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Effect of Pellet Die Thickness on the Standardized Ileal Digestibility of Crude Protein and Amino Acids in Commercial Diets Fed to Growing Pigs

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Summary

A total of 12 barrows (DNA 241 × 600; initially 169.95 ± 7.79 lb) were surgically fitted with a T-cannula in the distal ileum and allotted to a replicated 4 × 4 Latin square design with four treatments and four periods, for a total of 12 replicate pigs per treatment. Pigs were individually housed in pens equipped with a feeder, nipple drinker, fully slatted metal floor, and smooth side walls. Dietary treatments consisted of a mash diet and three separate diets that were pelleted using different pellet die length:diameter ratios (L:D) of 6 (1.04- × 0.17-in), 8 (1.38- × 0.17-in), and 10 (1.72- × 0.17-in). For each experimental period, the first 5 d were considered adaptation to the diet and the next 2 d were considered the collection period, where ileal digesta was collected for 8 h each day. Results indicate that the standardized ileal digestibility (SID) of crude protein was greater ($P < 0.05$) in the diet pelleted using the L:D 10 die, compared to the mash diet and the diet pelleted using the L:D 6 die, however, no differences were observed between the diets pelleted using the L:D 8 and 10 dies, or between mash diet and the diet pelleted using the L:D 6 die. The SID of amino acids was greater ($P < 0.05$) in the pelleted diets using the L:D 8 and 10, compared with the mash diet and the pelleted diet using the L:D 6 die. However, no differences were observed between the L:D 6 diet and the mash diet. The SID of Lys was greater ($P < 0.05$) in the pelleted diet using the L:D 10 die when compared with the mash diet, with the L:D 6 and 8 diets being intermediate. The SID of Met was greater ($P < 0.05$) in the diets pelleted with the L:D 8 and 10 die, compared with the mash diet, whereas no differences were observed in the SID of Met between the mash diet and the diet pelleted using the L:D 6 die. Similarly, no differences were observed in the SID of Met between the pelleted diets using the L:D 6 and 8 dies. The SID of Trp and Gly was greater ($P < 0.05$) in the diet pelleted using the L:D 8 die compared with the L:D 6, with all other treatments being intermediate. The results indicate that the degree of improvement in SID of crude protein and amino acids is dependent on pellet die thickness due to the differences in temperature, pressure, and friction that the feed is exposed to during the formation of the pellets.

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Introduction

During pelleting, feed is subject to different levels of heat, moisture, shear, and pressure, resulting in differences in the physical properties of the pellets. However, digestibility has also been recognized to be affected by pelleting, particularly crude protein (CP) and amino acids (AA), likely due to protein denaturation and possible inactivation of antinutritional factors[4]. However, heat damage is a constant concern during pelleting, leading to a decrease in digestibility of CP and AA. During conditioning, feed is exposed to high temperatures, but additional heat is produced when feed is compressed into the pellet die. One factor contributing to the additional heat that feed is exposed to in the pellet chamber is the thickness of the pellet die, which increases the time that feed is exposed to a greater temperature. This increase in residence time may lead to enhanced pellet quality, but it is unclear how it might affect the digestibility of nutrients. Therefore, the objective of this experiment was to test the hypothesis that increased pellet die thickness will increase ileal digestibility of CP and AA of growing pigs.

Procedures

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The experiment was conducted in the metabolism room at the Kansas State University Swine Teaching and Research Center (Manhattan, KS), where pigs were individually housed in pens equipped with a feeder, nipple drinker, fully slatted metal floor, and smooth side walls. Pigs were monitored daily and remained healthy throughout the experiment. Experimental diets were mixed and processed at the Kansas State University O.H. Kruse Feed Technology Innovation Center (Manhattan, KS).

Diets and animals

A corn, soybean meal, and DDGS-based diet was formulated (Table 1) to meet or exceed the requirements for pigs between 165 and 200 lb. Three batches of 1,600 lb and a fourth batch of 700 lb were mixed using a twin-shaft counterpoise mixer (Hayes and Stolz, model TRDB63-0152, Fort Worth, TX) for a total of 5,500 lb. The 700-lb batch was kept as mash and used as a control treatment. The remaining three batches were mixed, stored together, and divided again into three batches. The feed was steam conditioned (Wenger twin-shaft preconditioner, Model 150, Wenger, Sabetha, KS) for 30 s at 175.3, 175.6, and 154.4°F, and subsequently pelleted using a 1-ton pellet mill (1112-2, California Pellet Mill, Crawfordsville, IN) equipped with a 1.04- × 0.17-in (L:D 6), 1.38- × 0.17-in (L:D 8), or 1.72- × 0.17-in (L:D 10) pellet die, respectively. Different conditioning temperatures were used to accomplish similar hot pellet temperatures (183.0 to 185.9°F) and production rates (26.0 lb/min). During each pelleting run, the conditioning temperature, production rate, and hot pellet temperature were monitored and recorded every 8 min.

