Effects of Corn Particle Size, Complete Diet Grinding, and Diet Form on Finishing Pig Growth Performance, Caloric Efficiency, Carcass Characteristics, and Economics[1,2]

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Summary

A total of 855 pigs (PIC TR4 × Fast Genetics York × PIC Line 02), initially 56.54 lb BW) were used in a 111-d trial to evaluate the effects of corn particle size, complete diet grinding, and diet form (meal or pellet) on finishing pig growth performance, caloric efficiency, carcass characteristics, and economics. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 5 dietary treatments with 9 replications per treatment. The same corn-soybean meal–based diets containing 30% dried distillers grains with solubles (DDGS) and 20% wheat middlings (midds) were used for all treatments. Diets were fed in four phases. Different processing techniques were used to create the 5 dietary treatments: (1) roller grinding the corn to approximately 650 µ with the diet fed in meal form; (2) hammer-mill grinding the corn to approximately 320 µ with the diet fed in meal form; (3) Treatment 2 but pelleted; (4) corn initially roller-mill ground to approximately 650 µ, then the complete mixed diet reground through a hammer mill to approximately 360 µ with the diet fed in meal form; and (5) Treatment 4 but pelleted.

Overall (d 0 to 111), reducing corn particle size from approximately 650 to 320 µ improved ($P < 0.03$) F/G, caloric efficiency, feed cost per lb of gain, and income over feed cost (IOFC). Grinding the complete diet decreased ADG, ADFI, and final weight when the diet was fed in meal form, but increased performance when fed in pelleted form resulting in diet form × portion ground interactions ($P < 0.02$). Pelleting the diet improved ($P < 0.001$) ADG, F/G, caloric efficiency on an ME and NE basis, final weight, carcass weight, and IOFC.

For carcass characteristics, feeding a pelleted diet increased ($P < 0.001$) HCW, which led to a diet form × portion ground interaction ($P < 0.02$), meaning HCW decreased when the complete diet was ground and fed in meal form but increased when the same diet was fed in pellet form. Grinding the complete diet decreased ($P < 0.03$) loin depth, and pelleting diets increased ($P < 0.02$) loin depth.

Reducing corn particle size and pelleting complete diets improved performance, carcass characteristics, and economic return. Fine-grinding the entire diet was detrimental

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to performance, carcass characteristics, and economics when fed in meal form but improved performance and economic return when pelleted.

Key words: finishing pig, ingredient processing, particle size, pellet

Introduction

Increased cost of ingredients, specifically for corn and soybean meal, has resulted in producers feeding diets containing higher levels of by-products to finishing pigs. Some of the by-product alternatives lack the energy concentration of basic corn-soybean meal diets. This decrease in energy leads to decreased performance and an increase in time needed for hogs to reach market weight targets. In light of these circumstances, more emphasis is being placed on feed processing technologies to improve utilization of high by-product diets. First, reducing particle size of individual ingredients or whole diets may improve their digestibility and improve feed efficiency, but little research has explored the effects of fine-grinding the complete diets or pelleting high by-product diets on pig performance. Secondly, pelleting high by-product diets will improve diet bulk density, reduce feed wastage, and potentially improve diet digestibility. Adding the necessary infrastructure to pellet diets has a high initial cost and necessitates increased energy usage, which leads to higher feed cost for the producer, but these extra costs may provide more economic return though improved feed efficiency. Thus, the economics associated with the increased production costs of grinding and pelleting also need to be studied.

The objective of this study was to determine the effects of corn particle size (650 or 320 µ), complete diet grinding, and diet form (meal or pellet) on finishing pig growth performance, caloric efficiency, carcass characteristics, and economics.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the New Fashion Pork Research Facility (Round Lake, MN) in a commercial research-finishing barn in northwestern Iowa. The barn was tunnel ventilated and double-curtain-sided. Pens had completely slatted flooring and deep pits for manure storage. Each pen was equipped with a 5-hole stainless steel dry self-feeder and a cup waterer for ad libitum access to feed and water. Daily feed additions to each pen were accomplished through a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of providing and measuring feed amounts for individual pens.

