Effect of Conditioning Time on Standardized Ileal Digestibility of Amino Acids and Total Tract Digestibility of Energy in Diets Fed to Growing Pigs

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Summary

Two experiments were conducted to determine the effect of conditioning time prior to pelleting on digestibility of energy and AA in swine diets. Treatments consisted of a mash diet, and three separate pelleted diets that were conditioned for either 30, 60, or 180 s prior to pelleting. For exp. 1, a total of 12 barrows (DNA 200 × 400, DNA; initially 99.1 ± 5.95 lb) were 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 housed individually in metabolic crates equipped with a cup-drinker, a feeder, and partial metal diamond-slatted flooring. For each experimental period, the first 5 d were considered adaptation to the diet and during d 6-7 ileal digesta was collected. For exp. 2, a total of 12 barrows (DNA 200 × 400, DNA; initially 75.2 ± 2.27 lb.) were allotted to a replicated 4 × 3 balanced incomplete Latin square design with four treatments and three periods for a total of nine replicate pigs per treatment. Pigs were housed individually in the same metabolic crates as exp. 1. For each experimental period, the first 5 d were considered adaptation to the diet, and the following 5 d were considered the collection period. During collection, a screen and urine pan were installed to allow for the total and separate collection of feces and urine samples. For exp. 1, a treatment effect ($P < 0.001$) was observed for SID of CP, all indispensable AA, all dispensable AA, and total AA, excluding Lys, Met and Trp, which show no differences. The SID of CP, Arg, Leu, Thr, Ala, Ser, and Tyr was greater ($P < 0.05$) in the pelleted diets compared to the mash diet. For His, Ile, Phe, Val, Asp, and Glu, mash diets had decreased ($P < 0.05$) SID compared to the pelleted diets conditioned for 60 s and 180 s. However, there was no evidence of difference in SID of Val for any of the conditioning lengths. For SID of Cys, mash diets had decreased ($P < 0.05$) SID compared to the pelleted diets conditioned for 180 s, and there was no evidence of difference between the mash diets and pelleted diets conditioned for 30 s or 60 s. For the concentrations of DE and ME in both as-is and dry matter-basis, diets conditioned for 60 s had the greatest ($P < 0.05$) concentrations compared to the mash, 30 s, and 180 s treatments. These results indicated that long-term conditioning, up to 180 s, did not negatively impact AA acid digestibility or ME, and improved AA digestibility for certain AA compared to diets

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conditioned for 30 s. It was also demonstrated that conditioning the diets for 60 s optimized the DE and ME of the diet.

Introduction

Pelleting is a common process in swine diets that aims to reduce feed waste, segregation of nutrients, and feed sorting while increasing feed efficiency. During this process, feed is exposed to heat and moisture during conditioning to prepare the mixture for the high pressure and friction required to form the pellet as it is extruded through the pellet die. High temperatures can be reached both during conditioning and due to the friction of the roll and press in the pellet die, which can lead to the potential damage of heat-labile nutrients in the feed. Moreover, conditioning has been explored as a possible decontamination step for pathogens that could survive in the complete feed or feed ingredients. Conditioning at temperatures as low as 160°F can be efficient to destroy pathogens, which is lower than the standard temperature range of 175 to 185°F used for typical conditioning during the pelleting process. However, time is also an important factor to consider for pathogen control. While the conditioning process usually lasts for 30 to 60 s, manufacturers have developed equipment that allows for longer retention times, enhancing microbial control during thermal conditioning. Nevertheless, it is unclear whether the increased conditioning time could lead to even greater damage to heat-labile nutrients in the diets, rendering them unavailable for the animal. Therefore, the objective of this study was to determine the effect of different retention times during conditioning on the digestibility of energy and amino acids in pelleted diets fed to growing pigs.

Materials and Methods

The protocol for these experiments was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted in the metabolism room at the Kansas State University Swine Teaching and Research Center, where pigs were individually housed in metabolic crates that allow for the total and separate collection of feces and urine. All crates were equipped with a feeder, a water cup drinker, and partial metal diamond-slatted flooring.

A corn, soybean meal, DDGS-based diet was formulated (Table 1) to meet or exceed the recommended requirements for pigs between 88-140 lb. A total of 5,400 lb of feed was manufactured, from which 1,000 lb were kept as mash to serve as a control dietary treatment. The remaining 4,400 lb were divided into three batches of 1,400 lb to be used in the manufacture of the remaining three dietary treatments. The mash feed was conditioned for 30, 60, and 180 s at 180°F in a single pass conditioner (California Pellet Mill 18 INF 6.5). To accomplish the desired retention time, the paddles in the middle of the conditioner were adjusted to 10°, feeder flow was adjusted to 10%, and the speed of the conditioner was adjusted to 85%, 60%, and 10% to achieve target conditioning retention times. Diets were pelleted on a 100 HP pellet mill (CPM, model 3016-4 Master, Crawfordsville, IN) equipped with a 0.19 × 1.73 in and the production rate was constant at 0.55 T/h.

