Effects of Hard Red Winter Wheat Particle Size in Meal Diets on Finishing Pig Growth Performance, Diet Digestibility, and Caloric Efficiency[1]

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Summary
A total of 288 pigs (PIC 327 × 1050; initially 96.4 lb) were used in an 83-d study to determine the effects of hard red winter wheat particle size on finishing pig growth performance, diet digestibility, and caloric efficiency. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 3 treatments with 8 pigs per pen and 12 pens per treatment. The same wheat-soybean meal–based diets were used for all treatments. Diets were fed in three phases in meal form. The 3 dietary treatments were hard red winter wheat ground with a hammer mill to 730, 580, or 330 µ.

From d 0 to 40, decreasing wheat particle size decreased (linear; $P < 0.05$) ADFI but improved (quadratic; $P < 0.05$) F/G and caloric efficiency (CE), with no change in ADG. From d 40 to 83, decreasing wheat particle size increased (quadratic; $P < 0.05$) ADG and improved (linear; $P < 0.05$) F/G and CE, with no change in ADFI. Overall from d 0 to 83, decreasing wheat particle size improved (linear; $P < 0.05$) F/G and CE on both an ME and NE basis, with no difference in ADG or ADFI. Finally, reducing wheat particle size improved (linear; $P < 0.05$) DM and GE digestibility.

In summary, fine-grinding hard red winter wheat was detrimental to feed intake in early finishing, but improved ADG in late finishing and improved F/G in both periods and overall. Dry matter and GE digestibility as well as CE were all improved for the overall period with fine-grinding wheat. Grinding wheat from 730 to 330 improved the caloric content on an NE basis by 100 kcal/lb.

Key words: finishing pig, performance, particle size, wheat

Introduction
Particle size of cereal grains is an important aspect of swine nutrition when considering feed efficiency and performance in finishing pigs. In corn-soybean meal–based diets, reducing corn particle size below 400 µ can improve F/G in finishing pigs (De Jong

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et al., 2013[4]) fed mash diets. In wheat-based diets, Kim et al. (2005[5]) observed that decreasing wheat particle size from 929 to 580μ improved starch digestibility. In addition, Mavromichalis et al. (2000[6]) observed improved feed efficiency when wheat was ground from 600 to 400 μ. Although much data exists with corn ground below 400 μ, little is available that illustrates the impacts of feeding diets containing finely ground wheat. Therefore, the objective of this study was to determine the effects of hard red winter wheat particle size on finishing pig growth performance, diet digestibility, and caloric efficiency.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. The barn had completely slatted flooring and deep pits. Each pen was equipped with a 2-hole stainless steel feeder and bowl waterer for ad libitum access to feed and water. Feed was delivered to each individual pen by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN).

A total of 288 pigs (PIC 327 × 1050; initially 96.4 lb) were used in an 83-d study. Pens of pigs were balanced by initial BW and randomly allotted to 1 of 3 treatments with 8 pigs per pen and 12 pens per treatment. The same wheat-soybean meal–based diets were used for all treatments. Diets were fed in three phases from d 0 to 27, 27 to 60, and 60 to 83 (Table 1). The 3 dietary treatments included hard red winter wheat ground with a hammer mill to approximately 730, 580, or 330 μ. Pigs and feeders were weighed approximately every 2 wk to determine ADG, ADFI, and F/G. Caloric efficiency was determined on both an ME and NE basis. Caloric efficiency was calculated by multiplying total feed intake × energy in the diet (kcal/lb) and dividing by total gain. Feed ingredients were assigned ME values from the NRC (2012[7]). For NE, values were for the growing pig by INRA (2004[8]).

Feed was manufactured at the K-State O.H. Kruse Feed Technology Innovation Center. Wheat was ground to three particle sizes (728, 579, and 326 μ) by a hammer mill equipped with either a # 4, 8, or 12 screen (0.06, 0.13, 0.19 in., respectively).

Composite samples of the wheat used in the diets were collected prior to feed manufacturing and analyzed for DM, CP, fat, NDF, ADF, ash, and amino acids (Table 2). Analyzed values were then used in diet formulation. Feed samples were taken from each feeder during each phase and then combined within treatment and phase for analysis

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[6] 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 swine. J. Anim. Sci. 78:3086–3095.

[7] NRC. 2012. Nutrient Requirements of Swine. 11th ed. Natl. Acad. Press, Washington DC.

