

## Influence of Particle Size of Enogen Feed High Amylase and Conventional Yellow Dent Corn on Finishing Pig Performance, Carcass Characteristics, and Stomach Ulceration<sup>1</sup>

*Hadley R. Williams, Mike D. Tokach, Jason C. Woodworth, Robert D. Goodband, Joel M. DeRouchey, Steve S. Dritz,<sup>2</sup> Vinay Shivanna,<sup>2</sup> Chad B. Paulk,<sup>3</sup> and Hilda I. Calderón<sup>4</sup>*

### Abstract

A total of 323 pigs (DNA 241 × 600; initially 109.8 lb) were used in an 83-d growth trial to evaluate the influence of particle size of Enogen Feed corn (Enogen, Syngenta Seeds, LLC, Downers Grove, IL) and conventional yellow dent corn on finishing pig performance. Pigs were randomly assigned to pens (9 pigs per pen) and pens were allotted by weight to 1 of 6 dietary treatments in a randomized complete block design with 6 pens per treatment. Treatments were arranged in a 2 × 3 factorial with main effects of corn source (Enogen Feed corn or conventional yellow dent) and 3 ground corn particle sizes (300, 600, or 900 microns). Overall, from d 0 to 83, there were no differences among corn sources observed for average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). As particle size of the diet decreased from 900 to 300 microns, ADG increased (linear,  $P = 0.018$ ). Overall F/G improved (linear,  $P = 0.021$ ) as corn particle size was decreased. In summary, reducing the particle size of the diet improves feed efficiency with no major differences between corn sources for overall pig performance.

### Introduction

Enogen Feed corn is a variety developed by Syngenta Seeds (Downers Grove, IL). Although its primary use has been in 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

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<sup>2</sup> Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

<sup>3</sup> Department of Grain Science, College of Agriculture, Kansas State University.

<sup>4</sup> Department of Statistics, College of Arts and Sciences, Kansas State University.

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

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. However, some studies have observed reduced feed intake with corn ground finer than 600 microns.<sup>6</sup>

The high amylase content in Enogen Feed corn may improve starch digestion, similar to the effect of 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 maintaining 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 finishing 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 Swine Teaching and Research Center, Manhattan, KS. All diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center. Both Enogen Feed high amylase and conventional yellow dent corn samples were collected for chemical analysis (Table 1). During feed manufacturing, approximately 10 pounds of each ground corn treatment was collected. Prior to sending samples for chemical analysis, ground corn was passed through a riffle divider and split down to sample sizes of 200 g. Then 2 samples of each corn source were sent for chemical analysis at Ward Laboratories, Kearney, NE. When formulating the diets, nutritional values were assumed to be the same between conventional yellow dent and Enogen Feed corn and were not altered for changes in corn particle size.

A total of 323 pigs (241 × 600; DNA, Columbus, NE; initially 109.8 lb) were used in an 83-d study. There were 6 pens per treatment and 9 pigs per pen with 5 barrows and 4 gilts per pen. Pens were randomly assigned to dietary treatments and balanced based on pen weight at the start of the study. Dietary treatments (Table 2) were arranged in a 2 × 3 factorial with two corn sources (conventional yellow dent or Enogen Feed corn) and 3 corn particle sizes (300, 600, and 900 microns). The experimental diets were fed in 3 phases: d 0 to 14, 14 to 42, and 42 to 83.

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<sup>5</sup> 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.

<sup>6</sup> Mavromichalis, I., J. D. Hancock, B. W. Senne, T. L. Gugle, G. A. Kennedy, R. H. Hines, and C. L. Wyatt. 2000. Enzyme supplementation and particle size of wheat in diets for nursery and finishing pigs. *J. Anim. Sci.* 78:3086-3095. doi: [10.2527/2000.78123086x](https://doi.org/10.2527/2000.78123086x).

Pen and feeder weights were obtained approximately every 2 weeks in order to calculate ADG, ADFI, and F/G (Tables 5 and 6). On d 79, 2 pigs per pen, 1 barrow and 1 gilt, were removed and transported to Natural Food Holdings (Sioux Center, IA) to be slaughtered and collect stomachs. The stomachs were taken to the Kansas State Veterinary Diagnostic Laboratory where a scoring system was used to determine the severity of ulceration and keratinization of the esophageal opening of the stomach.<sup>7</sup> Stomachs were scored on a scale of 1 to 4 with 1 = no ulceration, 2 = < 25% ulceration, 3 = 25–75% ulceration, and 4 = > 75% ulceration. This scoring scale was also used for keratinization. On d 83, the remaining 244 pigs were individually weighed, ear-tagged with a radio frequency identification (RFID) tag and tattooed for individual carcass data measurements. Pigs were transported to a commercial packing plant (Triumph Foods, St. Joseph, MO) for processing and collection of hot carcass weight (HCW), loin depth, backfat depth, and percentage lean. Carcass yield was calculated as HCW divided by individual live animal weight.