A total of 855 pigs (PIC TR4 × Fast Genetics York-AND × PIC Line 02), initially 56.5 lb BW) were used in a 111-d trial. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 5 dietary treatments with 9 replications per treatment with 19 pigs per pen. Treatment diets were fed in a 4-phase feeding program from d 0 to 35, 35 to 65, d 65 to 93, and d 93 to 111 (Table 1). Within each phase, the same corn-soybean meal–based diet containing 30% DDGS and 20% midds was used for all 5 experimental treatments within each phase. The 5 treatments were achieved by applying different processing techniques to the same diet: (1) roller-milled corn ground to approximately 650 µ with the diet fed in meal form, (2) hammer-milled corn ground to approximately 320 µ with the diet fed in meal form, (3) Treatment 2 but pelleted; (4) Treatment 1 but complete diet reground through a hammer mill to approximately 360 µ with the diet fed in meal form, and (5) Treatment 4 but pelleted. All diets were prepared at New Fashion Pork's feed mill in Estherville, IA.

For caloric efficiency calculations, feed ingredients were assigned an ME value according from the NRC (1998[5]), except DDGS, which was assigned the energy value for corn (1,551 kcal/lb). For NE, values for the growing pig by INRA (2004[6]) were used.

On d 93 of the trial, pens of pigs were weighed and the 3 heaviest pigs (selected by the marketing serviceman) were loaded and transported 350 miles to Triumph Foods in St. Joseph, MO, for harvest. Similarly, on d 100, the next 3 heaviest pigs, as selected by the marketing serviceman, were loaded and transported to Triumph Foods for harvest. The remaining pigs were transported to Triumph Foods on d 111 for harvest. Due to the transportation length and summer temperatures, yield (calculated using live weight at the farm and plant HCW) was lower for all marketing events than typical commercial yields. At the plant, backfat depth and loin depth were measured, and percentage lean was calculated using NPPC (1991) guidelines for lean containing 5% fat: Lean % = (2.83 + (0.469 × (HCW)) – (18.47 × (fat depth)) + (9.824 × loin depth)) / (HCW).

Caloric efficiencies of pens were determined on both an ME and NE (INRA, 2004) basis. Efficiencies were calculated by multiplying total feed intake × energy in the diet (kcal/lb) and dividing by total gain. Lastly, feed cost/pig, feed cost/lb gain, revenue/pig, and IOFC were also calculated. Diet costs were determined with the following ingredient costs: corn = $0.14/lb, soybean meal = $0.24/lb, midds = $0.12/lb, DDGS = $0.14/lb. Processing costs were: grinding = $5/ton, mixing = $3/ton, delivery and handling = $7/ton, and pelleting = $6/ton. Feed cost/pig was determined by total feed intake × feed cost, $/lb. Feed cost/lb gain was calculated using F/G × feed cost, $/lb. Revenue/pig was determined by total gain × $0.65/lb live gain, and IOFC was calculated using revenue/pig – feed cost/pig.

Samples of corn, soybean meal, midds, DDGS, and complete diets were collected and submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CP, ADF, NDF, crude fiber, fat, ash, Ca, and P (Table 2). Bulk density and particle size of the corn, soybean meal, wheat middlings, DDGS, and complete diets also were determined along with angle of repose for all ingredients and diets in meal form. For all diets in pelleted form, pellet durability index (PDI) and percentage fines (Table 3) were determined.

Data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Data were analyzed to determine any diet form × portion ground interactions. Main effects of corn particle size (Treatment 1 vs. 2), grinding (diets 2, 3 vs. 4, 5) and diet form (diets 2, 4 vs. 3, 5) were determined. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

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[5] NRC. 1998. Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington DC.

[6] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez, and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

Results and Discussion

The chemical analysis of the midds, DDGS, corn, and soybean meal (Table 2) indicated that most nutrients were similar to formulated values. Crude protein levels were slightly higher for corn and DDGS and slightly lower for midds than calculated values. Crude fiber was slightly lower for midds and DDGS and slightly higher for corn and soybean meal, and Ca and P levels were slightly higher for all ingredients than formulated values (Table 3). Lastly, fat values were higher for DDGS and slightly lower for midds, corn, and soybean meal than formulated values. Bulk density was similar between all meal diets (Table 4). As expected, pelleting increased the bulk density of the diets. As a greater proportion of the diet was finely ground, particle size decreased and angle of repose increased, which indicates a poorer flowing diet. Pellet durability indexes were similar between pelleted diets, but fine-grinding the complete diet slightly decreased percentage fines in the pelleted diets.

