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Short Communication

Short communication: commercial diets for pigs in the United States contain more calcium than formulated

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Abstract

Data from Europe indicate that commercial diets for pigs and poultry contain significantly more Ca than formulated. Therefore, a survey of commercial pig diets used in the United States was conducted to test the hypothesis that the analyzed concentrations of total Ca and total P in commercial pig diets in the United States are not greater than formulated values. A total of 103 diet samples from the commercial swine industry in the United States were collected between 2019 and 2021. Diet samples were provided by feed mills, feed companies, or swine farms located in major swine-producing states in the United States including NC, TN, IA, IN, KS, MN, NE, and IL. Diets were formulated for nursery pigs, growing-finishing pigs, or sows. Each company provided formulated values for total Ca and P in all samples. Samples were sent to the University of Illinois where they were ground and analyzed for Ca and P by inductively coupled plasma-optical emission spectrometry. The formulated values for Ca and P were regressed against analyzed values, and the intercept was considered the estimated under- or over-supply of each mineral. Results indicated that there was an average of 0.19 percentage units more Ca (model; $P < 0.001$) in the diets than formulated, whereas, for total P, the average oversupply was only 0.06 percentage units (model; $P < 0.001$). In conclusion, diets used in the U.S. swine industry contain more total Ca than formulated, whereas total P is close to formulated values, which indicates that greater importance is given to P than to Ca in formulation. However, the current data indicate that more attention should be given to the actual concentration of Ca in all Ca-containing feed ingredients to avoid Ca oversupply and its detrimental effect on P digestibility and growth performance of pigs fed diets that do not contain excess P.

Lay Summary

Calcium is often oversupplied in pig diets because limestone, the main source of Ca in pig diets, is an inexpensive feed ingredient and is often used as a carrier in premixes or a diluent in feed ingredients. However, excess Ca may be detrimental to P digestibility and pig growth performance. It was recently reported that commercial pig and poultry diets sold in Europe contain significantly more Ca than formulated, but it is not known if the Ca concentrations in commercial pig diets in the United States also contain more Ca than formulated. Therefore, a survey of commercial diets from the United States was conducted to compare analyzed and formulated values for Ca. A total of 103 diets were collected from feed mills, feed companies, or swine integrators in the United States between 2019 and 2021. Samples were analyzed for total Ca and total P. Results from the regression model used to evaluate the data indicated that diets on average contained 0.19 percentage units more total Ca and 0.06 percentage units more total P than expected. Thus, more attention needs to be paid to the inclusion of Ca in pig diets to avoid Ca oversupply and the negative effects of Ca on pig growth performance.

Key words: calcium, commercial diets, phosphorus, pigs

Abbreviations: ADFI, average daily feed intake; ATTD, apparent total tract digestibility

Introduction

Calcium and P are required in swine diets, but the amount of Ca and P in plant-based feed ingredients is low or not digestible compared with what the animals need (NRC, 2012). Therefore, phytases and mineral supplements such as calcium carbonate, limestone, and calcium phosphates are usually included in diets for pigs to provide additional Ca and P. Special attention has been given to the amount of P supplied in diets for pigs due to economic and environmental impacts of over-supplementation of P in diets for pigs (Knowlton et al., 2004). However, because Ca is an inexpensive nutrient, the supply of limestone or calcium carbonate in diets is given less attention than the supply of P, but the metabolism of Ca is closely related to P, and unbalanced provisions of Ca and P may influence the availability of both minerals (Crenshaw, 2001). Indeed, there is a negative correlation between concentrations of dietary total Ca and the apparent total tract digestibility (ATTD) of P in pigs (Stein et al., 2011; Velayudhan et al., 2019). Likewise, results of a number of experiments have demonstrated that whereas bone mineralization is maximized by increasing dietary Ca and P, there is a negative impact of excess Ca on growth performance of pigs (González-Vega et al., 2016a, 2016b; Merriman et al., 2017; Lagos et al., 2019a, 2019b). Therefore, although an adequate supply of Ca in diets for pigs is crucial for normal growth and reproductive performance, it is also crucial to avoid supplying Ca above

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Table 1. Summary of diet samples collected, calculated, and analyzed nutrient values[1,2]

