Mineral Levels in Nursery Diets

Considering all the minerals supplemented in nursery diets, calcium, phosphorus, sodium, chloride, zinc, and copper are particularly important for adequate growth and health of nursery pigs. The requirements and practical levels of these minerals in nursery diets are discussed in this fact sheet.

Calcium and phosphorus

Calcium and phosphorus are essential for growth performance of nursery pigs. These minerals are involved in skeletal structure development and maintenance, lean tissue deposition, muscle contraction, and many other physiological functions. Phosphorus levels in nursery diets have typically a low safety margin because of environmental and economic concerns. Calcium levels, on the other hand, are typically high in nursery diets due to the unaccounted-for contribution of calcium from carriers, release from phytase, variability of calcium estimation in feed ingredients, and no environmental and economic concerns regarding calcium.

The accurate estimation of calcium and phosphorus requirements of nursery pigs is important to maximize growth performance, minimize phosphorus excretion in swine waste to the environment, and make savings in diet cost. Current statistical modelling techniques have been applied to determine the dose-response to calcium and phosphorus, as well as the ratio of calcium relative to phosphorus.

Calcium requirements

Calcium requirement estimates (**Table 1**) are typically expressed as total calcium. Total calcium accounts for the analyzed calcium content of ingredients. Recently, values for calcium digestibility in feed ingredients have been determined (González-Vega et al., 2015a,b; Merriman et al., 2016), allowing the requirements for digestible calcium to be estimated (González-Vega et al., 2016).

Nursery diets with excessive calcium levels have a severe negative impact on growth performance (González-Vega et al., 2016). The negative impact of excessive dietary calcium on growth performance is even more evident in diets with marginal or deficient phosphorus levels (González-Vega et al., 2016; Wu et al., 2018a).

The NRC (2012) calcium requirements for nursery pigs are very high, which may lead to an impact on growth performance when formulating diets to meet the calcium requirement estimates. A practical approach consists of maintaining adequate phosphorus levels and setting calcium levels relative to phosphorus, targeting between 1.10:1 and 1.25:1 total calcium to total phosphorus ratio or between 1:20 to 1.40:1 digestible calcium to digestible phosphorus ratio (González-Vega et al., 2016). By taking this approach, the NRC (2012) calcium requirement estimates can rather be used as an indication of maximum calcium levels in nursery diets.

Phosphorus requirements

Phosphorus requirement estimates (**Table 1**) are typically expressed as digestible phosphorus. Recently, the phosphorus requirements for nursery pigs have been determined by dose-response models, allowing for a more precise estimation of phosphorus levels to maximize growth performance and optimize economics while minimizing phosphorus excretion (Vier et al., 2017).

The phosphorus requirements of nursery pigs appear to be greater than the NRC (2012) recommendations of digestible phosphorus as a percentage of the diet (Vier et al., 2017; Wu et al., 2018b). The variation on phosphorus requirements depends on the goal, but typically the phosphorus requirements to optimize phosphorus retention is greater than to maximize growth (Vier et al., 2017; Wu et al., 2018b). A practical approach consists of maintaining phosphorus levels at approximately 140% and 130% of the NRC (2012) recommendations of digestible phosphorus for nursery pigs between 12 to 25 lb and 25 to 50 lb, respectively.

Table 1. Calcium and phosphorus requirement estimates for nursery pigs			
	Nursery pig weight, lb		
	12 to 15	15 to 25	25 to 50
Total calcium, %[1]	0.85	0.80	0.70
STTD calcium, %[2]	0.60	0.58	0.48
STTD phosphorus, %[3]	0.63	0.56	0.43

[1]From NRC (2012). Indication of maximum calcium levels in nursery diets. Set calcium by formulating to calcium:phosphorus ratio.
[2]From González-Vega et al. (2016).
[3]From Vier et al. (2017) and Wu et al. (2018b).

Calcium:phosphorus ratio

The calcium:phosphorus ratio greatly influences growth performance of nursery pigs and can even be more important than the absolute concentration of calcium and phosphorus. The ideal calcium:phosphorus ratio seems to be between 1.10:1 and 1.25:1 total calcium to total phosphorus ratio (Wu et al., 2018a) or between 1:20 to 1.40:1 digestible calcium to digestible phosphorus ratio (González-Vega et al., 2016).

Nursery diets with wide calcium:phosphorus ratios or excessive calcium and marginal or deficient phosphorus concentrations interfere with phosphorus absorption (Reinhardt and Mahan, 1986). Consequently, growth performance of nursery pigs is negatively affected by wide calcium:phosphorus ratios (González-Vega et al., 2016; Wu et al., 2018a). Diets with adequate phosphorus levels allow the calcium:phosphorus ratio to be on the upper range, with a decrease in growth performance around 1.9:1 to 2:1. However, diets with marginal phosphorus levels require a narrow calcium:phosphorus ratio (Reinhardt and Mahan, 1986; Qian et al., 1996; Wu et al., 2018a).

Phytase

Phytase is an enzyme that catalyzes the release of phosphorus from phytate. The addition of exogenous microbial phytase to nursery diets is a common practice to efficiently and economically enhance phosphorus utilization. Moreover, the use of phytase above conventional levels (500 to 1,000 FTU/kg) seems to have the potential to improve growth performance of nursery pigs beyond what is expected with adequate phosphorus levels (Zeng et al., 2014). The use of high levels of phytase is also becoming more common in nursery diets (Gourley et al., 2018; Laird et al., 2018).

More information about phytase is available at: Phytase in Swine Diets.