[8] 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 3). Bulk density, particle size, and angle of repose of major ingredients and all diets were measured (Table 4). Particle sizes were determined using Tyler sieves, with numbers 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, and 270 and a pan. A Ro-Tap shaker (W.S. Tyler, Mentor, OH) was used to sift the 100-g samples for 10 min. Particle size was conducted with and without a flow agent (Amorphous silica powder, Gilson Company Inc., Middleton, WI), which was added at 0.001 oz to 3.52 oz of feed. Angle of repose was measured by allowing feed to flow freely over a flat circular platform of a known diameter. The diameter of the platform and height of the resulting pile were used to calculate the angle of repose.

Fecal samples were collected on d 7 of phase 3 (d 67 of the study) from 2 pigs per pen. Phase 3 diets contained 0.5% titanium dioxide as an indigestible marker. After collection, fecal samples were dried in a 50°C forced-air drying oven, then ground for analysis of GE and titanium concentration. The digestibility values were calculated using the indirect method.

Data were analyzed as a completely randomized design using PROC MIXED in SAS with pen as the experimental unit. Linear and quadratic contrasts were completed to determine the effects of decreasing wheat particle size. Results were considered significant at $P \leq 0.05$ and tendencies between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Bulk density decreased (Table 4) as wheat particle size decreased. As expected, angle of repose increased as particle size decreased, which indicates poorer flowability.

From d 0 to 40, decreasing wheat particle size decreased (linear; $P < 0.05$) ADFI but improved (quadratic; $P < 0.05$) F/G and CE, with no change ($P > 0.10$) in ADG (Table 5). From d 40 to 83, decreasing wheat particle size increased (quadratic; $P < 0.05$) ADG and improved (linear; $P < 0.05$) F/G and CE, with no change ($P > 0.10$) in ADFI. Overall from d 0 to 83, reducing wheat particle size had no effect on ADG or ADFI but improved (linear; $P < 0.05$) F/G and CE on both an ME and NE basis. Finally, reducing wheat particle size improved (linear; $P < 0.05$) DM and GE digestibility.

In summary, fine-grinding wheat was detrimental to feed intake in early finishing, but this was not observed in late finishing. Fine-grinding wheat improved ADG in late finishing and F/G for both periods and for the overall study period. In addition, DM and GE digestibility were improved as wheat was more finely ground, as was caloric efficiency for the overall period. The improvement in caloric efficiency can be attributed to the finer particle size of the wheat resulting in improved digestibility. Grinding the wheat from 728 to 326 µ improved the caloric content of the wheat by 100 kcal/lb of NE, or approximately 25 kcal NE per 100 µ. It is recommended that wheat be ground to a particle size under 400 µ when feeding hard red winter wheat in meal diets for maximum nutrient digestibility.

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

	Phase[1]		
Item	1	2	3
Ingredient, %			
Hard red winter wheat	81.29	87.46	92.69
Soybean meal, 46.5% CP	15.84	10.14	4.94
Monocalcium P, 21%	0.28	0.03	---
Limestone	1.43	1.28	1.30
Salt	0.35	0.35	0.35
L-lysine HCl	0.33	0.33	0.35
DL-methionine	0.04	0.02	0.02
L-threonine	0.09	0.09	0.11
Trace mineral premix	0.15	0.13	0.10
Vitamin premix	0.15	0.13	0.10
Phytase[2]	0.08	0.08	0.05
Titanium dioxide	---	---	0.50
Total	100.00	100.00	100.00
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lysine	0.94	0.81	0.71
Isoleucine:lysine	64	63	61
Leucine:lysine	118	121	120
Methionine:lysine	30	30	30
Met & Cys:lysine	61	63	66
Threonine:lysine	62	63	66
Tryptophan:lysine	23.1	23.7	23.7
Valine:lysine	68	69	67
SID lysine:ME, g/Mcal	2.98	2.56	2.24
ME, kcal/lb	1,431	1,435	1,435
Total lysine, %	1.05	0.91	0.79
CP, %	19.7	17.9	16.2
Ca, %	0.67	0.56	0.55
P, %	0.50	0.44	0.42
Available P, %	0.30	0.25	0.24
Crude fiber, %	2.70	2.60	2.60

[1] Phase 1 diets were fed from approximately 85 to 140 lb; Phase 2 from 140 to 182 lb; and Phase 3 from 182 to 265 lb.
[2] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 204.3 phytase units (FTU)/lb, with a release of 0.11% available P.
[3] Titanium was included in the Phase 3 diet as an indigestible marker and was fed for the first 7 d of the phase at a level of 0.5% at the expense of corn.