		Average calculated		Average analyzed			
Production phase	Number	Ca, %	P, %	Ca, %	P, %	Dry matter, %	Ash, %
Nursery pigs	22	0.67 ± 0.148	0.60 ± 0.085	0.83 ± 0.167	0.65 ± 0.121	87.0 ± 6.5	6.17 ± 0.73
Growing-finishing pigs	37	0.54 ± 0.087	0.45 ± 0.078	0.59 ± 0.130	0.50 ± 0.112	84.9 ± 8.8	5.25 ± 2.01
Sows[3]	36	0.80 ± 0.073	0.60 ± 0.071	0.87 ± 0.139	0.64 ± 0.114	88.1 ± 4.4	5.57 ± 0.98
Not reported	8	-	-	-	-	89.2 ± 4.9	5.67 ± 0.66
Total	103	0.67 ± 0.144	0.55 ± 0.105	0.76 ± 0.253	0.60 ± 0.172	86.6 ± 7.1	5.59 ± 1.39

[1]From the 103 diet samples, 68 were in mash form, and 35 were pelleted.
[2]Values are expressed as mean ± standard deviation.
[3]Includes diets for gilts, gestating sows, and lactating sows.

the requirement because this may result in reduced absorption of P, and therefore, indirectly create a P deficiency.

Limestone is sometimes used as a carrier in vitamin and mineral premixes and in premixes supplying feed additives, but the concentration of Ca in premixes is not always taken into account in diet formulations. Limestone may also be used as a flow agent in soybean meal and other feed ingredients (Ibáñez et al., 2020), which may result in greater concentrations of Ca in feed ingredients than expected. However, feed ingredients are not routinely analyzed for Ca in feed mills and it is, therefore, possible that Ca originating from limestone added to ingredients is not accounted for in diet formulations. Therefore, it is possible that the concentration of Ca in commercial diets for pigs is underestimated. Indeed, the amount of Ca in 795 diets produced by the swine and poultry industries in Europe was on average 0.22 percentage units greater than formulated compared with an oversupply of 0.08 percentage units for P (Walk, 2016). There are, however, no data demonstrating if Ca and P in commercial diets for pigs produced in the United States also are oversupplied. Therefore, the objective of this work was to test the null hypothesis that the analyzed concentration of Ca and P in commercial pig diets in the United States is not greater than formulated values.

Materials and Methods

Sample collection

Samples of 103 diets formulated for pigs in different productive stages were collected from feed mills, feed companies, or swine farms in eight states in the United States (NC, TN, IA, IN, KS, MN, NE, and IL). All samples were sent to the University of Illinois (Urbana, IL, USA) along with information about diet specifications. A minimum of 250 g of each sample was labeled and stored and sample information about origin, diet form, production phase, and formulated values for total Ca and P were recorded.

Sample analysis

All diet samples were finely ground, subsampled, and analyzed at the University of Illinois (Urbana, IL, USA) for dry matter by oven drying at 135 °C for 2 h (Method 930.15; AOAC Int., 2019) and for ash by incineration at 600 °C for 2 h (Method 942.05; AOAC Int., 2019). Samples were also analyzed for Ca and P by inductively coupled plasma-optical emission spectrometry (Method 985.01 A, B, and C; AOAC Int., 2019) using an Avio 200 apparatus (PerkinElmer, Waltham, MA, USA). Sample preparation included dry ashing at 600 °C for 4 h (method 942.05; AOAC Int., 2019), and wet digestion with nitric acid (method 3050 B; US-Environmental Protection Agency, 2000).

Statistical analyses

Data were analyzed using a regression between analyzed and formulated values for Ca, P, and the Ca to P ratio using the PROC REG procedure of SAS (SAS Inst. Inc., Cary, NC, USA). The response variable, analyzed values for Ca or P, was regressed against the explanatory variable, which was the formulated concentration of Ca or P. Because there were linear relationships between analyzed and calculated values for dietary nutrients, the intercept of the equation represented the estimate for under- or over-supply of Ca or P in the diets.

Results and Discussion

Interest in digestibility and requirements for Ca by pigs has increased in the last decade because of the negative impact that excess dietary Ca has on the digestibility of P and growth performance of pigs (Stein et al., 2011; González-Vega et al., 2016a; Lee et al., 2020). Values for the digestibility of Ca in Ca-containing feed ingredients have been generated and digestible Ca requirements by growing pigs have been published (González-Vega and Stein, 2016; Lagos et al., 2021). However, limestone, the main source of Ca in pig diets, is an inexpensive feed ingredient that is often oversupplied in diets, as indicated by data from the European swine and poultry industries (Walk, 2016). There are, however, no data from the U.S. swine industry demonstrating if actual concentrations of Ca and P in mixed diets are in agreement with formulated values. As a consequence, the present work attempted to fill this gap.

Collected diet samples were formulated for nursery pigs, growing-finishing pigs, gilts, gestating sows, or lactating sows. The average dry matter in the 103 diets used in the present survey was 86.6 ± 7.1%, whereas samples on average contained 5.59 ± 1.39% ash (Table 1). Values for Ca and P ranged from 0.37 to 1.27% and 0.32 to 0.96% with an average of 0.75 ± 0.19% and 0.60 ± 0.13%, respectively.