Sodium and chloride

Sodium and chloride are particularly important for nursery pigs. The minerals are involved in nutrient absorption, electrolyte balance, and regulation of pH. Salt is the most common source of sodium and chloride, but it is often not included in sufficient quantities to meet the requirements of sodium and chloride of nursery pigs. Sodium and chloride concentration are often overlooked in nursery diets because some commonly used ingredients contain high levels of sodium, particularly dried whey (approximately 1% sodium) and spray-dried plasma protein (approximately 3% sodium).

The requirements of sodium and chloride are greater for nursery pigs and abruptly decrease for grow-finish pigs. Recently, the requirements of sodium and chloride for nursery pigs have been determined (Shawk et al., 2018a,b) and indicated that the NRC (2012) requirement estimates are accurate (**Table 2**). Nursery diets need as much as 0.5 to 0.6% added salt to meet the requirements of nursery pigs. Nursery diets deficient in salt result in decreased growth performance due to reduced feed intake and poor feed efficiency (Shawk et al., 2018a,b).

Table 2. Sodium and chloride requirement estimates for nursery pigs			
	Nursery pig weight, lb		
	12 to 15	15 to 25	25 to 50
Sodium, %	0.40	0.35	0.28
Chloride, %	0.50	0.45	0.32

From NRC (2012) and Shawk et al. (2018a,b).

Dietary electrolyte balance

Dietary electrolyte balance represents the ratio of cations and anions in a diet and is important for acid-base status of pigs. The dietary ions that mostly influence electrolyte balance are sodium, chloride, and potassium. Dietary electrolyte balance is determined by the difference between cations and anions in the diet: Na + K - Cl. However, more comprehensive estimation of dietary electrolyte balance also takes into account the contribution of divalent ions, such as calcium, magnesium, sulfur, and potassium.

Traditionally, the optimal dietary electrolyte balance for pigs is reported to be approximately 250 mEq/kg (NRC, 2012). In nursery pigs, increasing dietary electrolyte balance to approximately 200 to 250 mEq/kg seems to have beneficial effects on growth performance (Lei et al., 2017; Jones et al., 2018).

Zinc and copper

Zinc and copper are trace minerals required at concentrations of 80 to 100 ppm and 5 to 6 ppm, respectively to meet the requirements of nursery pigs (**Table 3**). However, the addition of zinc and copper at quantities greater than the requirement exerts a beneficial effect on growth performance of nursery pigs (Liu et al., 2018). Greater quantities of zinc and copper are often referred as growth promoting or pharmacological levels.

Pharmacological levels of dietary zinc between 2,000 and 3,000 ppm is a common recommendation to initial nursery diets to reduce post-weaning diarrhea and improve growth performance (Hill et al., 2000; Shelton et al., 2011). These effects have been consistently demonstrated with dietary zinc provided as zinc oxide (ZnO) (Hill et al., 2001; Hollis et al., 2005; Walk et al., 2015), while zinc sulfate ($ZnSO_4$) has greater potential to induce toxicity (Hahn and Baker, 1993). Organic sources of zinc with greater bioavailability have not consistently demonstrated the same benefits as zinc oxide when organic zinc is added at lower levels (Hahn and Baker, 1993; Carlson et al., 2004; Hollis et al., 2005). However, pharmacological levels of zinc appear to interfere with calcium and phosphorus absorption, prompting the use of phytase or greater levels of calcium and phosphorus in nursery diets to ameliorate this effect (Blavi et al., 2017).

Pharmacological levels of dietary copper between 125 and 250 ppm are commonly used in the diet to enhance fecal consistency and improve growth performance of nursery pigs (Bikker et al., 2016). The most commonly used source of dietary copper is copper sulfate ($CuSO_4$) (Cromwell et al., 1998), but tribasic copper chloride (TBCC) is as effective as copper sulfate in promoting growth performance (Cromwell et al., 1998; Coble et al., 2017). Organic sources of copper with greater bioavailability, such as Cu-amino acid chelate, also seem to have the potential to influence growth performance (Pérez et al., 2011; Carpenter et al., 2018).

A typical recommendation is to use pharmacological levels of zinc in initial nursery diets fed to pigs up to 25 lb and then replace zinc by pharmacological levels of copper for the remaining nursery period (**Table 3**). Additive effects of using pharmacological levels of zinc and copper are not common (Hill et al., 2000), but might occur to some degree (Pérez et al., 2011). In diets with in-feed antimicrobials, the use of pharmacological levels of zinc or copper seems to have an additive effect in growth performance (Stahly et al., 1980; Hill et al., 2001).

The use of pharmacological levels of zinc and copper poses an environmental concern because of the greater excretion of minerals in swine waste and ultimately in the soil fertilized with swine manure (Jondreville et al., 2003). In addition, the implication of pharmacological levels of zinc and copper as a cause of increasing antimicrobial resistance is a rising concern (Yazdankhah et al., 2014). Therefore, regulations have been implemented in some countries restricting or prohibiting the use of zinc or copper as growth promoters. Thus, there is an appeal for prudent use of pharmacological levels of zinc and copper in swine production.

Table 3. Zinc and copper requirement estimates and recommended pharmacological levels for nursery pigs

	Nursery pig weight, lb		
	12 to 15	15 to 25	25 to 50
Requirement estimates[1]			
Zinc, ppm	100	100	80
Copper, ppm	6	6	5
Pharmacological levels[2]			
Zinc oxide, ppm[3]	3,000	2,000	-
Copper, ppm	-	-	up to 250

[1]From NRC (2012).

[2]From Hill et al. (2001) and Shelton et al. (2011).

[3]Pharmacological levels of zinc should only be used for short time. Maximum tolerance level of 1,000 ppm for long-term use.

- No recommendation of use.

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