For the overall experiment (d 0 to 111), reducing particle size of the corn from 650 to 320 μ did not affect ADG or ADFI but improved ($P < 0.003$) F/G, caloric efficiency, feed cost/lb of gain, and IOFC (Table 5). Every 100-μ reduction in particle size improved F/G by approximately 1%.

Diet form × portion ground interactions were observed ($P < 0.02$) for ADG, ADFI, final weight, market weight per pig placed, percentage removals per pen, and HCW. These interactions occurred because finely grinding the complete diet reduced each variable when fed in meal form, whereas pigs fed that same diet in pellet form had increased responses for each of the measurements. The increased removals per pen for the finely ground complete diet that was pelleted were noticeable; however, no clear link was found between removals and feed processing in this study. The decrease in market weight per pig placed interaction is due to Treatment 5 having the lowest value, which was a cause of the high removal rate for the treatment. More research needs to be conducted to evaluate whether this effect was specifically diet-related.

Pelleting the diet improved ($P < 0.001$) ADG, F/G, caloric efficiency, final weight, HCW, and loin depth and tended to increase ($P < 0.07$) BF. Pelleting also reduced ($P < 0.002$) feed cost/lb of gain and increased ($P < 0.001$) IOFC. Grinding the complete diet increased ($P < 0.01$) feed cost/lb of gain and reduced ($P < 0.03$) IOFC and loin depth.

These data suggest that performance can be improved through a variety of feed-processing technologies. Fine-grinding corn and pelleting the diet improved efficiency of gain and economic return in finishing pigs. The response to corn particle size is particularly significant, because the diets used in the study included only 30 to 39% corn due to the inclusion of DDGS and midds; however, fine-grinding the entire diet and feeding in meal form reduced feed intake. We speculate this was caused by reduced palatability. Interestingly, when this diet was pelleted, feed intake improved, resulting in the highest numerical growth rate of any treatment. Disappointingly, feed efficiency and caloric efficiency were identical in pelleted diets regardless of whether only the corn was finely ground or if the complete diet was finely ground. This result indicates that fine-grinding DDGS, wheat midds, and soybean meal did not improve their energy value. Although we observed increased incidence of removals for the reground and pelleted diet treatment, more work should be done to determine if the removals are truly an effect of the processing technologies.

Table 1. Composition of experimental diets (as-fed basis)[1]

	Phase			
Item	1	2	3	4
Ingredient, %				
Corn	30.94	34.82	39.03	32.69
Soybean meal (46.5% CP)	16.81	12.98	8.77	15.09
Wheat middlings	20.00	20.00	20.00	20.00
Dried distillers grains with solubles	30.00	30.00	30.00	30.00
Limestone	1.50	1.50	1.50	1.50
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.10	0.10
L-lysine HCl	0.30	0.25	0.25	0.25
Ractopamine HCL, 9g/lb[2]	---	---	---	0.03
Total				
	100	100	100	100
Standard ileal digestible (SID) amino acids, %				
Lysine	0.98	0.85	0.75	0.90
Isoleucine:lysine	70	74	75	73
Methionine:lysine	32	34	36	34
Met & Cys:lysine	63	68	73	67
Threonine:lysine	63	67	69	66
Tryptophan:lysine	19	19	19	19
Valine:lysine	73	80	86	78
Total lysine, %	1.16	1.02	0.91	1.07
ME, kcal/lb[3]	1,468	1,472	1,477	1,469
NE, kcal/lb[4]	697	708	720	701
SID lysine:ME, g/Mcal	3.03	2.62	2.30	2.78
CP, %	21.2	19.7	18.1	20.5
Crude fiber, %	4.6	4.5	4.4	4.5
NDF, %	6.7	6.7	6.8	6.7
ADF, %	3.0	3.0	2.9	3.0
Ca, %	0.67	0.66	0.64	0.66
P, %	0.60	0.59	0.57	0.59
Available P, %	0.42	0.41	0.41	0.41

[1] Phase 1 diets were fed from d 0 to 35, Phase 2 from d 35 to 65, Phase 3 from d 65 to 93, and Phase 4 from d 93 to 111.
[2] Paylean; Elanco Animal Health (Greenfield, IN).
[3] NRC. 1998. Nutrient Requirements of Swine, 10th ed. Natl. Acad. Press, Washington DC.
[4] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

Table 2. Chemical analysis of ingredients (as-fed basis)[1]

