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Influence of Particle Size of Enogen Feed High Amylase and Conventional Yellow Dent Corn on Nursery Pig Performance¹

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Abstract

A total of 360 pigs (DNA 200 × 400; initially 14.5 lb) were used in a 35-d growth trial to evaluate the influence of particle size of Enogen Feed high amylase (Enogen, Syngenta Seeds, LLC, Downers Grove, IL) and conventional yellow dent corn on nursery pig performance. Pigs were randomly assigned to pens (5 pigs per pen) and pens were allotted by weight to 1 of 6 dietary treatments in a randomized complete block design with 12 pens per treatment. Treatments were arranged in a 2 × 3 factorial with main effects of corn source (high amylase or conventional yellow dent) and 3 ground corn particle sizes (300, 600, or 900 microns). All pigs were fed a common pelleted diet for 7 days after weaning, then switched to experimental diets. Overall, from d 0 to 35, there were no differences among corn sources observed for average daily gain (ADG). As particle size of the diet increased, there was a tendency (quadratic, $P = 0.074$) for ADG to be similar for pigs fed 300- and 600-micron ground corn, but ADG decreased for pigs fed corn ground to 900 microns. There was a tendency ($P = 0.086$) for a corn source × particle size interaction for average daily feed intake (ADFI), with no change in ADFI for pigs fed conventional yellow dent corn, but a quadratic increase then decrease in ADFI for pigs fed high amylase corn. For feed efficiency (F/G), there was also a corn source × particle size interaction ($P = 0.027$) observed with improved F/G as particle size was reduced for high amylase corn, but not for conventional yellow dent corn. In summary, reducing particle size of high amylase corn improves feed efficiency with no major differences between corn sources for overall daily gain.

Introduction

Enogen Feed high amylase is a corn variety developed by Syngenta Seeds (Downers Grove, IL). Although its primary use has been for the ethanol industry, there is potential application in livestock diets. Recent research has found that feeding high amylase corn improves feed efficiency in finishing cattle. A recent experiment conducted with finishing pigs observed that pigs

¹ Appreciation is expressed to Syngenta Seeds, LLC (Downers Grove, IL) for their partial financial support of this trial.

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fed high amylase corn tended to have greater ADG than pigs fed conventional yellow dent corn; however, feed efficiency was not influenced.⁵

The greater amylase concentration in Enogen Feed corn is expected to increase starch digestibility compared with yellow dent corn. Grinding corn to fine particle sizes has also been demonstrated to improve starch digestibility, resulting in improved feed efficiency. For nursery pigs, reducing corn particle size is commonly associated with improved feed efficiency; however, some studies have observed reduced feed intake with corn ground finer than 600 microns.⁶

The high amylase content in Enogen Feed corn may improve starch digestion similarly to reducing particle size. If this were the case, it is possible that pigs fed coarsely ground Enogen Feed corn might have similar feed efficiency as pigs fed finely ground conventional corn. The ability to grind Enogen Feed corn to a larger particle size, yet maintain optimal F/G, could provide several benefits including reduced grinding costs, improved flowability of diets in bins and feeders, and reduced gastric ulcers and mortality. Therefore, the objective of this study was to evaluate the effects of feeding Enogen Feed high amylase corn vs. conventional yellow dent corn ground to different particle sizes on nursery pig performance.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The trial was conducted at the Kansas State University Segregated Early Weaning facility in Manhattan, KS. All diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center. Enogen Feed corn was sourced from Syngenta Seeds, LLC, Downers Grove, IL. The conventional yellow dent corn was sourced from local producers in northern Kansas. Both Enogen Feed high amylase and conventional yellow dent corn were sampled for chemical analysis (Table 1). During feed manufacturing, approximately 10 pounds of each ground corn treatment were collected. Prior to sending samples for chemical analysis, ground corn was passed through a riffle divider and split down to 200 g. Then 2 samples of each corn source were sent for chemical analysis at Ward Laboratories, Kearney, NE, and the average of the 2 values was used. When formulating the diets, we assumed the same nutritional values between the conventional yellow dent corn and the Enogen Feed high amylase corn.

