Zinc, copper, potassium, sulfur, and iron excretion in pigs

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Various essential macro and microminerals are added to swine diets to support growth performance and immune functions. Key microminerals, including zinc (Zn), copper (Cu), and iron (Fe) and the macrominerals potassium (K) and sulfur (S) play regulatory, structural, and catalytic roles in normal pig metabolism (NRC, 2012). However, due to potential toxic effects at high dietary concentrations, mineral levels that exceed the physiological requirement are normally excreted in feces or urine. Consequently, the accumulation of these minerals in manure, soil, or water has been associated with environmental and public health concerns (Brugger and Windisch, 2015).

A complete description of the main functions of Zn, Cu, and Fe in pigs can be found in the KSU swine nutrition guide (KSU Mineral Sources for Swine Diets fact sheet.pdf). For these microminerals, homeostasis is controlled during the absorption process. When dietary levels exceed the nutritional requirements, the physiological processes involved in the mineral absorption are downregulated, reducing absorption of the mineral absorption through the intestinal wall, leading to greater mineral excretion in feces, with excretion proportional to the excess mineral intake (Windisch, 2002). In contrast, other minerals such as K and S are regulated through other post-absorption mechanisms leading to greater urine than fecal excretion.

Potassium is the third most abundant mineral in pigs (NRC, 2012). It plays a critical role in osmotic regulation, maintaining acid-base balance, nerve function, and muscle contraction (Groff et al., 1998). The K concentration in ingredients commonly used in swine diets is enough to meet the nutritional requirements. Therefore, it is less common to add external K sources to the diet (NRC, 2012). The main route of K excretion in pigs is through urine, in a physiological process regulated by the kidney (Udensi and Tchounwou, 2017), but a small proportion is eliminated in feces.

Sulfur is essential for the formation of S-containing compounds including vitamins and proteins. The amount of S present in ingredients, such as amino acids and sulfate-based minerals, is generally sufficient to meet the nutritional requirements of pigs (NRC, 2012). Sulfur is primarily excreted through urine as sulfate, with additional losses occurring through feces from undigested dietary sources (Rose et al., 2015). In manure, microbial activity can convert S into hydrogen sulfide (H_2S), contributing to odor emission (Andraskar et al., 2021).

Mineral excretion

Models were developed using data from 51 published studies to predict the effects of mineral intake on their excretion. The models for Zn, Fe, and Cu consider only fecal excretion as there are insignificant amounts excreted in urine, whereas models for K and S excretion accounted for both fecal and urinary losses. Model parameters are presented in Table 1 where the slope represents the proportion of ingested minerals the pig excretes. The intercept reflects basal mineral excretion, independent of dietary mineral intake.

To illustrate the model application, consider Zn, where the amount ingested that is excreted depends on whether the concentration in the diet is below or above the pig's requirement. When below the pig's requirement, 61% (slope = 0.614) of the Zn consumed is excreted. When Zn is fed above the requirement, 82.5% of Zn consumed is excreted in the feces. This same procedure was performed for Cu, Fe, K, and S with the slopes representing the excretion relative to intake.

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Table 1. Relationship (Y = Slope × X + intercept) between daily total mineral intake (X in mg/d) and daily mineral excretion (Y in mg/d)[1]

Mineral	Nutritional status	Slope	Intercept	n[2]	R^2
Zn	At or below the requirement	0.614	8.074	93	0.90
	Over the requirement	0.825	-10.547	197	0.96
Cu	At or below the requirement	0.684	0.016	14	0.67
	Over the requirement	0.879	-10.266	161	0.94
Fe	Over the requirement	0.619	55.823	116	0.79
K	Over the requirement	0.804	-128.313	26	0.97
S	General model	0.577	160.259	13	0.97

[1] Models for Zn, Cu, and Fe predict fecal mineral excretion, while K and S models predict total mineral excretion (urine + fecal excretion).
[2] n = number of datapoints included in the regression model.

Time-dependent mineral excretion

For some minerals, it is well established that there is a time component before excretion begins. Specifically, Zn excretion does not exhibit a linear relationship with dietary Zn intake until endogenous Zn pools have been replenished. For example, Rincker et al., (2005), demonstrated that Zn excretion within the first 10 days after weaning was minimal, even when pigs were fed with 2,000 mg/kg of Zn. This finding indicates that dietary Zn is initially retained to restore Zn pools before excess Zn begins to be excreted.

Takeaways

The models presented in this factsheet provide a tool for estimating Zn, Cu, Fe, K, and S mineral excretion in pigs. Developing such models is important to accurately assess the environmental impact of different feeding strategies. By enabling producers and researchers to evaluate and adjust diets, these models contribute to the development of sustainable nutritional strategies that minimize mineral excretion and reduce environmental impact.

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