Why limestone becomes important: practical implications of supplemental phytase for increased calcium digestibility of limestone in growing pigs

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Introduction

Calcium (Ca) ions may bind to phytate in the intestinal tract of pigs and form insoluble phytate-Ca complexes, which reduces digestibility because pigs do not secrete endogenous phytase. If phytase is supplemented to diets, phytate is hydrolyzed and Ca from the complex is released, which increases Ca digestibility. Effects of phytase on Ca digestibility depend on the feed ingredients used, but the digestibility of Ca in limestone increases with phytase supplementation in most cases. In practical diets for 20 to 50 kg pigs, 45% of total dietary Ca is supplied by limestone, but if 500 units of microbial phytase is included in the diet, less feed phosphates can be used, increasing the contribution of limestone to approximately 67% of total dietary Ca. Excess dietary Ca reduces phosphorus (P) digestibility and growth performance of pigs and increases in Ca digestibility by phytase, therefore, allow for a reduction in the provision of Ca in the diets. Formulating diets based on values for standardized total tract digestibility (STTD) of Ca ensures additivity among ingredients in diet formulation because the impact of endogenous Ca in the feces is eliminated. However, STTD values from multiple experiments using the basal endogenous loss of Ca determined from feeding Ca-free diets without or with microbial phytase have not been summarized. Therefore, the objective was to summarize data for the STTD of Ca in 32 sources of limestone without or with supplemental phytase and test the hypothesis that microbial phytase will increase the STTD of Ca in limestone, regardless of whether or not calculations accounted for a reduced basal endogenous Ca loss caused by microbial phytase.

Materials and Methods

A total of 32 sources of limestone were collected, including both published and unpublished datasets from experiments conducted at the Universtiy of Illinois. For each source of limetone, values for Ca and P in diets, Ca in limestone, and Ca digestibility values were collected. Values for the STTD of Ca in limestone without or with supplementatal phytase were summarized. Due to variation in calculated STTD of Ca among experiments, all STTD values with phytase were recalculated to ensure consistency. Two approaches were used. In the first approach, STTD of Ca was calculated by correcting ATTD values using an average basal endogenous loss of Ca obtained from diets without phytase. If only apparent total tract digestibility (ATTD) of Ca was reported, STTD values were calculated using an average value of 471 mg/kg dry matter intake (Lee et al., 2023). In the second approach, STTD of Ca was calculated by correcting ATTD values using a reduced basal endogenous loss of Ca to account for the effects of phytase on the endogenous loos of Ca using the following equation (Nelson et al., 2022): basal endogenous loss of Ca, mg/kg dry matter intake = $0.00003 \times \text{phytase level}^2 - 0.1749 \times \text{phytase level} + 390.29$. To estimate digestible Ca, analyzed Ca concentrations in limestone or complete diets were multiplied by STTD coefficients. The average STTD, standard deviation (SD), and coefficient of variance (CV) were calculated. The STTD values without phytase and the STTD values with phytase calculated using the 2 procedures were compared. Using the Proc Mixed of SAS (SAS Institute Inc., Cary, NC, USA), the statistical model included STTD values as fixed variable and limestone source as random variable. Means were separated using the pdiff option with Tukey's adjustment. Statistical significance was set at $P < 0.05$.