A total of 360 pigs (DNA 200 × 400; initially 14.5 lb) were used in a 35-d experiment. Pigs were weaned at 21 d of age and fed a common pelleted starter diet for 7 d prior to the start of the experiment. Pigs were randomly allotted to pens and were assigned to 1 of 6 dietary treatments in a randomized complete block design with 5 pigs per pen and 12 pens per treatment. Dietary treatments consisted of 2 different corn sources (Enogen Feed high amylase vs. conventional yellow dent) and 3 corn particle sizes (300, 600, and 900 microns). Treatments were fed for 35 days, split into 2 separate phases (Table 2). Phase 1 was fed from d 0 to 14 and phase 2 was fed from d 14 to 35. Pigs were weighed and feed disappearance was measured on d 0, 7, 14, 21, 28, and 35. Each pen (4 × 4 ft) contained a 4-hole, dry, self-feeder and a water cup to provide *ad libitum* access to feed and water.

⁵ P. Ochonski, F. Wu, E. Arkfeld, J. M. Lattimer, J. M. DeRouchey, S. S. Dritz, R. D. Goodband, J. C. Woodworth, and M. D. Tokach. 2019. Evaluation of High Amylase Corn on Growth Performance and Carcass Characteristics of Finishing Pigs. *Kansas Agricultural Experiment Station Research Reports*: Vol. 5: Iss. 8.

⁶ Healy, B. J., J. D. Hancock, G. A. Kennedy, P. J. Bramel-Cox, K. C. Behnke, R. H. Hines. 1994. Optimum particle size of corn and hard and soft sorghum for nursery pigs. *J. Anim. Sci.* 72:2227–2236. doi: 10.2527/1994.7292227x.

Diet samples were collected from the feeder 3 days after the start of each phase, and proximate analysis was conducted on the composite diet (Ward Laboratories, Inc., Kearney, NE). Particle size analysis was conducted on ground corn samples (100 g) with or without the inclusion of a flow agent. When running the particle size analysis, 2 samples of each corn source were used with and without the flow agent. All samples were determined according to ANSI/ASAE S319.2 standard particle size analysis method.⁷

Treatments were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package in R (version 3.5.1 (2018-07-02)) with pen considered the experimental unit, body weight as blocking factor, and treatment as fixed effect. The main effects of corn source and particle size, as well as their interactions, were tested. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

The chemical analyses of the ground corn sources are described in Table 1. There were no major differences in the chemical analysis of conventional and high amylase corn. Particle size analysis data are in Table 3. Particle size spread was met, but 300-micron ground corn tended to be higher than the intended 300 microns. Chemical analyses of the complete diets are in Table 4. In the complete diet analysis, the Enogen Feed corn had slightly higher calcium values than the conventional corn diets.

From d 0 to 14, pigs fed Enogen Feed corn had increased ($P < 0.05$) ADG and ADFI compared to those fed conventional yellow dent corn (Tables 5 and 6). There was a corn source by particle size interaction observed for F/G ($P = 0.027$). There were no changes in F/G of pigs fed conventional yellow dent corn, but a linear improvement in F/G as particle size decreased for those fed Enogen Feed corn.

For d 14 to 35, there was a tendency for pigs fed conventional yellow dent corn to have increased ($P = 0.063$) ADG compared with those fed Enogen Feed corn. For ADFI, there was a tendency for a corn source $\times$ particle size interaction (quadratic, $P = 0.071$) with no differences in ADFI for pigs fed conventional corn as particle size changed, but an increase then decrease in ADFI as particle size increased in pigs fed Enogen Feed corn. There was a tendency (linear, $P = 0.095$) for a corn source $\times$ particle size interaction observed for F/G. There was no difference in F/G among pigs fed conventional yellow dent corn, but F/G worsened as particle size increased in pigs fed Enogen Feed corn.

Overall, as particle size increased, ADG ($P = 0.074$) was similar for pigs fed 300 and 600-micron ground corn but decreased for those fed 900-micron corn. As during d 14 to 35, there was a tendency for a corn source $\times$ particle size interaction to be observed (quadratic, $P = 0.086$) for ADFI. There was no difference in pigs fed conventional yellow dent corn, whereas pigs fed Enogen Feed corn had an increase then decrease in ADFI as particle size increased. There was a corn source $\times$ particle size interaction (linear, $P = 0.027$) for overall F/G. There was no difference when pigs were fed conventional yellow dent corn, but in pigs fed Enogen Feed corn, F/G worsened with increasing particle size.

In summary, when grinding corn to finer particle sizes, we observed the expected improvement in F/G of pigs fed Enogen Feed high amylase corn, but not in conventional yellow dent corn. However, there were no overall differences observed for ADG among corn sources.

⁷ ASABE Standards. (1995). S319.2: Method of determining and expressing fineness of feed materials by sieving. St. Joseph, Mich: ASABE.