The regression analysis indicated that there was an average of 0.19 percentage units (model; $P < 0.001$) more total Ca in diets than formulated (Figure 1). This value concurs with data from Walk (2016) indicating an excess of 0.22 percentage units of total Ca in commercial diets from the European swine and poultry industries. The reason for this observation may be that limestone is often used as a carrier in vitamin-mineral

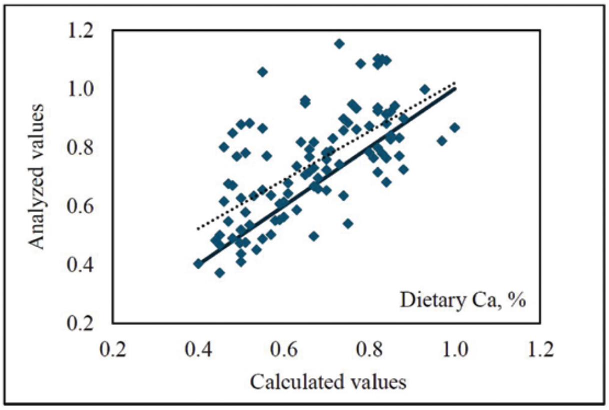

Figure 1. Regression (dotted line) of analyzed values for total Ca (%) on calculated values for total Ca (%) in swine diets from the United States [Y = (0.825 × X) + 0.194], with r^2 = 0.42 and P < 0.001. The solid line represents the expected outcome of X = Y.

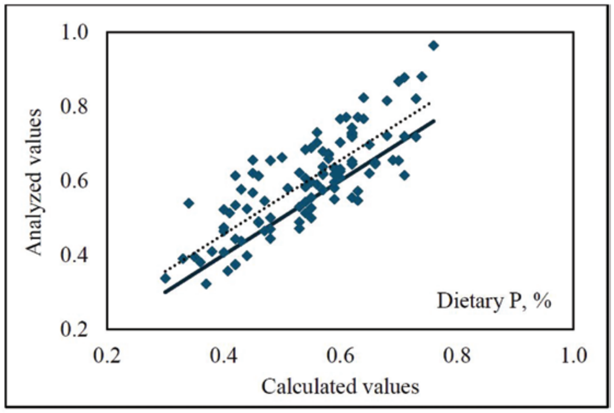

Figure 2. Regression (dotted line) of analyzed values for total P (%) on calculated values for total P (%) in swine diets from the United States [Y = (1.001 × X) + 0.055], with r^2 = 0.66 and P < 0.001. The solid line represents the expected outcome of X = Y.

premixes as well as in feed additive premixes, and limestone is also sometimes used as a flow enhancer in feed ingredients including soybean meal (Sotak-Peper et al., 2017). The average value for total Ca in soybean meal reported by the NRC (2012) is 0.33%, but values that ranged from 0.21 to 0.76% Ca in soybean meal from crushing plants in the United States have been reported (Sotak-Peper et al., 2016; Lagos and Stein, 2017). Bakery meal and distillers dried grains with soluble are believed to have a low concentration of Ca (0.13 and 0.10, respectively; NRC, 2012), but bakery meal may contain up to 0.51% Ca (Liu et al., 2018) and distillers dried grains with solubles may contain up to 0.28% Ca (Pedersen et al., 2007). Therefore, if Ca-containing feed ingredients are not analyzed for Ca before diet formulation, and an average value is used, the concentration of Ca in the diet may be underestimated. Likewise, if the concentration of Ca in premixes or the Ca-releasing effect of phytase is not accounted for in diet formulation, Ca in the final diets will be greater than formulated. The present data indicate that not all sources of Ca in feed ingredients used in the U.S. swine industry are accounted for in diet formulation, resulting in underestimation of the actual Ca in diets, and overfeeding of Ca to pigs.

