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Effect of Mill Type and Particle Size Variation on Growth Performance and Carcass Characteristics of Finishing Pigs

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Summary

The objective of this experiment was to determine the effects of mill type used to grind corn and its particle size variation on diet flowability and subsequent finishing pig growth performance and carcass characteristics. A total of 200 pigs (DNA Line 241 × 600; initially 121.9 lb) were used in a 75-d growth trial. Pigs were randomly assigned to pens with either 5 barrows or 5 gilts per pen. Pens were then randomly allotted to 1 of 4 treatments balanced by weight and gender with 10 pens per treatment. Treatments were arranged as a 2 × 2 factorial with 2 mill types (3-high roller mill; RMS, Model 924 or a hammermill; Bliss, model 22115) and 2 particle size variations (standard vs. blended). Increasing corn particle size variation was accomplished by blending 30% 400 μm corn, 40% 600 μm corn, and 30% 800 μm corn. Standard treatments were accomplished by grinding corn to an average of 600 μm with either mill. On d 75, pigs were transported to a commercial packing plant for processing and determination of carcass characteristics. The average analyzed complete diet mean particle sizes and standard deviations were 497, 540, 503, and 520 μm and 2.70, 2.75. 3.35, and 3.35 for the roller mill standard, roller mill blended, hammermill standard, and hammermill blended treatments, respectively. Diet flowability was calculated using angle of repose (AoR), percent compressibility, and critical orifice diameter (COD) measurements to determine the composite flow index (CFI). The AOR were 34.2, 33.0, 35.4, and 36.2°; COD were 32.0, 31.3, 30.0, and 33.0 mm; compressibilitys were 18.7, 18.4, 17.0, and 15.7%; and CFI were 52.9, 55.4, 53.9, and 53.2 for the roller mill standard, roller mill blended, hammermill standard, and hammermill blended treatments, respectively.

There were no interactions or main effects of mill type on growth performance or carcass characteristics. However, pigs fed the blended diets had marginally significant decreased ($P < 0.083$) average daily gain (ADG) compared to those fed the standard diets. No differences were observed in total feed cost or cost per lb of gain between treatments. Pigs fed blended diets also had marginally decreased ($P < 0.059$) gain value and income over feed costs (IOFC) compared to those fed diets that were not blended. In conclusion, mill type used to grind corn and increasing particle size variation did not impact flowability metrics of complete diets. Mill type used to grind corn did not influ-

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ence performance of finishing pigs, while increasing particle size variation by blending various particle sizes of corn led to a marginal reduction in ADG, gain value, and IOFC.

Introduction

Reducing the particle size of cereal grains can improve growth performance in all phases of swine production through increasing the surface area to volume ratio of grain particles.[2] Grains are ground to reduce particle size using either a roller mill or hammermill. A roller mill uses shear force and a hammermill uses impact force to reduce particle size of grains. This difference of grinding forces between mills can greatly impact the ground particle shape and particle size variability with the hammermill, resulting in increased particle size variability compared to a roller mill.[3] In addition, different roll configurations, gap sizes, and corrugation patterns in roller mills, and screen size, tip speed, and hammer wear in hammermills can all lead to an increase in particle size variation of the ground product.

It has been observed that corn ground using a roller mill increased the apparent digestibility of gross energy (GE) in finishing pig diets.[4] However, the difference between mills was greater when grinding corn to mean particle size of 800 µm compared to 400 µm. In contrast, an improvement was observed in apparent total tract digestibility of GE when corn was ground to 300 µm using a roller mill versus a hammermill, but no differences between mill type were observed when corn was ground to 500 or 700 µm.[5] The inconsistencies in response when grinding corn with different mill types warrants further investigation. Therefore, the objective of this study was to determine the effect of mill type and particle size variability on diet flowability, growth performance, and carcass characteristics of finishing pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used for this experiment. All dietary treatments were manufactured at Kansas State University O. H. Kruse Feed Technology Innovation Center in Manhattan, Kansas.

A total of 200 pigs (DNA Line 241 × 600; initially 121.9 lb) were used in a 75-d growth trial at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Pigs were randomly assigned to pens with either 5 barrows or 5 gilts per pen. Pigs were provided *ad libitum* access to feed and water for the duration of the trial. Each pen was equipped with 2-cup waterers and a dry self-feeder. Pens were randomly