Experiment 1: Amino acids digestibility

A total of 12 barrows (DNA 200 × 400; initial BW of 99.10 ± 5.95) were surgically equipped with a T-cannula in the distal ileum.[2] The animals were allotted to a triplicate 4 × 4 Latin square design with a total of four dietary treatments and four 7d periods, for a total of three pigs per period and 12 replicate pigs per dietary treatment. Pigs were restricted to three times the requirement of maintenance (i.e., 197 kcal of ME per kg of $BW^{0.60}$) but had ad libitum access to water throughout the experiment. Feed was administered in two equal meals at 0800 and 1400 h.

For each 7-d period, the first 5 d were considered adaptation to the diet. Collection took place on d 6 and 7 during 8 h each day. The lid of the cannula was removed, and a plastic bag was attached to the barrel of the cannula using a plastic cable tie. Bags were replaced with new bags every 30 min or every time the bag was full of digesta. The bags were emptied into pitchers assigned to each pig and immediately stored at -4°F, preventing all nutrient degradation. At the conclusion of each period, the pitchers were subsampled, and the resulting samples were lyophilized and ground.

Diet and digesta samples were analyzed for dry matter (DM; Method 930,15; AOAC, 2007). Samples were also analyzed for N using the combustion method (method 990.03; AOAC, 2007) and then crude protein (CP) was calculated by multiplying the concentration of N times 6.25. Diets were submitted to an external laboratory to be analyzed for AA (method 982.30 E [a, b, c]; AOAC, 2019) and titanium following the method described by Myers et al. (2004). Diet samples were analyzed for ash (method 942.05; AOAC, 2019), crude fiber (method 978.10; AOAC, 2019), and crude fat (method 920.39; AOAC, 2019).

The values of apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of CP and AA were calculated following the equations described by Stein et al. (2007).[3] However, the values for basal endogenous losses of CP and AA were obtained from Adeola (2016).[4]

Experiment 2: Energy digestibility

Twelve barrows (DNA 200 × 400, initial BW: 75.2 ± 2.27 lb.) were allotted to a 4 x 3 Balanced Incomplete Latin Square design with four dietary treatments and three periods of 10 d. Therefore, there were a total of nine replicate pigs per dietary treatment. During each period, the first 5 d were considered adaptation to the diet and the following 5 d were considered as collection period. Feeding was managed as previously described in exp. 1.

A screen and urine pan were installed underneath the floor of the crates to allow for the total and separate collection of fecal and urine samples. Fecal samples were collected

[2] Stein, H. H., C. F. Shipley, 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

[3] Stein, H. H., B. Seve, M. F. Fuller, P. J. Moughan, 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

[4] Adeola, O., P. C. Xue, A. J. Cowieson, K. M. Ajuwon. 2016. Basal endogenous losses of amino acids in protein nutrition research for swine and poultry. Anim. Feed. Sci. Tech. 221: 274-283. doi: 10.1016/j.anifeedsci.2016.06.004

following the marker-to-marker method.[5] In summary, an indigestible marker was fed in the morning of the first day of collection and the collection of feces started when the marker was spotted in the feces for the first time. Similarly, a second marker was used to sign the end of the collection, which was fed the morning of the last day of the collection. Feed rejection and orts were collected at the same time as feces. However, after the second marker, the feces were collected until the second marker was again spotted in the feces, whereas the collection of orts and rejected feed stopped right after the second marker was fed. Urine was collected every morning during the collection period using a bucket that contained 50mL of 6N HCl to prevent sample volatilization. The buckets were weighed daily, the value was recorded and a 10% of the total volume of urine was stored at -4°F, as well as fecal and orts samples. The remaining urine was emptied, and the bucket was refilled with HCl.

At the conclusion of the experiment, urine samples were thawed and mixed within animal and diet, and a subsample was taken for chemical analyses. Fecal samples were dried in a forced-air oven at 131°F, finely ground, mixed, and subsampled. Fecal, urine, and feed samples were analyzed for dry matter (DM; Method 930,15; AOAC, 2007), N (method 990.03; AOAC, 2007), and GE using bomb calorimetry.

Statistical analysis

For both experiments, experimental data was analyzed using the GLIMIX procedure of SAS (SAS Institute Inc., Cary, NC) using pig as the experimental unit and pig and period as the random effect. Least square means were calculated for each independent variable and means were separated using the PDIFF option. Studentized residuals were calculated for each observation. Observations with a studentized residual outside of ± 3 were considered outliers and removed. Treatment differences were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Analyzed concentrations of gross energy (GE), DM, CP, crude fat, crude fiber, and ash for the dietary treatments are presented in Table 2. Small to no variations were expected because the basal diet was batched and mixed before being divided into smaller batches for further processing.

