

Particle size of calcium carbonate does not affect apparent and standardized total tract digestibility of calcium, retention of calcium, or growth performance of growing pigs¹

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ABSTRACT: Two experiments were conducted to evaluate particle size of calcium carbonate used in diets fed to growing pigs. Experiment 1 was conducted to determine apparent total tract digestibility (ATTD), standardized total tract digestibility (STTD), and retention of Ca among diets containing calcium carbonate produced to different particle sizes, and Exp. 2 was conducted to determine if growth performance of weanling pigs is affected by particle size of calcium carbonate. In Exp. 1, 4 diets based on corn and potato protein isolate were formulated to contain 0.70% Ca and 0.33% standardized total tract digestible P, but the calcium carbonate used in the diets was ground to 4 different particle sizes (200, 500, 700, or 1,125 μm). A Ca-free diet was formulated to determine basal endogenous losses of Ca. In Exp. 2, 4 diets were based on corn and soybean meal and the only difference among diets was that each diet contained calcium carbonate ground to the 4 particle sizes used in Exp. 1. In Exp. 1, 40 barrows (15.42 \pm 0.70 kg initial BW) were allotted to the 5 diets with 8 replicate pigs per diet using a randomized complete block design, and in Exp. 2, 128 pigs with an initial BW of 9.61 \pm 0.09 kg were randomly allotted to 4 experimental diets. Results of

Exp. 1 indicated that basal endogenous losses of Ca were 0.329 g/kg DMI. The ATTD of Ca was 70.0 \pm 3.2, 74.3 \pm 2.7, 70.0 \pm 2.9, and 72.1 \pm 2.7 and the STTD of Ca was 74.2 \pm 3.2, 78.5 \pm 2.7, 74.1 \pm 2.9, and 76.2 \pm 2.7 for calcium carbonate ground to 200, 500, 700, or 1,125 μm , respectively. Retention of Ca was 67.4 \pm 3.1, 70.4 \pm 2.6, 63.9 \pm 2.8, and 67.2 \pm 2.2 for diets containing calcium carbonate ground to 200, 500, 700, or 1,125 μm , respectively. There were no differences among diets for ATTD of Ca, STTD of Ca, or retention of Ca. The ATTD of P was 64.5 \pm 1.7, 66.8 \pm 2.6, 64.2 \pm 3.0, and 63.2 \pm 1.7% and retention of P was 61.4 \pm 1.4, 63.8 \pm 2.8, 61.9 \pm 2.8, and 60.9 \pm 1.5 for diets containing calcium carbonate ground to 200, 500, 700, or 1,125 μm , respectively. Neither ATTD of P nor retention of P was influenced by the particle size of calcium carbonate. Results of Exp. 2 indicated that ADG, ADFI, and G:F were not impacted by the particle size of calcium carbonate. In conclusion, particle size of calcium carbonate did not affect ATTD of Ca, STTD of Ca, or retention of Ca; ATTD of P or retention of P; or growth performance of pigs. Any particle size of calcium carbonate in the range from 200 to 1,125 μm can therefore be used in diets fed to pigs.

Key words: calcium, calcium carbonate, digestibility, particle size, pigs, retention

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INTRODUCTION

A reduction in the particle size of feed ingredients has been associated with improved nutrient digestibility in swine due to increased surface area of the particles

(Owsley et al., 1981; Giesemann et al., 1990; Healy et al., 1994; Wondra et al., 1995; Rojas and Stein, 2015). However, data on effects of reducing the particle size of calcium carbonate in diets fed to pigs are limited. Particle size of calcium carbonate has been intensively studied in poultry, and results have indicated that particle size of calcium carbonate is important for egg shell formation, Ca retention, and bone mineral content (Roland, 1986; Rao et al., 1992; Zhang and Coon, 1997; de Araujo et al., 2011). For laying hens, it is recommended to use a particle size of 1.00 mm or greater, as