[4] Rojas, O. J., E. Vinyeta, and H. H. Stein. 2016. Effects of pelleting, extrusion, or extrusion and pelleting on energy and nutrient digestibility in diets containing different levels of fiber and fed to growing pigs. J. Anim. Sci. 94:1951–1960. doi:10.2527/jas.2015-0137.

A total of 12 barrows (DNA 241 × 600; initially 169.95 ± 7.79 lb) were surgically fitted with a T-cannula in the distal ileum[5] and allotted to a 4 × 4 triplicated Latin square design with four treatments and four periods, for a total of 12 replicate pigs per treatment. Feed allowance for the pigs was 3.0 times the maintenance requirement for metabolizable energy (i.e., 197 kcal/kg body weight0.60) with free access to water throughout the experiment. The daily allowance of feed was divided into two equal meals provided at 0800 and 1400 h.

For each experimental period, the first 5 d were considered adaptation to the diet, and the next 2 d were considered the collection period, for a total of 7 d per period. Samples were collected for 8 h each day by removing the plastic lid of the cannula and attaching a plastic bag to the barrel using a plastic cable tie. Bags were replaced every 30 min or when the bag was full of flowing digesta. Samples were immediately stored at -4°F to prevent nutrient degradation. At the conclusion of each period, ileal samples were thawed, subsampled, lyophilized, and ground to be analyzed.

Measurements and sampling

Diet and ileal samples were analyzed for N (method 990.03; AOAC, 2019), dry matter (DM; method 930.15; AOAC, 2019), AA (method 982.30 E [a, b, c]; AOAC, 2019), and titanium[6]. Crude protein was calculated as N × 6.25. Diet samples were analyzed for crude fat (method 920.39; AOAC, 2019), crude fiber (method 978.10; AOAC, 2019), and ash (method 942.05; AOAC, 2019).

Apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of CP and AA were calculated for the four dietary treatments following the equations described by Stein et al.[7] using the values for the basal endogenous losses of CP and AA obtained from a previous experiment that used the same group of pigs as the present experiment[8].

Statistical analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC) using pig as the experimental unit and the random effects of pig and period and the fixed effect of dietary treatment. For each independent variable, least squares means were calculated and then separated using the PDIFF option. Studentized residuals were used to remove outliers, for any value outside ±3. Treatment differences were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

The analyzed nutrient compositions of the diets (Table 2) were within expected ranges considering analytical and sampling variability.

[5] Stein, H. H., C. F. Shipley, and R. A. Easter. 1998. Technical note: A technique for inserting a T-cannula into the distal ileum of pregnant sows. J. Anim. Sci. 76:1433–1436. doi:10.2527/1998.7651433x.
[6] Myers, W. D., P. A. Ludden, V. Nayigihugu, and B. W. Hess. 2004. Technical note: a procedure for the preparation and quantitative analysis of samples for titanium dioxide. J. Anim. Sci. 82:179–183. doi:10.2527/2004.821179x.
[7] Stein, H. H., B. Seve, M. F. Fuller, P. J. Moughan, and C. F. M. de Lange. 2007. Invited review: Amino acid bioavailability and digestibility in pig feed ingredients: Terminology and application. J. Anim. Sci. 85:172–180. doi:10.2527/jas.2005-742.
[8] Lopez, D. A. 2025. Effect of feed technologies on the digestibility of energy and nutrients in diets fed to growing pigs. Diss. Kansas State University, Manhattan, KS.

The SID of CP was greater ($P < 0.05$) in the diets pelleted using the L:D 8 and 10 dies, compared with the L:D 6 die; however, no differences were observed between the mash diet and the pelleted diets using L:D 6 or L:D 8 dies (Table 3). Similarly, no differences were observed between diets pelleted using the L:D 8 die and the L:D 10 die. The diet pelleted using the L:D 10 had a greater ($P < 0.05$) SID of Lys compared with the mash diet. However, the SID of Lys was not different between the mash diet and the pelleted diet using the L:D 6 or L:D 8 dies, or between the diet pelleted using the L:D 10 die and the diets pelleted using the L:D 6 or L:D 8 dies. The SID of Met was greater ($P < 0.05$) in the diet pelleted using the L:D 10 die when compared with the mash diet as well as the diet pelleted using the L:D 6 die. However, no differences were observed in the SID of Met between the diets pelleted using the L:D 10 and the L:D 8 dies, between the mash diet and diet pelleted using the L:D 6 die, or between the diets pelleted using the L:D 6 and L:D 8 dies. No differences were observed in the SID of Trp and Gly between the mash diet and the pelleted diets, regardless of the pellet die used. However, the diet pelleted using the L:D 8 die had greater ($P < 0.05$) SID of Trp and Gly, compared with the diet pelleted using the L:D 6 die. No differences were observed in the SID of Trp and Gly between diets pelleted using the L:D 6 and the L:D 10 dies, or the L:D 8 and the L:D 10 dies. The SID of all other AA was greater ($P < 0.05$) in the pelleted diets using the L:D 8 or L:D 10 when compared with the mash diet and the pelleted diet using the L:D 6 die, but no differences were observed between the mash diet and the diet pelleted using the L:D 6 die.

