



## Non-Nutritional Factors that Influence Feed Efficiency and Nutrient Utilization

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### Introduction

Global meat production is expected to rise by 12% from 2023 to 2032, with pork production growing from 117 to 129 million metric tons per year (OECD and FAO). Pork is a major source of protein worldwide, but it also contributes to the environmental footprint of meat production. Most of the environmental impact in pig farming comes from the feed system, which includes crop cultivation, feed manufacturing, and transportation. Improving pig health, management, and feed efficiency, as well as better handling of swine waste, can help meet the growing demand for pork while reducing its environmental impact (Andretta et al., 2021).

### Genetics

Genetic selection has been a major driver of improvements in pig growth performance, feed efficiency, and carcass composition over the past several decades. Modern commercial lines are leaner, grow faster, and utilize feed more efficiently than older genotypes. Genetics play a major role in pig feed efficiency and nutrient utilization. Selection for traits like faster protein accretion and higher protein-to-fat ratios improves efficiency, since depositing lean tissue requires less energy than depositing fat. For sows, selecting for larger litter sizes reduces feed use per piglet weaned, as the sow's maintenance feed cost is distributed across more offspring. As a result, genetic lines differ in nutrient requirements, making tailored feeding programs essential to optimize performance. Ongoing genetic progress reduces greenhouse gas emissions from pork production by 0.5–1.5% annually (Dekkers, 2024).

Overall, genetics not only improve productivity and efficiency but also present opportunities to lower the environmental footprint of swine production. Genetic lines influence how nutrients are utilized, which means feeding strategies should be adapted accordingly. Dekkers (2024) highlights that future selection efforts will continue to enhance sustainability by improving nutrient efficiency and reducing emissions.

### Environmental Temperature

Ambient temperature strongly affects pig feed intake, energy metabolism, and nutrient utilization. Both heat stress and cold stress impair efficiency and alter nutrient partitioning. Pigs must maintain a stable body temperature within a narrow thermal comfort zone, and deviations in ambient temperature can strongly impact feed intake and efficiency. When temperatures fall below the lower critical threshold, feed intake rises by about 1.5% per °C, but feed efficiency worsens (NRC, 2012). For a 20 kg growing pig, the lower critical temperature is approximately 17 °C and for a 100 kg finishing pig it is around 15 °C, increasing by 2–3 °C in damp or drafty environments (Renaudeau et al., 2012). Conversely, heat stress reduces feed in, and for a 100 kg finishing pig, it is above the upper critical temperature, which is 9–11 °C above the lower limit. High ambient temperatures depress feed intake, growth performance, and heat production, although nutrient digestibility is generally not impaired, with the main effect being reduced intake (Campos et al., 2014; Ortega et al., 2022, 2023). Heat stress also shifts blood flow away from the gut, potentially causing hypoxia, intestinal damage, and leaky gut that may impair nutrient absorption (Lambert et al., 2002).

In sows, body size, body condition, and feeding level all influence thermal tolerance. Heavier and fatter sows have lower critical temperatures but are more sensitive to heat stress, while thinner sows require more feed intake to cope with cold stress (Gaillard et al., 2021). For example, a 140-kg thin sow requires ~59 g of additional feed per °C below her critical threshold, compared to 34 g for a fat sow of the same weight. Cold environments substantially raise feed demand. For example, a 200-kg gestating sow exposed to 5 °C below her lower critical temperature year round would require an extra 90 kg of feed annually for thermoregulation (Gaillard et al., 2021). These findings underscore the importance of adjusting feeding strategies based on environmental conditions to balance feed efficiency, nutrient use, and animal health.

