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Gage E. Nichols
Kansas State University, gage500@k-state.edu

Caitlin E. Evans
Kansas State University, caitlinevans@k-state.edu

Julia P. Holen
Kansas State University, jpholen@k-state.edu

See next page for additional authors

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Decreasing Corn Particle Size Increases Metabolizable Energy When Fed to Gestating Sows

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Summary

Previous research has demonstrated that reducing the particle size of corn improved metabolizable energy (ME) utilization in many phases of swine production. One phase that has had limited research thus far is the gestating phase for sows. The objectives of this paper were to determine the effects of corn particle size on the digestibility of gross energy (GE), and determine the digestible energy (DE) and ME in gestating sow diets. A total of 27 sows during the second phase of gestation (d 40 to 74) were chosen and fed a common diet with corn ground to 1 of 3 target average particle sizes (geometric mean diameter; d_{gw}) of 400, 800, or 1200 µm. Corn was ground using a 3 high roller mill (RMS model 924). Titanium dioxide (0.25%) was included in the diet as an indigestible marker for index digestibility calculations. Sows were fed experimental diets for 7 d to allow for diet adaptation before a 2-d collection period. At the beginning of the collection period, sows were fitted with a urinary catheter and urine was collected in buckets containing 20 mL of sulfuric acid. Fecal grab samples were also collected from each sow during the collection period. Subsamples were taken, mixed, analyzed for GE, and titanium levels to determine digestibility of gross energy and to calculate DE and ME. The ME of corn was calculated by subtracting the ME of soybean meal (1,494 kcal/lb) and soybean oil (3,889 kcal/lb) from diet ME, utilizing the NRC 2012[2] values for those ingredients. Apparent total tract digestibility (ATTD) of GE and calculated DE, ME, and corn ME content increased (linear, $P < 0.001$) as corn particle size was reduced from 1200 to 400 µm. The ME of the diet (88.5% DM) increased by 81 kcal/lb as the d_{gw} was reduced from 1,200 to 400 µm. The calculated corn ME (88.5% DM) also increased by 103 kcal/lb as the d_{gw} was reduced from 1,200 to 400 µm. Utilizing a linear regression model and the analyzed corn particle size data herein, it was determined that for every 100 µm reduction in corn d_{gw} from 1,372 to 404 µm, the ME value of corn is increased by 10.7 kcal/lb.

Introduction

Swine producers and feed manufacturers strive to reduce the cost of feed by improving performance and nutrient efficiency. One way to achieve this goal is to improve nutrient digestibility through reducing corn particle size. Particle size reduction of

[1] Department of Animal Science and Industry, College of Agriculture, Kansas State University.
[2] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

grains continues to be used in the swine industry to increase nutrient utilization regardless of production phase. Both roller mills and hammermills are utilized to grind grains. The type of mill used is commonly chosen by capacity, target particle size, and energy efficiency. Reducing the particle size of corn is a common practice because of its subsequent improvements on pig growth performance, especially feed efficiency. The improved feed efficiency can be attributed to an increase in surface area to volume ratio of particles in the corn as particle size decreases. The increase in surface area allows for greater enzyme activity, which can lead to improvements in nutrient utilization. Most of the particle size research has been conducted in nursery and finishing pigs. However, previous research has also demonstrated that decreasing corn particle size (d_{gw}) from 1200 to 400 µm improves gross energy (GE), DE, ME, and nitrogen (N) digestibility in lactating sows.[3]

To our knowledge, there has not been any research on the effects of corn particle size on nutrient digestibility in gestating sows. Therefore, the objectives of this study were to determine the effects of corn particle size on the digestibility of gross energy to determine the digestible energy and metabolizable energy in gestating sow diets.

Materials and Methods

Kansas State University Institutional Animal Care and Use Committee approved all protocols used in this trial. This experiment was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS, from mid to late February 2020.

Animal housing, diet, and feeding

A total of 27 gestating sows (Line 241; DNA, Columbus, NE) of varying parities were utilized in the study, during the second phase of their gestation (d 40 to 74). Sows were individually housed in an environmentally controlled room with mechanical ventilation. Sows had *ad libitum* access to water via nipple waterers. Sows were fed 4.4, 5.5, or 6.6 lb once daily at 7:00 a.m. based on backfat and body weight. A corn-soy diet was formulated. There were no ingredient inclusion changes across treatments (Table 1). For dietary treatments, diets consisted of corn ground to either 400, 800, or 1200 µm using a 3 high roller mill (Model 924, RMS Roller Grinder, Harrisburg, SD). Sows were split into 3 groups based upon breeding date and allotted to dietary treatment within group, and balanced by parity and back fat. Titanium dioxide (0.25%) was added to the diets as an indigestible marker. Sows were fed for 7 d to allow for adaptation to the treatment diets followed by a two-day collection period of fecal and urine samples.