[2]Hancock, J.D, and K.C. Behnke. 2001. Use of ingredient and diet processing technologies (grinding, mixing, pelleting, and extruding) to produce quality feeds for pigs. Swine Nutrition, 2nd (Ed. A. J. Lewis and L. L. Southern). CRC Press LLC, Boca Raton, Florida, pp. 469-497.
[3]Goodband R. 2003. Particle size, mill type, and added fat influence flowability of ground corn. Swine Day 2003.
[4]Wondra K. J. 1995. Effects of mill type and particle size uniformity on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. Journal of Animal Science, Volume 73, Issue 9, 1 September 1995, Pages 2564–2573.
[5]Acosta, Jesus and Patience, John F. (2016) "Effect of Reducing Mean Particle Size of Corn DDGS Using a Roller Mill or a Hammermill on Apparent Total Tract Digestibility of DM, GE, Nitrogen and NDF in Growing and Finishing Pigs," *Animal Industry Report*: AS 662, ASL R3121. Available at: https://lib.dr.iastate.edu/ans_air/vol662/iss1/82

assigned to 1 of 4 dietary treatments within the gender block and balanced by average weight with 10 replications per treatment. Treatments were arranged as a 2 × 2 factorial with 2 mill types (3-high roller mill; RMS, model 924 or a hammermill; Bliss, model 22115) and 2 particle size variations (standard vs. blended). Increasing corn particle size variation was accomplished by blending 30% 400 µm corn, 40% 600 µm corn and 30% 800 µm corn. Standard treatments were accomplished by grinding corn to an average of 600 µm. The average complete diet particle size was approximately 500 µm. Diets (Table 1) were fed in three phases from day 0 to 24, 24 to 49, and 49 to 75. Individual pig weights and feeder weights were collected on d 0, 24, 49, and 75 to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). On d 75, pigs were individually weighed and ear tagged with a unique radio frequency identification device number for carcass measurements to be recorded on a pig basis. Pigs were transported to a commercial packing plant (Triumph, St. Joseph, MO) for processing and carcass data collection. Data collected included hot carcass weight (HCW), backfat thickness, loin depth, and percent lean. Carcass yield was calculated as HCW divided by final live weight taken at the farm.

An economic analysis was performed at the conclusion of the trial to determine the financial impact of the treatments. Ingredient prices for economic calculations of corn were roller mill diets, $128/ton; hammermill, $128.25/ton. Soybean meal was calculated at $343/ton. A $0.25/ton adjustment to corn ground on a hammermill was used to represent the increased energy used by the hammermill when compared to a rollermill.[6] The cost of feed ($/ton) included ingredients and $12/ton for processing. The total feed cost per pig was calculated by multiplying the total pounds of feed consumed by the cost per pound of feed. Cost per pound of gain was calculated by dividing the total feed cost per pig by overall pounds gained. Gain value per pig was calculated by multiplying the total carcass gain by the assumed carcass price of $73.52 per cwt. Carcass gain was calculated using the carcass weight minus the initial live weight multiplied by an assumed yield of 75%. To calculate IOFC, total feed cost was subtracted from gain value.

Samples of each complete diet were collected and analyzed for particle size and flowability characteristics. Particle size analysis was completed according to ANSI/ASAE S319.4 with the inclusion of sieve agitators and flow agent. The flowability characteristics of finished diets were evaluated using a composite flow index (CFI), which includes tests such as percent compressibility, angle of repose, and critical orifice diameter.[4]

Data were analyzed using the MIXED procedure in SAS version 9.4 (SAS Institute Inc., Cary, NC). Data were analyzed as a generalized randomized complete block design with pen as the experimental unit and gender as the block. Results were considered significant if $P \leq 0.05$, and a trend if $0.05 < P \leq 0.10$. Hot carcass weight was used as a covariate for analysis of backfat, loin depth, and percent lean.

Results and Discussion

The flowability of the mash diets were evaluated based on the composite flow index, which characterized flow properties by integrating the results of angle of repose, percent

[6]CPM. Economics of Grinding for Pelleted Feed. https://www.cpm.net/downloads/Economics%20of%20Grinding%20for%20Pelleted%20Feeds.pdf

compressibility, and critical orifice diameter. In general, a composite flow index[7] value above 45 is considered acceptable. Applying this methodology and scale to the data, flowability of the all diets was considered acceptable (Table 2).

The particle size of all finished diets was collected and analyzed according to ANSI/ASAE S319.4 with the inclusion of sieve agitators and flow agent. With the inclusion of other ingredients with the standard and blended ground corn, a decrease in particle size was observed from the 600 µm average target of the ground corn to an average of 508 µm for complete diets. It is also noted that an increase in standard deviation was not seen in the blended treatments on either the roller mill or hammermill.

Overall, no interaction was observed between mill type and particle size variation on growth performance and carcass characteristics. Mill type used to grind corn did not influence growth performance or carcass characteristics. Pigs fed diets with blended corn of different particle sizes in order to create increased variability had marginally decreased ADG ($P < 0.083$) compared to those fed diets with standard particle size variability of corn ground to 600 µm. There was no evidence of treatment differences in ADFI, F/G, final weight, or carcass characteristics. Pigs fed diets that were blended had a tendency for decreased ($P < 0.059$) revenue and IOFC compared to those fed diets that were not blended. No differences were observed in total feed cost or cost per lb of gain between treatments.

Mill type used to grind corn and blending of varying corn particle sizes did not impact diet flowability, feed intake, feed efficiency, or carcass characteristics of finishing pigs in the current experiment. A marginal reduction in ADG, gain value, and IOFC was observed when pigs were fed diets with increased particle size variation through blending 400, 600, and 800 µm corn.