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particle size is directly related to retention time in the gizzard (de Araujo et al., 2011). With increased particle size, an increase in retention time is observed, which not only increases solubility but also provides a Ca reserve for egg shell formation (Zhang and Coon, 1997). In broiler chickens, coarse particle size reduces Ca retention in the intestines and decreases mineralization of bone (Guinotte et al., 1991, 1995). However, in ruminants, particle size of calcium carbonate has no effect on the digestibility of Ca (Matsushima et al., 1955), and in rats, reducing the particle size of calcium carbonate from 18.5 to 13.0 μm had no effect on balance of Ca, bone mineral content, or bone mechanical properties (Shahnazari et al., 2009). In pigs, particle size of calcium carbonate does not affect the relative bioavailability of Ca (Ross et al., 1984), but to our knowledge, the impact of particle size on the digestibility of Ca and on pig growth performance has not been reported. Therefore, the objective of this experiment was to determine if particle size of calcium carbonate influences the apparent total tract digestibility (ATTD) or the standardized total tract digestibility (STTD) of Ca or the growth performance of growing pigs.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at the University of Illinois reviewed and approved the protocols describing animal procedures for the 2 experiments. Pigs used in both experiments were the offspring of Line 359 boars mated to C46 females (Pig Improvement Company, Hendersonville, TN).

Experiment 1: Digestibility and Retention of Ca

Animals and Housing. Forty growing barrows (15.42 ± 0.70 kg average initial BW) were randomly allotted to 5 experimental diets. Each diet was fed to 8 replicate pigs using a randomized complete block design with BW being the blocking factor. Pigs were allotted to experimental diets using the Experimental Allotment Program (Kim and Lindemann, 2007). Pigs were individually housed in metabolism crates equipped with a feeder, a nipple waterer, and a fully slatted floor. During collection of urine and feces, a screen, a urine pan, and a urine bucket were placed under each crate to allow for total collection of urine and feces.

Diets and Feeding. Four diets based on corn and potato protein isolate were formulated to contain identical concentrations of Ca and P, but the calcium carbonate (ILC Resources, Alden, IA) used in these diets were ground to 4 different particle sizes (200, 500, 700, or 1,125 μm). The same batches of all ingredients were used in all diets (Table 1). All diets contained the same amount of corn and potato protein isolate to

Table 1. Analyzed composition of ingredients (as-fed basis)

Ingredient	Ingredient, %			
	DM	Ash	Ca	P
Ground corn (Exp. 1)	85.5	1.7	<0.01	0.19
Potato protein isolate (Exp. 1)	90.5	1.7	0.04	0.14
Calcium carbonate				
200 μm	99.9	93.8	37.43	<0.01
500 μm	99.9	82.4	38.3	<0.01
700 μm	99.9	87.6	38.18	<0.01
1,125 μm	99.9	86.4	38.44	<0.01
Monosodium phosphate	99.5	91.5	0.03	27.89
Ground corn (Exp. 2)	86.4	1.3	0.01	0.24
Soybean meal (Exp. 2)	84.2	5.9	0.31	0.59

keep the concentration of phytate constant among diets (Table 2). Diets were formulated to contain approximately 0.70% Ca and 0.33% STTD of P (Table 3). One additional diet that was similar to the other diets except that this diet contained no calcium carbonate was also formulated. This diet was considered calcium free and used to estimate the basal endogenous losses of Ca.

Pigs were offered feed at 3 times the maintenance requirement for energy (i.e., 197 kcal ME/kg BW^{0.60}; NRC, 2012) for the duration of the experiment. The amount of feed offered was recorded daily. Orts were weighed, dried in a forced air oven at 65°C, and accounted for in the calculation for feed consumption. Pigs were allowed free access to water at all times. The initial 5 d was an adaptation period to the diets, and fecal samples originating from the feed that was provided from d 6 to 11 were quantitatively collected using the marker-to-marker approach (Adeola, 2001). On d 6, an indigestible marker (indigo carmine) was added to the morning meal to mark the beginning of fecal collection, and on d 11, ferric oxide was added to the morning meal to mark the conclusion of fecal collection. Fecal samples were stored at -20°C immediately after collection. Urine was collected every morning from d 6 to 11 and a 20% subsample was stored at -20°C after collection. After each urine collection, 50 mL of 6 N HCL was added to each empty urine bucket. The stored urine was thawed and mixed at the conclusion of the experiment.

Sample Analyses

Fecal samples were dried in a forced-air oven at 65°C and ground using a 1-mm screen in a Wiley Mill (model 4; Thomas Scientific, Swedesboro, NJ). Urine samples were thawed at room temperature, mixed, and filtered, and a 10-mL subsample of each urine sample was collected.