Results from the regression analysis between analyzed and calculated values for total P indicated that on average, diets from the U.S. swine industry contain 0.06 percentage units (model; $P < 0.001$) more P than what was formulated (Figure 2), which is in agreement with the value of 0.08 percentage units excess *P* reported by Walk (2016). This indicates that both in Europe and in the United States, more attention is given to the concentration of P in swine diets compared with Ca. This is likely because the cost of feed phosphates is much greater than that of limestone. There are also negative environmental impacts of oversupplying P in diets because that will result in increased P in the manure (Selle and Ravindran, 2008). Microbial phytase contributes to reducing P excretion by releasing P and Ca from phytate in plant-based feed ingredients and also in some animal-based ingredients (Gonzalez-Vega et al., 2015), which reduces undigested P in the manure (Greiner and Konietzny, 2010). Nevertheless, the observation that more attention appears to be given to the inclusion of P than Ca in diets for pigs results in diets with adequate levels of P, but with excess Ca, are produced. This will likely lead to reduced growth performance of weanling pigs (González-Vega et al., 2016a; Lagos et al., 2019a) and growing-finishing pigs (Gonzalez-Vega et al., 2016b; Merriman et al., 2017; Lagos et al., 2019b). This effect is expected to be exacerbated in diets that are marginal in P, but may be prevented if diets contain P in excess of the requirement. Due to the greater excess of Ca than of P, the actual Ca to P ratio was also greater (P < 0.05) than calculated (Figure 3).

Increasing levels of Ca in diets with a fixed level of P decreased the ATTD of P, likely as a result of the formation of Ca-P complexes that make P unavailable for pigs (Stein et al., 2011; Lee et al., 2020). Based on the linear correlation between dietary total Ca and ATTD of P observed by Stein et al. (2011), the ATTD of P (%) can be estimated as 65.0–18.8 × dietary total Ca ($r^2 = 0.83$; $P < 0.05$). This indicates that if a diet is formulated to contain 0.66% total Ca, but the actual concentration is 0.85%, the ATTD of P will decrease from 52.6% to 49.0%. This reduced P digestibility may result in deficiency of P and P deficiency is associated with depression in feed intake by pigs (Sørensen et al., 2018). Data from Ca requirement experiments indicated that regardless of the concentration of dietary P, there was a linear decrease in average daily feed intake (ADFI) of pigs as dietary Ca increased (Merriman et al., 2017; Lagos et al., 2019b). Using equations for the correlation between dietary Ca and ADFI reported in pigs from 50 to 85 kg (Lagos et al., 2019b) and from 100 to 130 kg (Merriman et al., 2017), the inclusion of 0.19 percentage units more total Ca than the requirement, will result in 50 or 152 g less ADFI, respectively. A negative impact of excess dietary Ca on growth performance of younger pigs has also been demonstrated (González-Vega et al., 2016b; Wu et al., 2017; Lagos et al., 2019a). However, because Ca requirements for bone ash are greater than for growth performance (NRC, 2012), the impact of excess Ca on bone mineralization of pigs may be different from that on growth performance. Therefore, the fact that diets from the U.S. swine industry on average contain 0.19 percentage units more total Ca, but only 0.06 percentage units more total P than formulated, indicates that growth performance of pigs is likely being compromised by excess Ca in diets, and more attention should be given to the concentration of Ca in feed ingredients and complete diets. In addition, if limestone inclusion in diets is reduced to align diet Ca with the requirement, more corn will be added to the diets, which will increase diet energy concentration and likely positively impact growth performance.

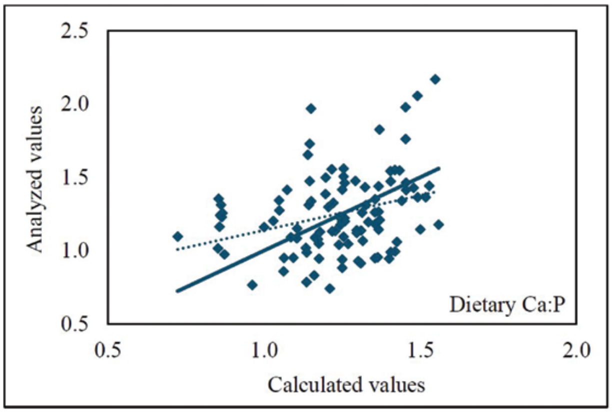

Figure 3. Regression (dotted line) of analyzed values for total Ca:P ratio on calculated values for total Ca:P in swine diets from the United States [Y = (0.474 × X) + 0.665], with r^2 = 0.09 and $P < 0.05$. The solid line represents the expected outcome of X = Y.

Conclusions

Commercial diets from the swine industry in the United States on average contain 0.19% more total Ca and 0.06% more total P than formulated. The reason for this observation is likely the use of limestone as a carrier in premixes and as a flow agent in feed ingredients. The consequence of the excess dietary Ca is reduced P digestibility and reduced growth performance of pigs. Therefore, all Ca-containing feed ingredients and premixes should be analyzed for Ca prior to diet formulation to avoid underestimation of Ca concentration in ingredients and oversupply in diets. Likewise, frequent analysis of complete diets to determine if actual concentrations of Ca align with formulated values also needs to be incorporated into the quality control programs used at feed mills.

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Conflict of Interest

The authors have no real or perceived conflicts of interest.

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