Diet samples were collected from the feeder 3 days after the start of each phase, and analyzed for dry matter, crude protein, acid detergent fiber, neutral detergent fiber, calcium, and phosphorus (Ward Laboratories, Inc., Kearney, NE). Particle size analysis was conducted on ground corn samples (100 g) with and without the inclusion of a flow agent. All samples were determined according to ANSI/ASAE S319.2 standard particle size analysis method.<sup>8</sup>

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

There were no major differences in the chemical analysis of conventional and high amylase corn (Table 1). The desired spread in particle size was met, although particle size for the high amylase corn tended to be lower than targeted during phase 1 (Table 3). The differences between particle size analysis methods were evident as expected, with greater particle size when analyzed without a flow agent than when analyzed with a flow agent. There were no major differences in complete diet analysis between diets within phase (Table 4).

There were no interactions between corn source and particle size for any response criteria. There was no evidence for difference in growth performance or carcass characteristics between corn sources, except for a tendency for greater ( $P = 0.064$ ) ADFI from d 56 to 83 of the experiment for pigs fed Enogen Feed corn compared with pigs fed conventional yellow dent corn. There was also a tendency for greater ( $P < 0.10$ ) BW on

<sup>7</sup> DeJong, J.A., J. M. DeRouche, M.D. Tokach, S.S. Dritz, R.D. Goodband, J.C. Woodworth, and M. W. Allerson. 2016. Evaluating pellet and meal feeding regimens on finishing pig performance, stomach morphology, and carcass characteristics. *J. Anim. Sci.* 2016.94:4781–4788. doi:10.2527/jas2016-0461.

<sup>8</sup> ASABE Standards. (1995). S319.2: Method of determining and expressing fineness of feed materials by sieving. St. Joseph, Mich: ASABE.

d 0 and 28 for pigs fed conventional corn compared to pigs fed Enogen Feed corn. This small difference, evident from the start of the trial, disappeared by d 56 with no differences in BW between pigs fed either corn source for the remainder of the experiment.

As expected, F/G improved (linear,  $P < 0.05$ ) during each phase and overall as particle size was reduced. Overall, ADFI decreased (linear,  $P = 0.043$ ) as corn particle size was reduced. The overall ADG response was unexpected with an increase (linear,  $P = 0.014$ ) in ADG as particle size decreased. The improvement in ADG led to a tendency for increased (linear,  $P = 0.57$ ) BW on d 83 as corn particle size was decreased in the diet. For carcass characteristics, there was a tendency for an increase (linear,  $P = 0.093$ ) in HCW as particle size decreased in the diet. Carcass yield also was improved (linear,  $P = 0.023$ ) as particle size decreased.

For stomach morphology, there was no evidence for an interaction or main effect for corn source or particle size on ulcer score. For keratinization score, there was a tendency ( $P = 0.055$ ) for a corn source  $\times$  particle size interaction, with lower keratinization score for pigs fed Enogen Feed corn when ground to 300 or 900 microns than pigs fed conventional yellow dent corn with similar keratinization when both corn sources were ground to 600 microns. These responses led to main effects for corn source and particle size. Pigs fed Enogen Feed corn had lower ( $P < 0.002$ ) keratinization scores than pigs fed conventional yellow dent corn. Keratinization scores increased ( $P < 0.015$ ) as corn particle size decreased.

In conclusion, average daily gain and feed efficiency improved as corn particle size decreased in the diet. The improvement in feed efficiency is consistent with previous studies that have shown that decreased particle size of ground corn to below 600 microns improved F/G. There were no differences between corn sources for overall growth performance, but pigs fed Enogen Feed corn had lower stomach keratinization scores than pigs fed conventional yellow dent corn.