Ingredients and diets were analyzed for DM using a drying oven at 135°C for 2 h (method 930.15; AOAC, 2007) and for ash (method 942.05; AOAC, 2007). Diets

Table 2. Ingredient composition of experimental diets, Exp. 1

Ingredient, %	Calcium carbonate particle size, μm				Ca free
	200	500	700	1,125	
Ground corn	75.60	75.60	75.60	75.60	77.30
Potato protein isolate	18.00	18.00	18.00	18.00	18.00
Soybean oil	3.00	3.00	3.00	3.00	3.00
Salt	0.40	0.40	0.40	0.40	0.40
Vitamin mineral premix ¹	0.20	0.20	0.20	0.20	0.20
Monosodium phosphate	0.98	0.98	0.98	0.98	0.98
Calcium carbonate	1.73	1.73	1.73	1.73	–
L-Lys HCl, 78% Lys	0.09	0.09	0.09	0.09	0.09

¹The vitamin–mineral premix provided the following quantities of vitamins and microminerals per kilogram of complete diet: 11,136 IU vitamin A as retinyl acetate, 2,208 IU vitamin D₃ as cholecalciferol, 66 IU vitamin E as DL- α -tocopheryl acetate, 1.42 mg vitamin K as menadione dimethylprimidinol bisulfite, 0.24 mg thiamin as thiamine mononitrate, 6.59 mg riboflavin, 0.24 mg pyridoxine as pyridoxine hydrochloride, 0.03 mg vitamin B₁₂, 23.5 mg d-pantothenic acid as d-calcium pantothenate, 44.1 mg niacin, 1.59 mg folic acid, 0.44 mg biotin, 20 mg Cu as copper sulfate, 126 mg Fe as iron sulfate, 1.26 mg I as ethylenediamine dihydriodide, 60.2 mg Mn as manganous sulfate, 0.25 mg Se as sodium selenite and selenium yeast, and 124.9 mg Zn as zinc sulfate.

were also analyzed for N using the combustion procedure (method 990.03; AOAC, 2007) on an Elementar Rapid N-cube protein/nitrogen apparatus (Elementar Americas Inc., Mt. Laurel, NJ), and CP was calculated as $\text{N} \times 6.25$. Diets were analyzed for crude fat using ether extraction (method 920.39 (A); AOAC, 2007), ADF (method 973.18; AOAC, 2007), NDF (Holst, 1973), and crude fiber (method 978.10; AOAC, 2007). Ingredient, diet, and urine samples were analyzed for Ca and P by inductively coupled plasma spectroscopy (method 985.01 A, B, and C; AOAC, 2007) after wet ash sample preparation (method 975.03 B(b); AOAC, 2007). Fecal samples were analyzed for DM and for Ca and P as explained for diets.

Calculations and Statistical Analysis. The ATTD values of Ca and P were calculated according to standard procedures (NRC, 2012). The basal endogenous Ca losses (E_{CaL}; mg/kg DMI) were determined from pigs fed the Ca-free diet according to the following equation (Almeida and Stein, 2010):

$$\text{basal E}_{\text{CaL}} = (\text{Ca}_{\text{feces}}/\text{F}_{\text{intake}}) \times 1,000 \times 1,000,$$

in which Ca_{feces} is the average daily fecal Ca output (g) and F_{intake} is the ADFI (g of DM) from d 6 to 11. The daily basal E_{CaL} in pigs fed the Ca-containing diets was calculated by multiplying the calculated E_{CaL} per kilogram DMI by the daily DMI of each pig.

By correcting ATTD values for the basal E_{CaL}, the STTD (%) of Ca was calculated for each ingredient (Almeida and Stein, 2010):

$$\text{STTD} = \left[\frac{\text{Ca}_{\text{intake}} - (\text{Ca}_{\text{feces}} - \text{basal E}_{\text{CaL}})}{\text{Ca}_{\text{intake}}} \right] \times 100.$$

Table 3. Analyzed composition of experimental diets (as-fed basis), Exp. 1

Item, %	Calcium carbonate particle size, μm				Ca free
	200	500	700	1,125	
DM	87.05	87.06	87.13	87.20	86.62
CP	20.36	19.83	20.35	19.84	20.52
Crude fat	3.13	3.19	3.21	3.50	3.14
NDF	10.44	9.09	9.48	12.08	13.34
ADF	3.29	3.45	3.62	4.41	3.81
Crude fiber	2.09	2.12	2.21	2.17	2.14
Ash	3.83	3.93	3.80	3.98	2.16
Ca	0.68	0.70	0.82	0.67	0.02
P	0.47	0.50	0.53	0.48	0.44

Retention of Ca was calculated using the following equation (Petersen and Stein, 2006):

$$\text{Ca}_R = \left[\frac{(\text{Ca}_{\text{intake}} - \text{Ca}_{\text{fecal}} - \text{Ca}_{\text{urine}})}{\text{Ca}_{\text{intake}}} \right] \times 100,$$

in which Ca_R is Ca retention (%), Ca_{fecal} is Ca output in the feces, and Ca_{urine} is the total Ca output in the urine (g). The retention of P was also calculated using this equation.