Sample collection

At the start of the collection period, each sow was fitted with a Foley catheter (Bard Bardia 2-way, 30 mL balloon, 18 French; Bard Medical Canada Inc., Oakville, ON, Canada) with methods adapted from Holen et al.[4] A total of 5 min was allotted for each placement to help prevent infection. If a catheter could not be fitted within the allotted

[3] Wondra, K.J., J.D. Hancock, G.A. Kennedy, K.C. Behnke, and K.R. Wondra.1995a. Effects of reducing particle size of corn in lactation diets on energy and nitrogen metabolism in second-parity sows. J Anim Sci. 73:427–32. doi.org/10.2527/1995.732427x.

[4] Holen, J.P., L.J. Johnston, P.E. Urriola, J.E. Garrett, and G.C. Shurson. 2020. Comparative digestibility of polysaccharide-complexed zinc and zinc sulfate in diets for gestating and lactating sows. J. Anim. Sci. 98(4): 1-14. doi:10.1093/jas/skaa079.

time, the sow was removed from test. There were 9 sows placed on the 800 and 1200 µm treatments and 8 sows placed on the 400 µm treatment as one sow was not able to be catheterized within the allotted placement time. During urine collection, 20 mL of sulfuric acid was added to each bucket to keep the pH below 3 to limit bacterial growth and maintain nitrogen levels. Collection vessels were emptied, and subsamples were collected to obtain 20% aliquots. Aliquots were stored separately at -4°F and subsamples were pooled within sow at the end of the trial. Sow temperatures were also collected twice daily during the collection period, and for 5 days following to monitor for any signs of urinary tract infection.

Fecal grab samples were collected throughout the collection period for each sow, bagged, and stored separately at -4°F. At the end of the trial, fecal samples were pooled within sow. At the end of the trial, samples were pooled within sow and subsamples were collected and stored at -4°F until analyzed.

Sample analysis

To determine particle size of both the corn used in the diets and the finished diets the Rotap 13 sieve method utilizing 0.5 g sieving agent with a 10-min run time was used.[5] To determine dry matter (DM) of feed, aluminum pans were weighed, and a ground sample was placed in the drying oven at 221°F for 24 h[6] (AOAC Method 934.01). Fecal DM was determined in a two-step process. Samples were weighed and dried in a forced-air oven at 131°F for 48 h. Samples were then weighed and moisture loss was recorded. Samples were ground and placed in plastic bags to be used for nutrient analysis and final DM analysis. To determine final dry matter of the fecal samples, aluminum pans were weighed, and a ground sample was weighed and placed in a forced air oven at 221°F for 24 h in duplicate. Dried sample weights were recorded, and moisture levels were added from both drying steps to determine overall DM.

Feed and fecal gross energy was determined via bomb calorimetry by ATC Scientific (North Little Rock, AR) using a Parr model 6100 (Parr Instrument Company, Moline, IL) bomb calorimeter. Urine samples were analyzed utilizing a Parr model 6200 (Parr Instrument Company, Moline, IL) bomb calorimeter using methods adapted from Jones.[7] To analyze urine for energy, cellulose was ground and dried at 221°F for 24 h and stored in a sealed Ziplock bag until use. Then, 1 g of cellulose was placed into a bomb cup and 4 mL of urine was pipetted over the cellulose. The cup with cellulose and urine was dried for 12 h in a forced air oven at 131°F. Cups were removed from the oven and placed in a desiccator until they were analyzed. Fecal and feed samples were analyzed for titanium dioxide via the methods described by Leone.[8]

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[5] ASABE Standards. (1995). S319.2: Method of determining and expressing fineness of feed materials by sieving. St. Joseph, Mich.: ASABE.

[6] Official Methods of Analysis of AOAC International. 19th Ed. Method 934.01. Loss on Drying (Moisture) at 95–100°C for Feeds/Dry Matter on Oven Drying at 95–100°C for Feeds. AOAC INTERNATIONAL, Gaithersburg, MD, USA.

[7] Jones, A.M. 2015. Management effects on the environmental footprint of swine production. Purdue University. M.S. Thesis. Lib.Purdue.edu.