## Health Status

Pig health status is a critical determinant of nutrient utilization. Disease challenges alter feed intake, digestion, and nutrient partitioning toward immune function rather than growth. Disease challenges in pigs reduce feed intake and growth while diverting nutrients toward immune system activation rather than growth. In an LPS injection model, Rakhshandeh et al. (2012) observed a 9.2% drop in apparent ileal protein digestibility and a 3.1% drop in fecal protein digestibility, largely due to increased endogenous losses and reduced intestinal absorptive capacity. Viral infections also vary in their impact: PRRSV lowered feed intake and growth without changing digestibility, while PEDV reduced digestibility of DM and energy by 8% and 12%, respectively (Schweer et al., 2016). Mixed pathogen challenges reduced ADG by 8-14% and feed efficiency by nearly 5% (Cornelison et al., 2018).

Disease status not only affects pig performance but also environmental outcomes. Cadéro et al. (2020) modeled that disease-challenged pigs had 9.4% lower feed intake, 14.1% lower ADG, and 4.4% poorer feed efficiency compared with healthy pigs. This translated into 6-8% higher climate change, acidification, eutrophication, energy demand, and land use potential. Nitrogen excretion also rose by 1.9%, and health status accounted for more than 50% of the variance in environmental impact, more than factors like feed rationing or infrastructure. Mortality further compounds inefficiency: pigs dying late in finishing waste more feed than those dying earlier (Dritz, 2012). For example, increasing mortality from 4% to 6% at 75% through finishing reduces feed efficiency by 1.8%. Field data show wean-to-finish mortality rates are higher in herds with PRRSV, *Mycoplasma hyopneumoniae*, or PEDV (Magalhães et al., 2022).

## Porcine Somatotrophin Hormone (PST)

Porcine somatotrophin hormone (PST) is a metabolic modifier that improves nutrient utilization by altering growth partitioning. Although not widely used in commercial U.S. production, PST provides a model for understanding how hormonal regulation can enhance efficiency. PST improves pig performance by shifting how absorbed energy and nutrients are used, promoting protein deposition while reducing fat synthesis, rather than by changing digestibility or muscle fiber types (Shurson and Kerr, 2023). Research shows PST can increase ADG by 10-20% and improve feed efficiency by about 20% (Moore et al., 2012). However, despite these benefits, PST is not widely adopted due to consumer concerns about hormone use in swine production.

## Summary

- Feed intake rises 1.5% per °C below the lower critical temperature but at the cost of poorer feed efficiency
- Heat stress reduces feed intake by 1-2% per °C above the upper critical temperature, with minimal effects on digestibility
- Heat stress can cause intestinal hypoxia and leaky gut, potentially impairing nutrient absorption
- Thin sows require more feed under cold stress, while heavier sows are more vulnerable to heat stress
- A 200-kg sow kept 5°C below lower critical temperature may need 90 kg more feed annually

## Literature Cited

- Andretta, I., F. M. W. Hickmann, A. Remus, C. H. Franceschi, A. B. Mariani, C. Orso, M. Kipper, M. P. Létourneau-Montminy, and C. Pomar. 2021. Environmental impacts of pig and poultry production: insights from a systematic review. *Front. Vet. Sci.* 8:750733. doi:10.3389/fvets.2021.750733
- Cadéro, A., A. Aubry, J. Y. Dourmad, Y. Salaün, and F. Garcia-Launay. 2020. Effects of interactions between feeding practices, animal health and farm infrastructure on technical, economic and environmental performances of a pig-fattening unit. *Animal.* 14:s348–s359. doi:10.1017/S1751731120000300
- Cornelison, A. S., L. A. Karriker, N. H. Williams, B. J. Haberl, K. J. Stalder, L. L. Schulz, and J. F. Patience. 2018. Impact of health challenges on pig growth performance, carcass characteristics, and net returns under commercial conditions. *Transl. Anim. Sci.* 2:50–61. doi:10.1093/tas/txx005
- Campos, P. H. R. F., E. Labussière, J. Hernández-García, S. Dubois, D. Renaudeau, and J. Noblet. 2014. Effects of ambient temperature on energy and nitrogen utilization in lipopolysaccharide-challenged growing pigs. *J. Anim. Sci.* 92:4909–4920. doi:10.2527/jas.2014-8108
- Dekkers, J. 2024. Opportunities to improve environmental sustainability of pork production through genetics. *J. Anim. Sci.* skaf042. doi:10.1093/jas/skaf042
- Dritz, S. S., M. D. Tokach, R. D. Goodband, and J. L. Nelssen. 2002. Effects of administration of antimicrobials in feed on growth rate and feed efficiency of pigs in multisite production systems. *J. Am. Vet. Med. Assoc.* 220:1690–1695. doi:10.2460/javma.2002.220.1690
- Gaillard, C., M. Durand, C. Largouët, J. -Y. Dourmad, and C. Tallet. 2021. Effects of the environment and animal behavior on nutrient requirements for gestating sows: future improvements in precision feeding. *Anim. Feed Sci. Technol.* 279:115034. doi:10.1016/j.ani-feedsci.2021.115034