Data were analyzed as a randomized complete block design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model contained diet as fixed effect and block as the random effect. To test for outliers, the UNIVARIATE procedure of SAS was used, but no outliers were identified. The experimental unit was the crate. Because differences among the 4 sources of calcium carbonate in particle size were not evenly spaced among sources, the interactive matrix language procedure of SAS (PROC IML) was used to obtain appropriate coefficients, and polynomial contrasts were used to determine linear and quadratic effects of calcium carbonate particle size. Statistical significance was observed when $P < 0.05$ and tendencies were considered at $0.05 \leq P < 0.10$.

Experiment 2: Growth Performance

Animals and Housing. One hundred twenty-eight pigs with an average initial BW of 9.61 ± 1.00 kg were randomly allotted to 4 experimental diets. There were 4 pigs per pen and each experimental diet was fed to 8 replicate pens. Pigs were housed in an environmentally controlled room and had free access to water via a nipple waterer throughout the experiment. All pens were equipped with fully slatted floors. The Experimental Animal Allotment Program (Kim and Lindemann, 2007) was used to allot pigs to experimental diets.

Diets and Feeding. Four corn–soybean meal–based diets were formulated to contain identical concentrations of Ca and P, but the calcium carbonate used in the diets was ground to 4 different particle sizes

Table 4. Ingredient composition of experimental diets, Exp. 2

Ingredient, %	Calcium carbonate particle size, μm			
	200	500	700	1,125
Ground corn	63.47	63.47	63.47	63.47
Soybean meal	30.00	30.00	30.00	30.00
Soybean oil	3.00	3.00	3.00	3.00
Salt	0.40	0.40	0.40	0.40
Vitamin mineral premix ¹	0.20	0.20	0.20	0.20
Monosodium phosphate	0.70	0.70	0.70	0.70
Calcium carbonate	1.55	1.55	1.55	1.55
L-Lys HCl, 78% Lys	0.41	0.41	0.41	0.41
DL-Met	0.10	0.10	0.10	0.10
L-Thr	0.12	0.12	0.12	0.12

¹The vitamin–micromineral premix provided the following quantities of vitamins and microminerals per kilogram of complete diet: 11,136 IU vitamin A as retinyl acetate, 2,208 IU vitamin D₃ as cholecalciferol, 66 IU vitamin E as DL- α tocopheryl acetate, 1.42 mg vitamin K as menadione dimethylprimidinol bisulfite, 0.24 mg thiamin as thiamine mononitrate, 6.59 mg riboflavin, 0.24 mg pyridoxine as pyridoxine hydrochloride, 0.03 mg vitamin B₁₂, 23.5 mg d-pantothenic acid as d-calcium pantothenate, 44.1 mg niacin, 1.59 mg folic acid, 0.44 mg biotin, 20 mg Cu as copper sulfate, 126 mg Fe as iron sulfate, 1.26 mg I as ethylenediamine dihydriodide, 60.2 mg Mn as manganous sulfate, 0.25 mg Se as sodium selenite and selenium yeast, and 124.9 mg Zn as zinc sulfate.

(200, 500, 700, or 1,125 μm). The 4 sources of calcium carbonate used in this experiment were from the same batches as those used in Exp. 1. All diets contained the same quantity of corn and soybean meal to keep the level of phytate constant among diets (Table 4). Diets were formulated to contain 0.70% total Ca and 0.33% standardized total tract digestible P (Table 5).

Pigs were allowed ad libitum access to feed throughout the experiment. Pigs were weighed at the beginning and at the conclusion of the 21-d experiment. The amount of feed offered to each pen was recorded, and at the end of the experiment, the amount of feed left in the feeder was weighed and used to cal-

Table 5. Analyzed composition of experimental diets (as-fed basis), Exp. 2

Item	Calcium carbonate particle size, μm			
	200	500	700	1,125
DM, %	88.17	88.04	87.71	87.75
CP, %	16.72	16.95	19.31	18.00
GE, kcal/kg	4,023	3,997	3,935	3,953
Ash, %	0.04	0.04	0.05	0.05
Ca, %	0.70	0.86	0.73	0.69
P, %	0.52	0.55	0.50	0.55

culate feed disappearance. All diets were analyzed for DM, ash, GE, CP, Ca, and P as explained for Exp. 1.

