Improving Feed and Nutrient Utilization by Optimizing Diet Energy and Nutrient Levels: Calcium & Phosphorus

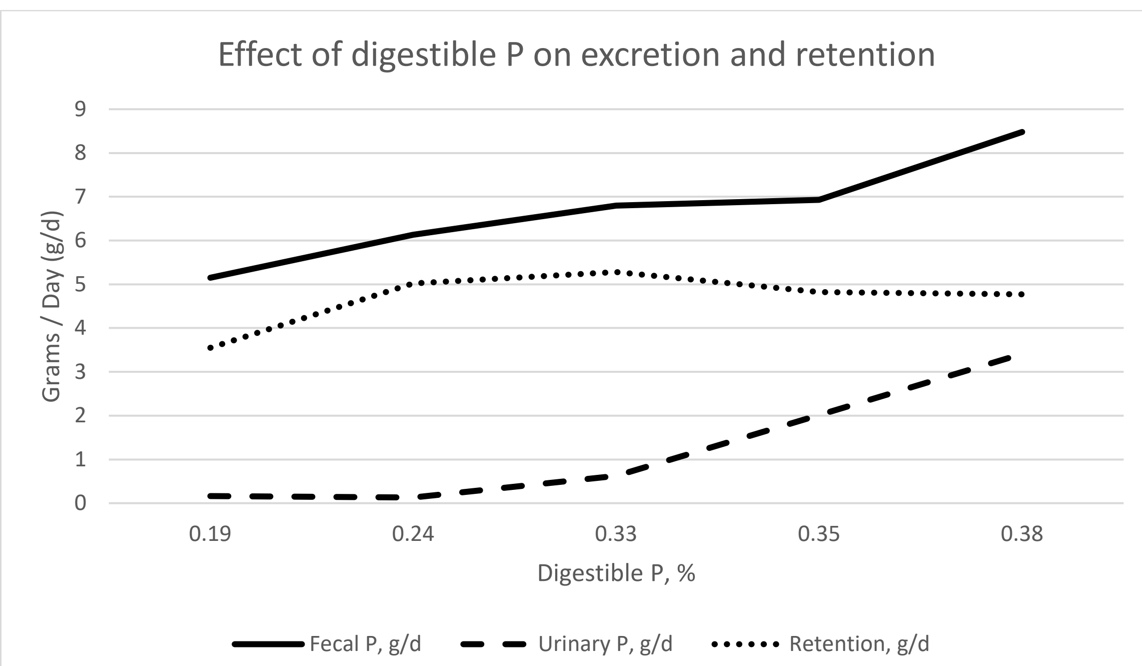
Ron Aldwin S. Navales, Mike D. Tokach, Joel M. DeRouchey, Katelyn N. Gaffield, Jason C. Woodworth, Robert D. Goodband, Jordan T. Gebhardt, Russell M. Euken, Jack C. M. Dekkers, and Caitlyn M. Phillips

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). 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). Calcium (Ca) and phosphorus (P) are critical nutrients in skeletal development, reproduction, and growth in pigs. However, excess dietary P is a major environmental concern because much of it is excreted in manure, contributing to eutrophication and water quality issues. Over the past decades, advances in understanding P digestibility and the use of phytase enzymes have improved nutrient utilization and reduced manure P outputs (Ekpe et al., 2002; NRC, 2012).

Calcium & Phosphorus

Phosphorus retention increases as dietary digestible P intake rises until requirements are met, after which retention plateaus and excretion increases and can be estimated as: P retention = -0.20001 x digestible P intake^2 + 2.6044 x digestible P intake – 3.269 (Ekpe et al., 2002). Fecal P increases linearly with P intake, while urinary P follows a quadratic pattern, rising sharply when dietary P exceeds requirements. Excess Ca in the diet can further reduce P utilization by binding P in the gastrointestinal tract and raising stomach pH, leading to more fecal P losses (Stein et al., 2011).



Adapted from Ekpe et al., 2002

Precision in estimating P and Ca requirements has improved. Earlier NRC (1998) recommendations gave single values for gestation and lactation, while NRC (2012) now provides phase-specific recommendations, enabling closer alignment with animal needs. Importantly, exogenous phytase supplementation improves digestibility of phytate-bound P in plant-based feeds, reducing inorganic P supplementation and manure P excretion (González-Vega and Stein, 2014; Zhai et al., 2022). Phytase also enhances utilization of other minerals such as Ca, Zn, and Fe.

Differentiating P excretion into soluble (high runoff risk) and insoluble (less mobile) fractions is valuable for evaluating environmental impact (Symeou et al., 2014). Managing Ca and P balance in diets is therefore critical for both performance and sustainability outcomes.

Summary

- Excess dietary P leads to higher manure P excretion, which contributes to eutrophication
- P retention follows a quadratic pattern: it increases with intake up to requirement, then plateaus
- Fecal P increases linearly with P intake; urinary P rises quadratically after requirements are exceeded
- High dietary Ca reduces P digestibility and retention due to Ca-P binding in the gut
- Exogenous phytase improves digestibility of phytate-bound P and reduces P losses
- Evaluating soluble vs. insoluble P in manure is important because soluble P is more environmentally reactive

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

Ekpe, E. D., R. T. Zijlstra, and J. F. Patience. 2002. Digestible phosphorus requirement of grower pigs. Can. J. Anim. Sci. 82:541–549. doi:10.4141/a02-006

González-Vega, J. C., and H. H. Stein. 2014. Calcium digestibility and metabolism in pigs. Asian-Australas. J. Anim. Sci. 27:1–9. doi:10.5713/ajas.2014.r.01

National Research Council. 1998. Nutrient Requirements of Swine: 10th Revised Edition. The National Academies Press, Washington, DC. https://nap.nationalacademies.org/catalog/6016/nutrient-requirements-of-swine-10th-revised-edition

National Research Council. 2012. Nutrient Requirements of Swine: 11th Revised Edition. Washington, DC: The National Academies Press. http://www.nap.edu/catalog/13298

Stein, H. H., O. Adeola, G. L. Cromwell, S. W. Kim, D. C. Mahan, and P. S. Miller; North Central Coordinating Committee on Swine Nutrition (NCCC-42). 2011. Concentration of dietary calcium supplied by calcium carbonate does not affect the apparent total tract digestibility of calcium, but decreases digestibility of phosphorus by growing pigs. J. Anim. Sci. 89:2139–2144. doi:10.2527/jas.2010-3522

Symeou, V., I. Leinonen, and I. Kyriazakis. 2014. Modelling phosphorus intake, digestion, retention and excretion in growing and finishing pigs: model description. Animal. 8:1612–1621. doi:10.1017/S1751731114001402

Zhai, H., O. Adeola, and J. Liu. 2022. Phosphorus nutrition of growing pigs. Anim. Nutr. 9:127–137. doi:10.1016/j.aninu.2022.01.010

This work was supported by the National Pork Board grant #22-092.