[8] Leone, J.L. 1973. Collaborative Study of the Quantitative Determination of Titanium Dioxide in Cheese. Journal of the AOAC. 56(3):535-537. doi.org/10.1093/jaoac/56.3.535.

Calculations and statistical analysis
The following equation[9] was used to calculate the digestibility energy of the diet using titanium dioxide as an indigestible marker.

DE (kcal/lb) = (100 – (100 × (% TiO_2 in feed / % TiO_2 in feces) × (gross energy in feces / gross energy in feed)))

Gross energy of urine was then used to calculate ME from DE. The ME of corn was calculated by subtracting the ME of soybean meal (1,494 kcal/lb) and soybean oil (3,889 kcal/lb) utilizing the NRC 2012[2] values for these ingredients and their inclusion rates in the diet. The DE, ME, and corn ME values were adjusted to 88.5% DM.

Statistical analysis
Data were analyzed using the PROC GLIMMIX procedure of SAS v. 9.4 (SAS Institute, Inc., Cary, NC), utilizing linear and quadratic polynomial contrast with sow as the experimental unit and treatment as the fixed effect. In addition, the REG procedure of SAS was used to develop a regression equation to predict the ME value of corn using analyzed corn particle size values. Results were considered significant if $P \leq 0.05$ and marginally significant if $P \leq 0.10$.

Results and Discussion
The actual d_{gw} achieved were 404, 823, and 1372 µm for the targeted treatments of 400, 800, and 1200 µm, respectively (Table 2). The standard deviation of the geometric mean (S_{gw}) for each treatment was 2.59, 2.80, and 2.83 for the 400, 800, and 1200 µm treatments, respectively. The d_{gw} of the complete diets were 448, 733, and 1155; and S_{gw} were 2.52, 2.80, and 2.98 for the 400, 800, and 1200 µm, respectively. As corn is ground to a coarser particle size, it is expected that the standard deviation will increase likely due to larger roll gaps in the larger particle size treatments that allow a wider range of particle sizes to flow through. The target particle size of the diet can vary from that of corn as the particle size of other ingredients often does not match that of corn.

Throughout the experiment, sows remained healthy with no signs of urinary tract infection related to being catheterized. All DE and ME calculations were conducted on a DM basis and then were adjusted to an as-is basis using a DM of 88.5%. The ATTD of GE, and the calculated diet DE and ME improved (linear, $P < 0.01$) as d_{gw} of corn was decreased from 1200 to 400 µm. The experiment reported herein demonstrated a 67 and 81 kcal/lb increase in diet DE and ME, respectively, as particle size was reduced from 1200 to 400 µm.

The ME value of corn was calculated by assuming the energy value of soy oil and soybean meal were 3,889 and 1,494 kcal/lb, respectively.[2] As the particle size of corn was reduced, the ME of corn (88.5% DM) increased (linear, $P = 0.009$) from 1,427 to 1,530 kcal/lb. The NRC[7] reports that the ME value of corn is 1,540 kcal/lb, which is similar to the estimated ME of corn when ground to d_{gw} of 400 µm in the present study. A linear regression model was fit to the data conducted herein using the analyzed d_{gw} values (404, 823, and 1372 µm) to estimate the ME value of corn for various particle

[9] Agudelo, J.H., MD Lindemann, and G.L Cromwell. 2010. A Comparison of two methods to assess nutrient digestibility in pigs. Livestock Science. 133. 74-77. doi:10.1016/j.livsci.2010.06.029.

sizes (Figure 1). It was determined that for every 100 µm reduction in corn d_{gw} from 1,372 to 404 µm, the ME value of corn is increased by 10.7 kcal/lb. Therefore, similar to previous research in finishing pigs, reducing the particle size of corn improves the ME in gestating sows.

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Table 1. Diet composition (as-fed basis)

Ingredient	%
Corn	78.15
Soybean meal (46.5% CP)	17.27
Soy oil	0.50
Monocalcium P (21% P)	1.30
Calcium carbonate	1.30
Salt	0.50
Trace mineral premix	0.15
Vitamin premix	0.25
Sow add pack	0.25
Phytase[1]	0.08
Titanium dioxide	0.25
Total	100
Calculated analysis, as-fed basis:	
ME, kcal/lb	1,481
NE, kcal/lb	1,128
CP, %	14.7
Ca, %	0.91
P, %	0.61
Ca:P	1.50
Analyzed nutrients, as-fed basis	
DM, %	89.40
GE, kcal/lb	1,764
CP, %	14.74

[1] Ronozyme HiPhos (GT) 2700 (DSM Nutritional Products, Parsippany, NJ) provided 500,000 phytase units (FTU)/lb of product with a release of 0.10% available P.
DM = dry matter. GE = gross energy.