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**Table 1. Chemical analysis of corn varieties, (as-fed basis)<sup>1</sup>**

Item, %	Conventional <sup>2</sup>	Enogen Feed corn <sup>3</sup>
Dry matter	87.72	87.80
Starch	60.60	59.76
Crude protein	7.68	7.40
Ether extract	3.88	4.16
Acid detergent fiber	1.55	1.73
Neutral detergent fiber	6.20	7.22
Ca	0.10	0.11
P	0.22	0.21

<sup>1</sup>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 phase.

<sup>2</sup>Yellow dent corn.

<sup>3</sup>Enogen, Syngenta Seeds, LLC, Downers Grove, IL.

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

Item	Phase 1 <sup>1</sup>	Phase 2 <sup>2</sup>	Phase 3 <sup>3</sup>
<b>Ingredient</b>			
Corn <sup>4</sup>	75.45	81.90	85.25
Soybean meal, 46.5% CP	21.80	15.65	12.35
Calcium carbonate	0.93	0.85	0.85
Monocalcium phosphate, 21%	0.55	0.40	0.35
Sodium chloride	0.50	0.50	0.50
L-Lysine HCl	0.30	0.30	0.30
DL-Methionine	0.07	0.03	0.02
L-Threonine	0.09	0.10	0.11
L-Tryptophan	0.01	0.02	0.02
Trace mineral	0.15	0.13	0.10
Vitamin premix	0.15	0.13	0.10
Phytase <sup>5</sup>	0.02	0.02	0.02
Total	100	100	100
<b>Calculated analysis</b>			
<b>Standardized ileal digestible (SID) amino acids %</b>			
Lysine	0.95	0.80	0.72
Isoleucine:lysine	62	61	60
Leucine:lysine	139	148	154
Methionine:lysine	32	31	30
Methionine and cysteine:lysine	58	58	58
Threonine:lysine	63	65	68
Tryptophan:lysine	18.6	18.5	18.7
Valine:lysine	69	70	70
Histidine:lysine	42	43	43
Total lysine, %	1.07	0.90	0.82
Net energy, kcal, lb	1,128	1,147	1,157
SID lysine:net energy, g/Mcal	3.83	3.16	2.82
Crude protein, %	18.4	14.6	13.3
Calcium, %	0.60	0.51	0.48
Phosphorus, %	0.47	0.41	0.38
Analyzed Ca:analyzed P	1.27	1.25	1.26
STTD P, % <sup>6</sup>	0.33	0.28	0.26

<sup>1</sup>Phase 1 diets were fed from d 0 to 14.

<sup>2</sup>Phase 2 diets were fed from d 14 to 42.

<sup>3</sup>Phase 3 diets were fed from d 42 to 83.

<sup>4</sup>Enogen corn replaced conventional corn on a lb:lb basis in the diets.

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

<sup>6</sup>Standardized total tract digestible phosphorus.

**Table 3. Particle size analysis of ground corn samples<sup>1,2</sup>**

Item	Conventional <sup>3</sup>		Enogen Feed corn <sup>4</sup>	
	With flow agent <sup>5</sup>	Without flow agent	With flow agent <sup>5</sup>	Without flow agent
Particle size phase 1, $\mu\text{m}$				
300	343	423	287	419
600	510	673	414	577
900	911	975	785	931
Particle size phase 2, $\mu\text{m}$				
300	338	434	309	417
600	561	704	567	646
900	932	1,096	983	1,123
Particle size phase 3, $\mu\text{m}$				
300	374	469	350	476
600	602	743	618	750
900	974	1,167	975	1,202

<sup>1</sup>Ground corn samples were collected on the day of feed manufacturing.

<sup>2</sup>Ground corn samples were split down using a riffle device to have 100 g of the corn sample left over. The ground corn sample was placed into the sieves and run on the RoTap machine for 15 minutes. After the 15 minutes, the sieves were each individually weighed to see how much sample was left on each sieve.

<sup>3</sup>Yellow dent corn.

<sup>4</sup>Enogen, Syngenta Seeds, LLC, Downers Grove, IL.

<sup>5</sup>Powdered synthetic amorphous silicon dioxide. Five g of the flow agent was added to the sample.

**Table 4. Chemical analysis of experimental diets, (as-fed basis)<sup>1</sup>**

Item, %	Phase 1 <sup>2</sup>		Phase 2		Phase 3	
	Conventional <sup>3</sup>	Enogen Feed corn <sup>4</sup>	Conventional	Enogen Feed corn	Conventional	Enogen Feed corn
Dry matter	89.15	88.62	88.22	88.53	88.04	88.69
Crude protein	17.25	16.30	14.35	13.65	12.30	12.60
Acid detergent fiber	2.55	2.75	2.65	2.45	2.15	2.35
Neutral detergent fiber	5.55	5.65	4.90	5.75	5.25	5.65
Ca	0.72	0.73	0.76	0.71	0.59	0.59
P	0.42	0.40	0.37	0.34	0.33	0.33

<sup>1</sup>Feed samples were collected approximately 3 days after each feed delivery, pooled within corn source for each phase, and analyzed. (Ward Laboratories, Inc., Kearney, NE).