Item	Wheat middlings	DDGS[2]	Corn	Soybean meal
DM, %	90.76	90.63	87.73	91.14
CP, %	16.3(15.9)	27.0(27.2)	6.8(8.5)	46.5(46.5)
ADF, %	11.0	13.5	2.4	6.1
NDF, %	31.2	27.1	7.8	6.7
Crude fiber, %	7.6(7.0)	8.7(7.3)	1.8(2.2)	2.9(3.9)
NFE, %[3]	56.4	37.2	75.0	32.7
Ca, %	0.14(0.12)	0.06(0.03)	0.06(0.03)	0.37(0.34)
P, %	1.19(0.93)	0.89(0.71)	0.29(0.28)	0.71(0.69)
Fat, %	3.7(4.2)	11.4(10.7)	2.99(3.9)	1.1(1.5)
Ash, %	5.47	4.28	1.09	5.94
Particle size, µ	627	580	647; 322[4]	1,070
Bulk density, lb/bu	28.05	45.74	50.59; 48.18[5]	61.68

[1] Values in parentheses indicate those used in diet formulation.
[2] DDGS: dried distillers grains with solubles.
[3] NFE: nitrogen-free extract.
[4] Average roller-milled corn was 647 µ; average hammer-milled corn was 322 µ.
[5] Average roller-milled corn was 50.6 lb/bu; average hammer-milled corn was 48.2 lb/bu.

Table 3. Chemical analysis of diets (as-fed basis)[1]

Item[2]	Phase 1	Phase 2	Phase 3	Phase 4
DM, %	89.87	89.48	89.61	89.89
CP, %	20.6	19.3	18.4	20.6
ADF, %	7.1	7.3	7.1	7.2
NDF, %	15.9	16.3	15.8	26.8
Crude fiber, %	4.4	4.5	4.4	4.8
NFE, %[3]	53.5	54.3	55.6	52.5
Ca, %	0.48	0.66	0.38	0.39
P, %	0.61	0.63	0.57	0.67
Fat, %	4.7	4.9	4.9	5.5
Ash, %	5.45	5.23	5.01	5.61

[1] A composite sample consisting of 6 subsamples was used for analysis.
[2] Diet 1 was used for analysis, because all treatments were formulated identically.
[3] NFE: nitrogen-free extract.

Table 4. Analysis of diets[1]

Item	Portion ground:[2] Diet form:	---[3] Meal	Corn Meal	Corn Pellet	Complete diet Meal	Complete diet Pellet
Bulk density, lb/bu						
Phase 1		45.5	44.9	61.3	46.6	62.2
Phase 2		44.6	44.3	59.7	44.2	61.4
Phase 3		44.3	44.9	61.0	44.6	62.4
Phase 4		45.1	44.8	61.7	44.9	62.3
Particle size, μ						
Phase 1		552	515	---	394	---
Phase 2		619	483	---	344	---
Phase 3		612	440	---	365	---
Phase 4		602	511	---	355	---
Angle of repose, °						
Phase 1		51.8	52.8	---	58.6	---
Phase 2		54.4	53.1	---	58.8	---
Phase 3		52.3	57.1	---	58.4	---
Phase 4		52.1	55.5	---	59.1	---
Standard pellet durability index						
Phase 1		---	---	96.1	---	96.3
Phase 2		---	---	94.4	---	96.7
Phase 3		---	---	92.9	---	93.0
Phase 4		---	---	94.5	---	97.2
Modified pellet durability index						
Phase 1		---	---	93.2	---	91.5
Phase 2		---	---	91.7	---	95.0
Phase 3		---	---	88.1	---	90.0
Phase 4		---	---	90.9	---	92.9
Fines, %						
Phase 1		---	---	14.1	---	11.3
Phase 2		---	---	31.7	---	15.7
Phase 3		---	---	8.1	---	7.8
Phase 4		---	---	13.8	---	14.6

[1] A composite sample of four subsamples was used for analysis.
[2] Ingredients or complete diets were ground through a hammer mill using a 1/16-in. screen. Corn was ground to an approximate particle size of 320 μ; complete diets were ground to approximately 360 μ.
[3] Corn for the first treatment was ground through a roller mill and was approximately 650 μ.