Results and Discussion

Analyzed Ca in diets ranged from and 0.43 to 0.83% (SD = 0.; CV = 11.7%; Table 1). Because Ca makes up approximately 40% of pure limestone (i.e., Ca carbonate) by molecular weight, any analyzed values exceeding 40% were truncated to 40%. Calcium in all sources ranges from 32.1% to 40.0% (SD = 1.8; CV = 4.8%). The average STTD of Ca in limestone without phytase was 74.3% (SD = 4.8; CV = 6.4%). Microbial phytase was included at 500 units in 5 sources, 1,000 units in 25 sources, and 2,000 units in 2 sources. The average STTD of Ca with phytase was 84.6% (SD = 4.8; CV = 5.6%) if the same basal endogenous loss was used in calculations of STTD in limestone without and with phytase. However, the STTD was 82.1% (SD = 4.0; CV = 4.9%) if the basal endogenous loss that is specific to phytase-containing diets was used in the calculation. The STTD of Ca in limestone was greater ($P < 0.05$) if phytase was used, but the STTD of Ca was less ($P < 0.05$) if calculation accounted for reduced basal endogenous loss by phytase. Digestible Ca in limestone ranged from 23.8 to 32.7% without phytase and from 27.9 to 36.2% (using the fixed basal endogenous loss) or 26.8 to 35.1% (using phytase-specific basal endogenous loss). Digestible Ca released by phytase from diets containing phytate and limestone ranged from 0.03 to 0.14%. Resuts from this work indicated that there were substantial variability in analyzed Ca concentrations, STTD of Ca, digestible Ca, and digestible Ca released by microbial phytase among different sources of limestone. The practical implication is that because limestone is the main source of Ca in commercial pig diets, accurate estimation of digestible Ca in complete diets is needed for accurate diet formulation. Failure to account for increased Ca digestibility in limestone when microbial phytase is used may result in excess Ca in the diet, which reduces P digestibility and growth performance of pigs.

Table 1. Concentrations of Ca and STTD of Ca in 32 sources of limestone without or with phytase

Item, %	Ca in diet, %	Ca in limestone, %	Phytase, units/kg	STTD of Ca[1], %		
				Without phytase	With phytase (Approach 1)	With phytase (Approach 2)
Limestone source (by year)						
1	0.75	40.0	0 or 500	64.0	71.2	73.3
2	0.61	39.4	0 or 1000	72.5	77.2	76.2
3	0.63	37.3	0 or 1000	70.0	76.1	77.4
4	0.69	37.3	0 or 2000	70.0	81.3	81.4
5	0.83	36.4	0 or 2000	67.8	85.0	81.0
6	0.68	38.9	0 or 500	74.8	87.5	85.4
7	0.69	40.0	0 or 500	75.2	80.8	78.7
8	0.62	40.0	0 or 500	72.0	80.9	78.8
9	0.69	39.7	0 or 500	70.6	79.4	77.3
10	0.43	40.0	0 or 1000	73.3	88.3	83.3
11	0.44	40.0	0 or 1000	75.1	84.7	79.8
12	0.69	40.0	0 or 1000	80.5	86.6	85.2
13	0.66	38.0	0 or 1000	80.1	90.4	87.7
14	0.71	37.7	0 or 1000	77.9	88.3	85.5
15	0.69	39.7	0 or 1000	78.9	86.2	83.5
16	0.72	37.3	0 or 1000	65.5	77.4	74.6
17	0.65	35.9	0 or 1000	77.2	88.2	85.2
18	0.63	34.8	0 or 1000	77.0	86.6	83.6
19	0.67	37.3	0 or 1000	80.9	89.1	86.2
20	0.72	39.0	0 or 1000	74.2	87.3	84.6
21	0.72	39.0	0 or 1000	80.2	89.5	86.8
22	0.71	40.0	0 or 1000	80.0	88.5	85.9
23	0.71	39.2	0 or 1000	77.9	86.1	83.4
24	0.68	36.8	0 or 1000	75.1	82.5	79.7
25	0.67	37.7	0 or 1000	75.4	89.2	86.4
26	0.65	37.6	0 or 1000	73.6	89.8	87.0
27	0.53	32.1	0 or 1000	76.1	86.7	83.5
28	0.67	36.5	0 or 1000	77.5	88.8	85.9
29	0.68	36.5	0 or 1000	65.1	82.2	79.3
30	0.71	39.3	0 or 1000	73.7	78.6	75.9
31	0.69	37.5	0 or 1000	73.3	85.7	82.9
32	0.69	36.6	0 or 1000	66.3	85.8	83.0
Average	0.66	38.0	-	74.1[c]	84.6[a]	82.1[b]
SD	0.08	1.8	-	4.7	4.8	4.0
CV, %	11.7	4.8	-	6.4	5.6	4.9

[a-c]Means within a row without a common superscript differ ($P < 0.05$).

[1]Two approaches were used to calculate the STTD of Ca with phytase: Approach 1 used fixed basal endogenous loss whereas Approach 2 accounted for reduced basal endogenous loss by phytase.

References

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