<sup>2</sup>The experimental diets were fed in 3 phases: d 0 to 14, d 14 to 42, and d 42 to 83.

<sup>3</sup>Yellow dent corn.

<sup>4</sup>Enogen, Syngenta Seeds, LLC, Downers Grove, IL.

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**Table 5. Interactive effects of particle size and corn source on finishing pig performance and carcass characteristics<sup>1</sup>**

Item	Micron:	Conventional <sup>2</sup>			Enogen Feed corn <sup>3</sup>			SEM	Source	Probability, <i>P</i> =	
		300	600	900	300	600	900			Source × particle size, linear	Source × particle size quadratic
<b>BW, lb</b>											
d 0		111.5	110.9	109.8	109.9	107.4	109.7	2.278	0.091	0.554	0.228
d 28		175.7	174.5	171.6	172.3	170.1	171.6	2.730	0.064	0.314	0.339
d 56		237.6	235.8	231.3	235.0	234.3	232.2	2.860	0.494	0.380	0.849
d 83		298.3	292.0	293.5	298.5	293.6	291.1	3.787	0.933	0.669	0.600
<b>d 0 to 28</b>											
ADG, lb		2.30	2.28	2.22	2.23	2.24	2.21	0.040	0.185	0.388	0.883
ADFI, lb		4.94	4.99	5.06	4.85	5.06	5.04	0.116	0.875	0.731	0.484
F/G		2.15	2.19	2.28	2.18	2.26	2.28	0.040	0.231	0.681	0.250
<b>d 28 to 56</b>											
ADG, lb		2.21	2.19	2.13	2.25	2.29	2.16	0.049	0.128	0.960	0.366
ADFI, lb		6.37	6.51	6.50	6.50	6.57	6.67	0.104	0.131	0.837	0.622
F/G		2.88	2.97	3.05	2.89	2.87	3.08	0.049	0.615	0.821	0.140
<b>d 56 to 83</b>											
ADG, lb		2.13	2.07	2.08	2.17	2.15	2.07	0.054	0.349	0.645	0.397
ADFI, lb		6.53	6.53	6.79	6.72	6.88	6.81	0.128	0.064	0.485	0.248
F/G		3.07	3.16	3.27	3.10	3.20	3.29	0.061	0.512	0.913	0.915
<b>d 0 to 83</b>											
ADG, lb		2.22	2.18	2.15	2.22	2.23	2.15	0.027	0.398	0.922	0.327
ADFI, lb		5.93	5.99	6.10	6.00	6.15	6.16	0.083	0.145	0.957	0.491
F/G		2.68	2.75	2.84	2.71	2.76	2.86	0.030	0.368	0.895	0.801
<b>Carcass characteristics</b>											
HCW, lb		220.4	216.3	215.7	222.0	219.8	215.2	3.733	0.576	0.754	0.600
Carcass yield, %		74.1	74.2	73.6	74.3	74.1	73.8	0.002	0.437	0.960	0.259
Backfat depth, in		0.64	0.64	0.65	0.64	0.65	0.65	0.020	0.965	0.871	0.930
Loin depth, in		2.65	2.57	2.56	2.60	2.56	2.61	0.037	0.921	0.171	0.989
Lean, %		54.8	54.4	54.4	54.6	54.4	54.6	0.295	0.955	0.519	0.891

<sup>1</sup>A total of 323 mixed gender pigs (DNA 241 × 600) were used in an 83-d growth study to determine the effects of particle size of high amylase and conventional corn on grow-finish pig performance. There were 9 pigs per pen, 6 pens per treatment.

<sup>2</sup>Conventional yellow dent.

<sup>3</sup>Enogen, Syngenta Seeds, LLC, Downers Grove, IL.