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

Item	Hard red winter wheat	Soybean meal
DM, %	90.86	90.14
CP, %	11.8	45.8
ADF, %	3.2	6.2
NDF, %	8.1	6.8
NFE, %	72.9	33.6
Ca, %	0.07	0.40
P, %	0.38	0.70
Fat, %	1.8	1.2
Ash, %	1.81	6.11
Starch	55.4	1.5
Particle size (no flow agent), μ	728; 579; 326[2]	942
Particle size (flow agent), μ	714; 554; 284[3]	
Bulk density, lb/bu	60.7; 60.7; 59.3[4]	60.8

[1] A composite sample consisting of 3 subsamples was used for analysis.
[2] Particle sizes were determined using Tyler sieves, with numbers 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, and 270 and a pan. A Ro-Tap shaker (W.S. Tyler, Mentor, OH) was used to sift the 3.52-oz samples for 10 min.
[3] Particle sizes were run with and without flow agent, which was used at an inclusion level of 0.001 oz.
[4] Wheat for treatments 1, 2, and 3 respectively.

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

Item[2]	Phase 1	Phase 2	Phase 3
DM, %	90.28	89.91	89.16
CP, %	19.7	18.4	16.1
ADF, %	2.9	2.8	2.5
NDF, %	9.3	8.2	7.8
Crude fiber, %	2.6	2.2	2.3
NFE, %	62.4	62.9	65.7
Ca, %	0.74	0.89	0.74
P, %	0.51	0.48	0.41
Fat, %	1.4	1.5	1.6
Ash, %	4.41	4.79	3.70
Starch, %	44.1	45.0	51.3

[1] A composite sample consisting of 6 subsamples was used for analysis.
[2] All treatments were analyzed and values were averaged as all treatments were formulated identically.

Table 4. Analysis of diets[1]

	Wheat particle size, µ		
Item	728	579	326
Bulk density, lb/bu			
Phase 1	59.6	59.4	57.6
Phase 2	59.9	59.7	57.8
Phase 3	59.1	59.1	56.1
Particle size, µ[2]			
Phase 1	634	527	432
Phase 2	665	493	354
Phase 3	650	492	336
Angle of repose, °			
Phase 1	44.4	45.6	51.4
Phase 2	44.0	44.1	49.0
Phase 3	45.8	50.3	51.8

[1] A composite sample of four subsamples was used for analysis.
[2] Analysis were run without flow agent.

Table 5. Effects of wheat particle size on finishing pig performance[1]

	Wheat particle size, μ				Probability, $P <$	
Item	728	579	326	SEM	Linear	Quadratic
d 0 to 40						
ADG, lb	2.02	2.04	1.98	0.03	0.349	0.247
ADFI, lb	5.04	4.94	4.84	0.06	0.033	0.966
F/G	2.50	2.42	2.44	0.02	0.015	0.014
d 40 to 83						
ADG, lb	2.02	1.99	2.10	0.02	0.015	0.014
ADFI, lb	6.33	6.18	6.25	0.08	0.484	0.228
F/G	3.14	3.11	2.98	0.03	0.001	0.180
d 0 to 83						
ADG, lb	2.02	2.01	2.04	0.02	0.470	0.470
ADFI, lb	5.71	5.58	5.57	0.06	0.130	0.434
F/G	2.83	2.77	2.73	0.02	0.001	0.824
Caloric efficiency[2]						
ME	4,056	3,973	3,913	28.7	0.001	0.755
NE	3,024	2,963	2,919	21.5	0.001	0.746
Digestibility[3]						
DM, %	88.95	91.15	91.46	0.64	0.013	0.246
GE, %	65.47	70.33	73.46	1.71	0.004	0.685
BW, lb						
d 0	96.5	96.5	96.5	1.1	0.996	0.998
d 40	177.2	177.9	176.2	1.8	0.716	0.586
d 83	264.0	263.4	266.9	2.5	0.414	0.511

[1] A total of 288 pigs (PIC 327 × 1050) were used, with 12 pens per treatment and 8 pigs per pen.
[2] Caloric efficiency is expressed as kcal/lb of gain and represents the d 0 to 83 data.
[3] Fecal samples were taken on d 67 of the study via rectal massage from two pigs per pen.