Table 5. The effect of grinding corn or a complete diet and diet form (meal vs. pellet) on finishing pig performance[1]

Treatments:	1	2	3	4	5		Probability, P<			
Portion ground:[2]	---[3]	Corn		Complete diet						
Item / Diet form:	Meal	Meal	Pellet	Meal	Pellet	SEM	Corn μ[4]	Diet form × portion ground	Grinding[5]	Diet form[6]
d 0 to 111										
ADG, lb	2.02	2.06	2.11	1.99	2.17	0.018	0.15	0.001	0.89	0.0001
ADFI, lb	5.70	5.57	5.47	5.46	5.63	0.058	0.13	0.02	0.68	0.52
F/G	2.82	2.71	2.60	2.74	2.60	0.035	0.003	0.58	0.50	0.0001
Caloric efficiency[7]										
ME	4,153	3,991	3,824	4,034	3,828	37.0	0.003	0.59	0.50	0.0001
NE	1,998	1,920	1,840	1,941	1,841	17.9	0.003	0.56	0.51	0.0001
BW, lb										
d 0	56.5	56.6	56.6	56.5	56.6	0.83	0.93	0.96	0.99	0.98
d 111	270.7	275.6	276.8	268.5	285.3	2.44	0.15	0.002	0.76	0.001
Market wt per pig placed, lb	254.4	252.8	269.7	262.7	250.4	7.50	0.88	0.04	0.51	0.75
Removal/pen, %	6.6	8.8	4.1	2.3	12.9	2.69	0.56	0.005	0.65	0.26

continued

Table 5. The effect of grinding corn or a complete diet and diet form (meal vs. pellet) on finishing pig performance[1]

	Treatments: 1	2	3	4	5		Probability, P<			
Portion ground:[2]	---[3]	Corn		Complete diet						
Item / Diet form:	Meal	Meal	Pellet	Meal	Pellet	SEM	Corn μ[4]	Diet form × portion ground	Grinding[5]	Diet form[6]
Carcass characterisitcs[8,9,10]										
HCW, lb	200.4	201.1	205.2	196.9	208.7	1.643	0.74	0.02	0.82	<.0001
Yield, %	73.6	72.6	73.0	73.2	72.7	0.347	0.06	0.21	0.72	0.83
Backfat, mm	19.2	19.5	19.7	19.3	20.5	0.342	0.52	0.10	0.36	0.07
Loin depth, mm	60.1	59.5	61.5	59.4	60.2	0.539	0.35	0.25	0.13	0.02
Lean, %[11]	52.9	52.7	53.0	52.8	52.5	0.169	0.35	0.07	0.15	0.91
Economics										
Feed cost/pig, $	99.23	97.35	96.87	96.48	102.19	1.007	0.18	0.002	0.02	0.01
Feed cost/lb gain, $[12]	0.44	0.43	0.41	0.44	0.43	0.004	0.004	0.87	0.01	0.002
Total revenue/pig, $[13,14]	152.50	155.29	159.07	150.44	163.54	1.373	0.15	0.001	0.89	<.0001
IOFC[15]	53.27	57.94	62.20	53.96	61.35	1.143	0.01	0.15	0.03	<.0001

[1] A total of 855 pigs (PIC TR4 × (Fast Genetics York-AND x PIC Line 02) , initially 56.54 lb BW) were used in a 111-d trial, with 19 pigs per pen and 9 pens per treatment.
[2] Ingredients or complete diets were ground through a hammer mill using a 1/16-in. screen. Corn was ground to approximate particle size of 320μ; complete diets were ground to approximately 360 μ.
[3] Corn was ground through a roller mill and was approximately 650 μ.
[4] Treatment 1 vs. 2.
[5] Treatments 2, 3 vs. 4, 5.
[6] Treatments 2, 4 vs. 3, 5.
[7] Caloric efficiency is expressed as kcal/lb of gain.
[8] The three largest pigs were marketed from each pen on d 93.
[9] The three largest pigs were marketed from each pen on d 100.
[10] All remaining pigs were marketed from each pen on d 111.
[11] Calculated using NPPC (1991) guidelines for lean containing 5% fat. Lean % = (2.83 + (0.469 × (HCW)) – (18.47 × (fat depth)) + (9.824 × loin depth)) / (HCW).
[12] Feed cost/lb gain = (feed cost/pig)/total gain. Costs were grinding = $5/ton, mixing = $3/ton, delivery and handling = $7/ton, pelleting = $6/ton.
[13] One lb of body gain = $0.68/lb.
[14] Total revenue/pig = total gain/pig × $0.68.
[15] Income over feed cost = total revenue/pig – feed cost/pig.