Table 2. Particle size of corn and the final diets[1,2]

	Target corn particle size, µm		
Item	**400**	**800**	**1200**
Corn particle size			
d_{gw}	403	823	1372
S_{gw}	2.59	2.80	2.83
Diet particle size			
d_{gw}	447	732	1154
S_{gw}	2.52	2.80	2.98

[1] Diets were ground on a 3 high RMS roller mill (Model 924, RMS Roller Grinder, Harrisburg, SD). D_{gw} = geometric mean diameter. S_{gw} = standard deviation of the geometric mean.
[2] Particle sizes were determined via the ASAE method S319.2 utilizing 0.5 g of sieving agents and a 10 min run time. (ASABE Standards. (1995). S319.2: Method of determining and expressing fineness of feed materials by sieving. St. Joseph, Mich.: ASABE.)

Table 3. Effect of corn particle size on energy and protein digestibility of gestating sows[1]

	Corn particle size (d_{gw})				*P* <	
Item	**400 µm**	**800 µm**	**1200 µm**	**SEM**	**Linear**	**Quadratic**
Diet GE, %	86.6	84.6	82.6	1.0	0.006	0.971
Diet DE, kcal/lb[2]	1,511	1,474	1,444	17.7	0.008	0.836
Diet ME, kcal/lb[2]	1,473	1,443	1,392	18.4	0.004	0.646
Corn ME, kcal/lb[2,3]	1,530	1,491	1,427	23.5	0.004	0.646

[1] This 9-day digestibility study included 27 gestating sows, with a 7-day adjustment period and 2-day collection period. Sows were fed a common diet with three particle sizes of corn. Feed, fecal, and urine samples were collected and analyzed for dry matter (DM), gross energy (GE), and TiO_2 to determine digestibility.
[2] Diet DE and ME, and corn ME values were corrected to 88.5% DM.
[3] Corn ME was calculated by subtracting the ME of soybean meal and soy oil utilizing the NRC 2012 adjustment values. (NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Washington (DC): National Academies Press.)
D_{gw} = geometric mean diameter.

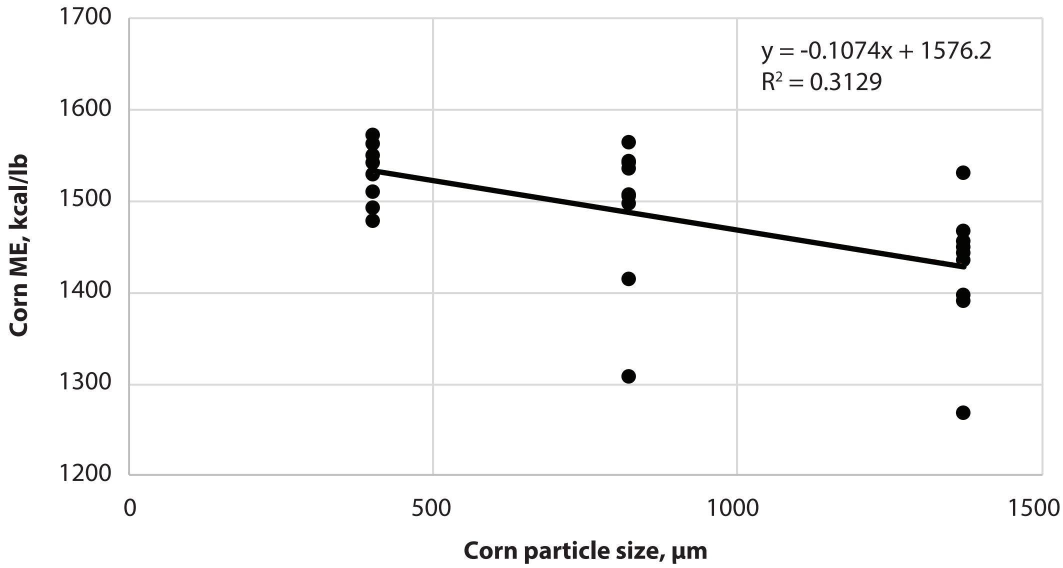

Figure 1. Influence of particle size on ME of corn.