[7]Horn, E. (2008). Development of a composite index for pharmaceutical powders. PhD dissertation. Potchefstroom, South Africa: North-west University, School for Pharmacy.

Table 1. Diet composition (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Corn[2]	79.55	82.90	86.30
Soybean meal, 48% crude protein	17.70	14.80	11.50
Monocalcium phosphate, 21% P	0.65	0.45	0.40
Limestone	1.00	0.93	0.85
Salt	0.35	0.35	0.35
L-Lysine-HCL	0.30	0.25	0.25
DL-Methionine	0.015	---	---
L-Threonine	0.075	0.060	0.060
L-Tryptophan	0.015	0.0125	0.0125
Vitamin and trace mineral premix	0.30	0.25	0.25
Phytase[3]	0.02	0.02	0.02
Total	100.00	100.00	100.00

[1]A three phase diet formulation was manufactured using specified corn grind (roller mill or hammermill) and blending measures
[2]Particle size variability treatments were accomplished by blending 30% 400 μm corn, 40% 600 μm corn, and 30% 800 μm corn, standard treatment corn was ground to 600 μm.
[3]HiPhos 2700 (DSM Nutritional Products, Inc., Parsippany, NJ), providing 184.3 phytase units (FTU)/lb and an estimated release of 0.10% available P.

Table 2. Physical analysis of diets (as-fed basis)[1]

	Roller mill		Hammermill	
Item	Standard	Blended	Standard	Blended
Particle size,[1] μm	490	502	519	522
Standard deviation, S_{gw}	2.70	2.75	3.35	3.35
Angle of repose,[2] °	34.2	33.0	35.4	36.2
Critical orifice diameter[3]	32.0	31.3	30.0	33.0
Compressibility,[4] %	18.7	18.4	17.0	15.7
Composite flow index[5]	52.9	55.4	54.0	53.3

[1]Particle size and standard deviation (Sgw) are determined according to ASABE 319.4 methods.
[2]Angle of repose was determined by measuring the height and radius of the cone formed by the material and using the following equation Tan θ = height of cone (mm)/radius of cone (mm).
[3]Critical orifice diameter was determined using a Flodex device to determine product mass flow characteristics through varying discharge outlet sizes.
[4]% Compressibility is calculated by using the Hausner ratio (PTapped/PBulk).
[5]The composite flow index is calculated by the following equation CFI = (-0.667(AoR Result) + 50) + (-0.667(%C Result) + 36.667) + (-1.778(COD Result) + 37.778).

Table 3. Effects of mill type and particle size variation on pig growth performance and carcass characteristics[1]

	Mill type							
	Roller mill		Hammermill			Probability, $P <$		
	Standard[2]	Blended[3]	Standard	Blended	SEM	Mill	Variation	Interaction
Body weight, lb								
d 0	121.9	122.7	122.4	123.2	1.52	0.753	0.604	0.998
d 75	287.9	282.3	287.2	285.7	4.39	0.677	0.276	0.537
d 0 to 75								
ADG, lb	2.21	2.13	2.20	2.17	0.047	0.534	0.083	0.429
ADFI, lb	5.91	5.76	5.97	5.97	0.217	0.184	0.455	0.449
F/G	2.68	2.71	2.72	2.75	0.054	0.324	0.336	0.987
Carcass characteristics								
HCW, lb	215.9	212.0	214.5	212.8	3.53	0.889	0.248	0.632
Yield, %	75.01	75.07	74.67	74.60	0.254	0.124	0.999	0.801
Backfat, in.	0.64	0.63	0.60	0.63	0.040	0.175	0.554	0.196
Loin depth, in.	2.51	2.50	2.50	2.46	0.041	0.279	0.274	0.534
Lean, %	54.24	54.29	54.57	54.16	0.517	0.642	0.413	0.288
Economic analysis[2]								
Total feed cost,[5], $/pig	45.28	44.07	45.74	45.71	1.672	0.161	0.404	0.425
Cost,[6] $/lb of gain	0.274	0.276	0.277	0.281	0.006	0.275	0.389	0.946
Gain value, $/pig[7]	91.52	88.21	90.17	88.54	2.277	0.685	0.056	0.507
Income over feed cost,[8] $	46.24	44.15	44.43	42.83	0.947	0.107	0.059	0.801

[1]A total of 200 pigs (DNA 241 × 600) were used in a 75-d experiment to evaluate the effects of mill type and particle size variation on growth performance and carcass characteristics of finishing pigs.
[2]Standard refers to the normal particle size variation of grinding approximately 600 micron grain with either a hammermill or roller mill.
[3]Blended indicates diets comprised of 30% 400, 46% 600, and 30% 800 micron corn.
[4]Standardized cost at time of feed manufacture: corn $128/ton, soybean meal $343/ton, and electricity $0.12/kwh.
[5]Total feed cost = feed cost × feed consumed per pig.
[6]Cost = total feed cost divided by total gain per pig.
[7]One lb of live weight gain was estimated to be worth $0.52.
[8]Income over feed cost = total revenue per pig – feed cost per pig.
ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency. HCW = hot carcass weight.