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

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**Table 6. Main effects of particle size and corn source on finishing pig performance<sup>1</sup>**

Item	Source		SEM	Probability, <i>P</i> =	Particle size, $\mu\text{m}$			SEM	Probability, <i>P</i> =	
	Conventional <sup>2</sup>	Enogen Feed corn <sup>3</sup>			300	600	900		Linear	Quadratic
BW, lb										
d 0	110.7	109.0	1.984	0.091	110.7	109.2	109.7	2.054	0.457	0.324
d 28	173.9	171.3	2.288	0.064	174.0	172.3	171.6	2.396	0.164	0.702
d 56	234.9	233.8	2.223	0.494	236.3	235.0	231.8	2.383	0.031	0.564
d 83	294.6	294.4	2.582	0.933	298.4	292.8	292.3	2.901	0.057	0.328
d 0 to 28										
ADG, lb	2.27	2.23	0.023	0.185	2.26	2.26	2.22	0.028	0.187	0.497
ADFI, lb	5.00	4.98	0.072	0.875	4.89	5.02	5.05	0.084	0.133	0.541
F/G	2.21	2.24	0.027	0.231	2.16	2.22	2.28	0.030	0.002	0.929
d 28 to 56										
ADG, lb	2.18	2.23	0.029	0.128	2.23	2.24	2.15	0.034	0.067	0.177
ADFI, lb	6.46	6.58	0.057	0.131	6.43	6.54	6.58	0.071	0.125	0.702
F/G	2.97	2.95	0.026	0.615	2.88	2.92	3.07	0.033	0.001	0.166
d 56 to 83										
ADG, lb	2.09	2.13	0.030	0.349	2.15	2.11	2.08	0.037	0.187	0.932
ADFI, lb	6.62	6.80	0.070	0.064	6.62	6.71	6.80	0.087	0.151	0.975
F/G	3.17	3.20	0.033	0.512	3.09	3.18	3.28	0.041	0.003	0.979
d 0 to 83										
ADG, lb	2.18	2.20	0.015	0.398	2.22	2.21	2.15	0.018	0.014	0.289
ADFI, lb	6.01	6.10	0.045	0.145	5.96	6.07	6.13	0.056	0.043	0.691
F/G	2.75	2.77	0.017	0.368	2.69	2.75	2.85	0.021	0.001	0.419
Carcass Characteristics										
HCW, lb	217.5	219.0	2.666	0.576	221.2	218.1	215.5	2.988	0.093	0.919
Carcass yield, %	74.0	74.1	0.001	0.437	74.2	74.1	73.7	0.002	0.023	0.253
Backfat depth, in	0.64	0.64	0.012	0.965	0.65	0.64	0.64	0.014	0.645	0.949
Loin depth, in	2.60	2.60	0.024	0.921	2.63	2.57	2.60	0.028	0.317	0.193
Lean, %	54.5	54.5	0.175	0.955	54.7	54.4	54.5	0.213	0.509	0.482

<sup>1</sup>A total of 323 mixed gender pigs (DNA 241 × 600) were used in an 83-d growth study to determine the effects of particle size of high amylase and conventional corn on grow-finish pig performances. There were 9 pigs per pen, 6 pens per treatment.

<sup>2</sup>Conventional corn was locally sourced.

<sup>3</sup>Enogen, Syngenta Seeds, LLC, Downers Grove, IL.

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

**Table 7. Effects of particle size on stomach ulceration and keratinization<sup>1</sup>**

Item	Conventional <sup>2</sup>			Enogen Feed corn, <sup>3</sup> $\mu\text{m}$			Probability, <i>P</i> =		
	300	600	900	300	600	900	Source $\times$ particle size	Source	Particle size
Ulcer score <sup>4</sup>	1.42	1.42	1.67	1.92	1.50	1.42	0.178	0.438	0.840
Keratinization score	2.92	2.00	1.58	1.42	1.92	1.17	0.055	0.002	0.015

<sup>1</sup>On d 79, 2 pigs per pen, 1 barrow and 1 gilt of equal weight, were selected and transported to Natural Food Holdings (Sioux Center, IA) to collect stomachs. The stomachs were taken to the Kansas State Veterinary Diagnostic Laboratory where a scoring system was used to determine the severity of ulceration and keratinization of the esophageal opening of the stomach.

<sup>2</sup>Yellow dent corn.

<sup>3</sup>Enogen, Syngenta Seeds, LLC, Downers Grove, IL.

<sup>4</sup>Stomachs were scored on a scale of 1 to 4 with 1 = no ulceration, 2 = <25% ulceration, 3 = 25–75% ulceration, and 4 = >75% ulceration. This scoring scale was also used for keratinization.