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Table 1. Chemical analysis of corn varieties, (as-fed basis)¹

Item, %	Conventional		Enogen Feed high amylase corn ²	
	Phase 1	Phase 2	Phase 1	Phase 2
Dry matter	87.48	87.27	87.60	87.86
Starch	58.98	60.37	63.85	64.44
Crude protein	7.69	7.78	7.58	7.29
Crude fat	4.07	4.13	4.07	4.12
Acid detergent fiber	1.93	1.47	1.98	1.84
Neutral detergent fiber	6.49	6.14	7.44	7.18
Calcium	0.11	0.09	0.13	0.12
Phosphorus	0.23	0.23	0.20	0.21

¹ Corn samples were collected at time of feed manufacturing and pooled for analysis (Ward Laboratories, Inc., Kearney, NE). Each value represents the mean of six analyses per diet per phase.

²High amylase corn (Enogen, Syngenta Seeds, LLC, Downers Grove, IL)

Table 2. Diet composition, (as-fed basis)

Ingredient, %	Phase 1 ¹	Phase 2 ²
Corn ³	56.40	66.45
Soybean meal, 46.5% CP	24.70	29.75
Dried whey	10.00	---
HP 300 ⁴	5.00	---
Calcium carbonate	0.80	0.80
Monocalcium phosphate, 21%	0.90	0.90
Sodium chloride	0.50	0.60
L-Lysine HCl	0.45	0.50
DL-Methionine	0.22	0.20
L-Threonine	0.18	0.23
L-Tryptophan	0.03	0.04
L-Valine	0.11	0.13
Trace mineral	0.15	0.15
Vitamin premix	0.25	0.25
Zinc oxide	0.25	---
Ronozyme HiPhos 2700 ⁵	0.04	0.04
Total	100	100

continued

Table 2. Diet composition, (as-fed basis)

Ingredient, %	Phase 1 ¹	Phase 2 ²
Calculated analysis		
Standardized ileal digestible (SID) amino acids %		
Lysine	1.35	1.30
Isoleucine:lysine	58	55
Leucine:lysine	116	115
Methionine:lysine	37	36
Methionine and cysteine:lysine	58	58
Threonine:lysine	63	64
Tryptophan:lysine	19.0	19.2
Valine:lysine	70	70
Histidine:lysine	36	37
Total lysine, %	1.49	1.44
NE, kcal/lb ⁶	1,109	1,161
SID lysine:NE, g/Mcal	5.52	5.34
Crude protein, %	21.2	20.5
Calcium, %	0.71	0.66
Phosphorus, %	0.62	0.58
Analyzed Ca:analyzed P	1.14	1.13
STTD P, % ⁷	0.50	0.45

¹Phase 1 diets were fed from approximately 15 to 25 lb.

²Phase 2 diets were fed from approximately 25 to 55 lb.

³Enogen corn will replace conventional yellow dent corn on a lb:lb basis in the diets.

⁴HP 300 (Hamlet Protein, Findlay, OH).

⁵HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.

⁶NE = net energy.

⁷Standardized total tract digestible phosphorus.

Table 3. Particle size analysis of ground corn samples^{1,2}

Item	Conventional		High amylase	
	With flow agent ³	Without flow agent	With flow agent	Without flow agent
Particle size phase 1, μm ⁴				
300	345	407	345	403
600	576	675	554	564
900	954	1058	883	972
Particle size phase 2, μm				
300	376	454	328	417
600	606	725	525	646
900	1069	1169	926	1460

¹Ground corn samples were collected on the day of feed manufacturing.

²Ground corn samples were split down using a riffle device to have 100 g of the corn sample left over. Five g of the flow agent was added to the sample. The ground corn sample was placed into the sieves and processed on the RoTap machine for 15 minutes. After the 15 minutes, the sieves were each individually weighed to see how much sample is left on each sieve.

³Powdered synthetic amorphous silicon dioxide.

⁴Kansas State University particle size analysis template was used to calculate the particle size of each sample.

Table 4. Chemical analysis of experimental diets, (as-fed basis)¹

Item, %	Phase 1 ²		Phase 2	
	Conventional ³	High amylase ⁴	Conventional	High amylase
Dry matter	90.32	90.78	89.41	89.42
Crude protein	20.95	20.55	20.35	19.85
Acid detergent fiber	3.1	3.0	3.1	3.3
Neutral detergent fiber	6.5	6.8	5.7	6.6
Calcium	0.76	0.81	0.73	0.78
Phosphorus	0.54	0.52	0.48	0.51

¹Feed samples were collected approximately 2 days after each feed delivery, pooled within corn source for each phase, and analyzed (Ward Laboratories, Inc., Kearney, NE).