Statistical Analyses. Data were analyzed using linear and quadratic contrasts as explained for Exp. 1. The pen was the experimental unit and the α value was 0.05.

RESULTS

Experiment 1

Feed intake (g DM/d) and fecal output (g DM/d) were linearly ($P < 0.01$) reduced as the particle size was reduced (Table 6). Intake of Ca (g/d) and urine Ca output (g/d) also were reduced (linear, $P < 0.05$) as the particle size of calcium carbonate was reduced, and a tendency ($P = 0.10$) for a linear reduction in daily output of Ca was observed as particle size was reduced.

The basal endogenous loss of ECAL was 0.329 ± 0.035 g/kg DMI. No linear or quadratic effects of particle size were observed for ATTD of Ca (%), STTD of Ca (%), or retention of Ca, but daily basal endogenous loss of ECAL (g/d) was reduced (linear, $P < 0.01$) as particle size of calcium carbonate was reduced.

Phosphorus intake (g/d) and absorption of P were reduced (linear and quadratic, $P < 0.05$) and fecal P

Table 6. Apparent total tract digestibility (ATTD) and standardized total tract digestibility (STTD) of Ca in diets containing calcium carbonate ground to different particle sizes¹

Item	Calcium carbonate particle size, μm				SEM	<i>P</i> -value	
	200	500	700	1,125		Linear	Quadratic
Feed intake, g DM/d	529	572	639	677	34	<0.01	0.55
Fecal output, g DM/d	60	59	70	75	4.52	<0.01	0.71
Ca in feces, %	2.07	1.97	2.09	1.97	0.15	0.73	0.93
Ca intake, g/d	4.17	4.52	5.04	5.34	0.27	<0.01	0.54
Ca feces, g/d	1.24	1.17	1.46	1.49	0.14	0.10	0.94
Ca in urine, g/d	0.29	0.36	0.52	0.48	0.07	0.02	0.24
Ca absorbed, g/d	2.93	3.34	3.57	3.85	0.25	0.01	0.55
ATTD of Ca, %	69.98	74.29	69.96	72.07	2.89	0.81	0.76
Endogenous ² Ca, g/d	0.17	0.19	0.21	0.22	0.01	<0.01	0.55
STTD of Ca, %	74.15	78.45	74.13	76.24	2.89	0.81	0.77
Ca retention, %	67.38	70.40	63.93	67.18	2.69	0.69	0.82

¹Data are least squares means of 8 observations for all treatments.

²Basal endogenous losses were determined from pigs fed the Ca-free diet as 0.329 ± 0.035 g/kg DMI.

Table 7. Apparent total tract digestibility (ATTD) of P in diets containing calcium carbonate ground to different particle size¹

Item	Calcium carbonate particle size, μm				SEM	<i>P</i> -value	
	200	500	700	1,125		Linear	Quadratic
P intake, g/d	2.80	3.23	3.82	3.66	0.20	<0.01	0.02
P in feces, %	1.62	1.75	1.77	1.40	0.09	0.57	0.24
P in feces, g/d	1.00	1.07	1.32	1.35	0.08	<0.01	0.45
P in urine, g/d	0.08	0.10	0.10	0.08	0.03	0.91	0.60
ATTD of P, %	64.46	66.78	64.18	63.18	2.33	0.55	0.56
P absorbed, g/d	1.80	2.15	2.50	2.31	0.16	0.02	0.04
P retention, %	61.39	63.83	61.90	60.93	2.23	0.74	0.50

¹Data are least squares means of 8 observations for all treatments.

output was reduced (linear, $P < 0.05$) with reducing particle size of calcium carbonate, but no effect of particle size was observed for urine P output (Table 7). Likewise, no effects of calcium carbonate particle size on ATTD of P or retention of P (%) were observed.

Experiment 2

There were no linear or quadratic effects of the particle size of calcium carbonate on ADFI of pigs during the 21-d experimental period (Table 8). Likewise, ADG and G:F of pigs were neither linearly nor quadratically affected by the particle size of calcium carbonate.

