattening pig production depending on the conditions of thermal comfort: with focus on hot climate. *Zbornik Međunarodnog kongresa o KGH*, 46(1), 326-335. Available in: https://www.izdanja.smeits.rs/index.php/kghk/article/view/2804 Access in: July 2022.

18. Melz, L. J., & Gastardelo, T. A. R. (2014). A suinocultura industrial no mundo e no Brasil. *Revista*

UNEMAT de contabilidade, 3(6). https://doi.org/10.30681/ruc.v3i6.266

19. Mendonça, F., & Danni-Oliveira, I. M. (2017). Climatologia: noções básicas e climas do Brasil. *Oficina de textos*.

20. Parois, S. P., Cabezón, F. A., Schinckel, A. P., Johnson, J. S., Stwalley, R. M., & Marchant-Forde, J. N. (2018). Effect of floor cooling on behavior and heart rate of late lactation sows under acute heat stress. *Frontiers in Veterinary Science*, 5, 223. https://doi.org/10.3389/fvets.2018.00223

21. Rioja-Lang, F. C., Brown, J. A., Brockhoff, E. J., & Faucitano, L. (2019). A review of swine transportation research on priority welfare issues: a Canadian perspective. *Frontiers in Veterinary science*, 6, 36. https://doi.org/10.3389/fvets.2019.00036

22. Robbins, L. A., Green-Miller, A. R., Johnson, J. S., & Gaskill, B. N. (2021). One Is the Coldest Number: How Group Size and Body Weight Affect Thermal Preference in Weaned Pigs (3 to 15 kg). *Animals*, 11(5), 1447. https://doi.org/10.3390/ani11051447

23. Saath, K. C. D. O., & Fachinello, A. L. (2018). Crescimento da demanda mundial de alimentos e restrições do fator terra no Brasil. *Revista de Economia e Sociologia Rural*, 56, 195-212. https://doi.org/10.1590/1234-56781806-94790560201

24. USDA - Livestock, U. S. D. A. (2021). Poultry: World Markets and Trade. United States Department of Agriculture. Available in: https://www.fas.usda.gov/data/livestock-and-poultry-world-markets-and-trade Access in: July 2022.

25. Vitali, M., Sardi, L., Martelli, G., & Nannoni, E. (2021). Literature Review on the Pre-Slaughter Welfare of Italian Heavy Pigs. *Animals*, 11(12), 3352. . https://doi.org/10.3390/ani11123352

26. Wankar, A. K., Rindhe, S. N., & Doijad, N. S. (2021). Heat stress in dairy animals and current milk production trends, economics, and future perspectives: the global scenario. *Tropical Animal Health and Production*, 53(1), 1-14. https://doi.org/10.1007/s11250-020-02541-x

27. Zhang, T., Liu, L., Hao, J., Zhu, T., & Cui, G. (2021). Correlation analysis based multi-parameter optimization of the organic Rankine cycle for medium-and high-temperature waste heat recovery. *Applied Thermal Engineering*, 188, 116626. https://doi.org/10.1016/j.applthermaleng.2021.116626