²The experimental diets were fed in 2 phases: d 0 to 14, and d 14 to 35.

³Yellow dent corn.

⁴High amylase corn (Enogen, Syngenta Seeds, LLC, Downers Grove, IL).

Table 5. Interactive effects of corn source and particle size on nursery pig performance¹

	Conventional, μm^2			Enogen Feed, μm^3			SE	Probability, $P =$		
Item	300	600	900	300	600	900		Source	Source $\times$ linear	Source $\times$ quadratic
BW, lb										
d 0	14.5	14.5	14.5	14.5	14.5	14.5	0.118	0.778	0.754	0.856
d 14	25.8	25.7	25.6	26.7	27.0	26.4	0.445	0.001	0.911	0.467
d 35	52.6	52.4	51.8	52.6	53.3	51.4	0.731	0.731	0.749	0.283
d 0 to 14 ⁴										
ADG, lb	0.81	0.80	0.79	0.87	0.89	0.85	0.027	0.001	0.939	0.497
ADFI, lb	0.99	0.97	0.97	1.01	1.06	1.06	0.032	0.003	0.237	0.472
F/G ⁵	1.23	1.21	1.24	1.16	1.19	1.25	0.017	0.094	0.027	0.945
d 14 to 35										
ADG, lb	1.26	1.27	1.24	1.23	1.25	1.19	0.021	0.063	0.530	0.584
ADFI, lb	2.00	1.98	1.98	1.94	2.07	1.99	0.043	0.641	0.408	0.071
F/G	1.59	1.55	1.60	1.58	1.65	1.67	0.025	0.016	0.095	0.125
d 0 to 35										
ADG, lb	1.08	1.08	1.05	1.09	1.11	1.05	0.020	0.309	0.801	0.462
ADFI, lb	1.59	1.57	1.57	1.57	1.67	1.62	0.034	0.062	0.203	0.086
F/G	1.48	1.45	1.49	1.44	1.51	1.54	0.018	0.143	0.027	0.127

¹A total of 360 pigs (DNA 200 $\times$ 400, initially 14.5 lb) were used in a 35-d trial. There were 12 pens per treatment with 5 pigs per pen.

²Yellow dent corn.

³High amylase corn (Enogen, Syngenta Seeds, LLC, Downers Grove, IL).

⁴The experimental diets were fed in 2 phases: d 0 to 14, and d 14 to 35.

BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.

Table 6. Main effects of particle size of high amylase and corn source on nursery pig performance¹

Item	Source		SE	Probability, <i>P</i> =	Particle size, μm			SE	Probability, <i>P</i> =	
	Conventional ²	Enogen Feed ³			300	600	900		Linear	Quadratic
BW, lb										
d 0	14.5	14.5	0.116	0.778	14.5	14.5	14.5	0.117	0.531	0.612
d 14	25.7	26.7	0.336	0.001	26.2	26.4	26.0	0.367	0.498	0.394
d 35	52.3	52.4	0.546	0.731	52.6	52.9	51.6	0.598	0.091	0.131
d 0 to 14 ⁴										
ADG, lb	0.80	0.87	0.017	0.001	0.84	0.85	0.82	0.020	0.424	0.391
ADFI, lb	0.98	1.05	0.022	0.003	1.00	1.02	1.02	0.025	0.563	0.712
F/G	1.23	1.20	0.010	0.094	1.20	1.20	1.24	0.012	0.006	0.268
d 14 to 35										
ADG, lb	1.26	1.23	0.014	0.063	1.25	1.26	1.21	0.016	0.101	0.064
ADFI, lb	1.99	2.00	0.030	0.641	1.97	2.02	1.99	0.034	0.708	0.160
F/G, lb	1.58	1.63	0.015	0.016	1.58	1.60	1.64	0.018	0.036	0.757
d 0 to 35										
ADG, lb	1.07	1.08	0.014	0.309	1.08	1.10	1.05	0.016	0.090	0.074
ADFI, lb	1.58	1.62	0.025	0.062	1.58	1.62	1.59	0.027	0.681	0.190
F/G	1.47	1.50	0.010	0.143	1.46	1.48	1.51	0.012	0.005	0.573

¹A total of 360 pigs (DNA 200 × 400, initially 14.5 lb) were enrolled in a 35-d trial. There were 12 pens per treatment with 5 pigs per pen.

²Yellow dent corn.

³High amylase corn (Enogen, Syngenta Seeds, LLC, Downers Grove, IL).

⁴The experimental diets were fed in 2 phases: d 0 to 14, and d 14 to 35.

BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.