DISCUSSION

Results of experiments using diets based on corn, potato protein isolate, monosodium phosphate, and calcium carbonate indicate that the ATTD of Ca is between 61 and 71% and the ATTD of P is between 47 and 61% (Stein et al., 2011; González-Vega et al., 2015a). Values obtained in this experiment were slightly greater, but less corn was included in diets used in this experiment, which may have influenced results because corn contributes phytate to the diet and phytate may bind Ca and P and thus reduce digestibility. The ATTD of Ca in grain–soybean meal diets in which calcium carbonate supplied more than 85% of the Ca in the diet is between 63 and 74% (Malde et al., 2010), and the ATTD of Ca in calcitic limestone fed to Japanese quail is 72% (Kim et

al., 1985). Therefore, results of the present experiment are in good agreement with previous data.

Particle size of calcium carbonate did not influence the relative bioavailability of Ca in calcium carbonate if bone ash or bone breaking strength were used as the response criteria (Ross et al., 1984). However, we are not aware of any previous reports on the effects of particle size on the ATTD or STTD of Ca in calcium carbonate, but the present results indicate that pigs are able to digest and absorb Ca from calcium carbonate with the same efficiency if the particle size is between 200 and 1,125 μm . As a consequence, retention of Ca is also not influenced by particle size of calcium carbonate. This observation agrees with data from ruminants (Matsushima et al., 1955) and rats (Shahnazari et al., 2009) but is different from data for poultry. Anatomical differences between chickens and pigs may explain why responses to particle size differ among species, because chickens have a crop and a gizzard and laying hens require the inclusion of larger particle size of calcium carbonate to maintain a Ca reserve for overnight egg formation (Zhang and Coon, 1997).

Calcium from calcium carbonate is mostly absorbed in the proximal duodenum (González-Vega et al., 2014). Secretion of HCl from the stomach solubilizes Ca from calcium carbonate into the ionic form. Even if greater particle sizes reduce the absorption of Ca in the duodenum, the pig may be able to absorb Ca later in the gastrointestinal tract, and as a result, ATTD of Ca may not be reduced. Data from a study that compared site of absorption of Ca from different sources of Ca indicated that

Table 8. Growth performance of pigs fed diets containing calcium carbonate ground to different particle size, Exp. 2¹

Item	Calcium carbonate particle size, μm				SEM	<i>P</i> -value	
	200	500	700	1,125		Linear	Quadratic
Initial BW, kg	9.61	9.62	9.62	9.61	0.03	0.98	0.85
Final BW, kg	19.52	19.40	19.45	19.58	0.05	0.86	0.75
ADFI, g/d	728	733	731	738	2.0	0.69	0.97
ADG, g/d	472	466	468	475	1.6	0.85	0.72
G:F	0.649	0.637	0.640	0.643	0.001	0.81	0.58

¹Data are least squares means of 8 observations per treatment.

differences among Ca sources exist in terms of where in the gastrointestinal tract Ca is absorbed (González-Vega et al., 2014). It is, therefore, possible that particle size of Ca from calcium carbonate also influences the site of absorption of Ca, but research to determine the site of absorption of calcium carbonate within the intestinal tract will have to be conducted to answer that question.

In this experiment, basal endogenous losses of ECaL were 0.329 g/kg DMI. In previous experiments, values for endogenous losses ECaL have been reported in the range between 0.123 and 0.396 g/kg of DMI (González-Vega et al., 2013, 2014, 2015a,b), so the value obtained in this experiment is within the range previously reported.

In Exp. 1, feed intake, and therefore, also Ca and P intake and output, were impacted by the particle size of calcium carbonate. This was surprising because pigs were offered the same amount of feed each day. The differences in ADFI therefore reflect differences inorts collected from the pigs, with increasing quantities being collected as the particle size of calcium carbonate was reduced. Although ATTD and STTD values were not different among diets, the differences in feed intake were unexpected. The second experiment was, therefore, conducted to determine if particle size of calcium carbonate influences feed intake of pigs that are allowed free access to commercial corn-soybean meal-based diets. The observation that there were no effects of particle size of calcium carbonate on ADG, ADFI, or G:F of pigs in the second experiment indicated that particle size does not affect feed intake in pigs fed corn-soybean meal-based diets. It is, therefore, likely that the differences in feed intake observed among treatments in Exp. 1 are a result of the semisynthetic diets used in that experiment.

Conclusions

Results from these experiments indicate that calcium carbonate can be included in swine diets at a broad range of particle sizes without impacting the digestibility of Ca or P. The retention of Ca and P are also not influenced by the particle size of calcium carbonate. Likewise, there is no influence of particle size of calcium carbonate on growth performance of weanling pigs. It is therefore concluded that any particle size of calcium carbonate within the range from 200 to 1,125 μm may be used in diets fed to pigs.

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