In conclusion, pelleting alters numerous chemical and physical characteristics of feed, and the conditions experienced during the pelleting process can influence AA digestibility. Pelleting diets using L:D 8 or L:D 10 pellet dies resulted in greater SID of CP and most AA when compared with a mash dietary treatment. However, no differences were observed between the diet pelleted using the L:D 6 die and the mash diet. These results indicate that increasing pellet die thickness enhances the digestibility of CP and most AA, whereas a thinner die provides little improvement over mash, highlighting the importance of pellet die design as a factor influencing nutrient availability.

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Table 1. Ingredient and calculated nutrient composition of experimental diet (as-fed basis)[1]	
Item	Basal diet
Ingredient, %	
Corn	60.84
Soybean meal, 46.5% CP	15.00
Distillers dried grains with solubles	20.00
Soybean oil	1.00
Calcium carbonate	1.05
Monocalcium phosphate, 21% P	0.50
Sodium chloride	0.40
L-Lys-HCl	0.30
Trace mineral premix[2]	0.15
Vitamin premix[3]	0.25
Phytase[4]	0.01
Titanium dioxide	0.50
Total	100.00
Calculated composition	
ME, kcal/lb	1,513
CP, %	17.9
Crude fat, %	5.1
Crude fiber, %	3.6
Ca, %	0.65
STTD P, %	0.41
Standardized ileal digestible AA, %	
Lys	0.85
Ile:Lys	69
Leu:Lys	180
Met:Lys	32
Met & Cys:Lys	61
Thr:Lys	60
Trp:Lys	17.4
Val:Lys	81
His:Lys	48
Total Lys, %	1.01

[1] A basal diet was formulated and divided into 4 aliquots. One aliquot was used without further processing, and the remaining three aliquots were pelleted using different pellet dies (L:D 6, 8, and 10).

[2] Provided the following quantities of minerals per lb of premix: 73,413 ppm of Zn from zinc sulfate; 73,413 ppm of Fe from iron sulfate; 22,046 ppm of Mn from manganese oxide; 11,000 ppm of Cu from copper sulfate; 198 ppm of Se from sodium selenite; 0.13 mg of I from calcium iodate.

[3] Provided the following quantities of vitamins per lb of premix: Vitamin A 750,000 IU, Vitamin D 300,000 IU, Vitamin E 8,000 mg, Vitamin B12 6 mg, menadione 600 mg, riboflavin 1,500 mg, d-Pantothenic Acid 5,000 mg, niacin 9,000 mg.

[4] Quantum Blue 10G (AB Vista, Marlborough, Wiltshire, UK) contained 10,000 FTU/g. At 0.01% inclusion, complete diets were expected to contain 500 FTU/kg with an estimated release of 0.10% STTD P.

Table 2. Analyzed composition of experimental diets (as-fed basis)[1]				
		Pellet die length:diameter		
Item, %	Mash diet	6	8	10
DM	89.92	88.57	87.77	87.82
CP	18.33	18.45	17.67	18.16
Crude fat	4.20	4.92	4.72	4.79
Crude fiber	3.14	3.78	3.26	3.09
Ash	4.80	5.17	5.15	5.13
Indispensable AA				
Arg	0.99	1.05	1.08	0.99
His	0.49	0.50	0.51	0.48
Ile	0.74	0.76	0.78	0.73
Leu	1.85	1.77	1.86	1.79
Lys	1.02	1.15	1.14	1.02
Met	0.33	0.33	0.33	0.31
Phe	0.90	0.91	0.94	0.88
Thr	0.66	0.69	0.70	0.65
Trp	0.16	0.16	0.17	0.15
Val	0.88	0.92	0.93	0.87
Dispensable AA				
Ala	1.12	1.09	1.13	1.09
Asp	1.50	1.61	1.64	1.53
Cys	0.36	0.36	0.37	0.35
Glu	3.24	3.22	3.33	3.18
Gly	0.72	0.76	0.78	0.72
Ser	0.76	0.78	0.80	0.76
Tyr	0.65	0.65	0.68	0.65

[1] Samples were analyzed at the University of Missouri Agricultural Experiment Station Chemical Laboratories in Columbia, MO.