- Lambert, G. P., C. V. Gisolfi, D. J. Berg, P. L. Moseley, L. W. Oberley, and K. C. Kregel. 2002. Hyperthermia-induced intestinal permeability and the role of oxidative and nitrosative stress. *J. Appl. Physiol.* 92:1750–1761. doi:10.1152/jappphysiol.00787.2001
- Magalhães, E. S., J. J. Zimmerman, P. Thomas, C. A. A. Moura, G. Trevisan, D. J. Holtkamp, C. Wang, C. Rademacher, G. S. Silva, and D. C. L. Linhares. 2022. Whole-herd risk factors associated with wean-to-finish mortality under the conditions of a Midwestern USA swine production system. *Prev. Vet. Med.* 198:105545. doi:10.1016/j.prevetmed.2021.105545
- Moore, K. L., B. P. Mullan, and D. N. D’Souza. 2012. The interaction between ractopamine supplementation, porcine somatotropin and moisture infusion on pork quality. *Meat Sci.* 92:125–131. doi:10.1016/j.meatsci.2012.04.022
- National Research Council. 2012. *Nutrient Requirements of Swine: 11th Revised Edition*. Washington, DC: The National Academies Press. <http://www.nap.edu/catalog/13298>
- Ortega, A. D. S. V., L. Babinszky, X. E. Ozsváth, O. H. Oriado, and C. Szabó. 2022. The effect of heat stress and vitamin and micro-- mineral supplementation on some mineral digestibility and electrolyte balance of pigs. *Animals (Basel)*. 12:386. doi:10.3390/ani12030386
- Rakhshandeh, A., J. C. M. Dekkers, B. J. Kerr, T. E. Weber, J. English, and N. K. Gabler. 2012. Effect of immune system stimulation and divergent selection for residual feed intake on digestive capacity of the small intestine in growing pigs. *J. Anim. Sci.* 90:233–235. doi:10.2527/jas.53976
- Renaudeau, D., H. Gilbert, and J. Noblet. 2012. Effect of climatic environment on feed efficiency in swine. In: J. F. Patience, editor. *Feed efficiency in swine*. Wageningen: Wageningen Academic Publishers. p. 183–210. [http://link.springer.com/10.3920/978-90-8686-756-1\\_9](http://link.springer.com/10.3920/978-90-8686-756-1_9)
- Schweer, W. P., K. Schwartz, E. R. Burrough, K. J. Yoon, J. C. Sparks, and N. K. Gabler. 2016. The effect of porcine reproductive and respiratory syndrome virus and porcine epidemic diarrhea virus challenge on growing pigs I: growth performance and digestibility. *J. Anim. Sci.* 94:514–522. doi:10.2527/jas.2015-9834
- Shurson, G. C., and B. J. Kerr. 2023. Challenges and opportunities for improving nitrogen utilization efficiency for more sustainable pork production. *Front. Anim. Sci.* 4:1204863. doi:10.3389/fanim.2023.1204863

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