There was an overall treatment effect ($P < 0.001$) for SID of CP, and all indispensable AA, except for Lys, Met and Trp, and indispensable and total AA (Table 3). Therefore, there was no evidence of difference in dietary treatments for SID of Lys and Trp. The SID of CP, Arg, Leu, Thr, Ala, Ser, and Try was greater ($P < 0.05$) in pelleted diets compared to the mash diet. There was no evidence of differences for CP and Thr between conditioning retention times of pelleted diets; however, increasing the conditioning time from 30 to 180 s increased SID of Arg, Leu, Ala, Ser, and Tyr. For SID of His, Ile, Phe, Val, Asp, Glu, mash diets had decreased ($P < 0.05$) SID compared to the pelleted diets conditioned for 60 s and 180 s, and there was no evidence of difference between the mash diets and pelleted diets conditioned for 30 s. Increasing the conditioning time from 30 s to 180 s increased ($P < 0.05$) the SID of His, Ile, Phe, Asp, and Glu with diets conditioned for 60 s being intermediated. However, there was no

[5] Adeola, O. 2001. Digestion and balance techniques in pigs. In: A. J. Lewis, and L. L. Southern, editors, Swine nutrition. CRC Press, Washington, D.C. p. 903-916

evidence of difference in SID of Val when conditioned for varying lengths. For SID of Cys and Gly, mash diets had decreased ($P < 0.05$) SID compared to the pelleted diets conditioned for180 s and there was no evidence of difference between the mash diets and pelleted diets conditioned for 30 s or 60 s. Increasing conditioning retention time from 30 s to 180 s increased ($P < 0.05$) SID of Cys, with diets conditioned for 60 s being intermediate. For SID of Gly, there was no evidence of difference with increasing conditioning retention time.

No differences were observed for the ATTD of DM (Table 4). There was an overall treatment effect ($P < 0.001$) for ATTD of GE, DE and ME. All pelleted diets had increased ($P < 0.001$) ATTD of GE, compared to the mash treatments with no evidence of difference between varying conditioning times. For the concentrations of DE and ME (as-is and dry matter-basis), diets conditioned for 60 s had the greatest ($P < 0.05$) concentrations compared to the mash, 30-s, and 180-s treatments.

In conclusion, this study indicates that if conditioning time is increased in an effort to reduce the pathological load of feed or increase pellet quality, there is no negative effects on digestibility of nutrients within the parameters used for this experiment and potential a benefit in the SID of most AA and CP. However, the present experiments tested a conditioning time of up to 180 s with a constant temperature of 185° F. Nevertheless, results also indicate that the concentration of DE and ME might be optimal when diets are conditioned 60 s at the given pellet mill settings.

Table 1. Ingredient composition of experimental diet for experiments 1 and 2 (as-fed basis)[1]

Ingredient, %	Basal diet
Corn	59.62
Soybean meal, 46.5% CP	16.15
Corn dried distillers' grains with soluble	20.00
Soybean oil	1.00
Limestone	0.95
Monocalcium P, 21% P	0.30
Sodium Chloride	0.40
L-Lys-HCl	0.45
DL-Met	0.05
L-Thr	0.12
L-Trp	0.05
L-Val	0.02
Mineral premix[2]	0.15
Vitamin premix[3]	0.25
Phytase[4]	0.10
Titanium dioxide	0.50
Total	100.00

[1]A basal diet was formulated and divided into four batches. Three batches were pelletized at different conditioning times (30, 60, and 180 seconds). The resulting four dietary treatments were used in both experiments 1 and 2.
[2] Provided the following quantities of minerals per lb of diet: 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.
[3]Provided per kg of premix: 750,000 IU vitamin A; 300,000 IU vitamin D; 8,000 mg vitamin E; 600 mg vitamin K; 6 mg vitamin B12; 9,000 mg of niacin; 5000 mg pantothenic acid; 1,500 mg riboflavin.
[4]Quantum Blue 10g (AB Vista, Marlborough, Wiltshire, UK) provided 500 FTU/kg with an expected STTD P release of 0.10%.

Table 2. Analyzed composition of experimental diets (as-fed basis)

		Pelleted diets		
Item	**Mash diet**	**30 sec**	**60 sec**	**180 sec**
Gross energy, kcal/lb	1,999	1,938	2,013	1,928
Dry matter, %	87.89	87.47	87.44	87.51
Crude protein, %	19.29	19.04	19.14	19.07
Crude fat, %	3.04	4.15	4.18	4.03
Crude fiber, %	3.06	4.06	4.33	5.09
Ash, %	5.81	4.98	5.06	5.04

Table 3. Standardized ileal digestibility of CP and AA in dietary treatments[1,2]

		Retention time, s				
Item, %	**Mash**	**30**	**60**	**180**	**SEM**	***P*** **<**
CP	73.46[b]	79.22[a]	81.24[a]	81.86[a]	1.007	0.001
Indispensable AA						
Arg	87.28[c]	89.21[b]	90.51[ab]	91.14[a]	0.708	0.001
His	78.01[c]	79.31[bc]	81.14[ab]	82.14[a]	0.893	0.001
Ile	76.44[c]	78.86[bc]	80.93[ab]	82.16[a]	1.096	0.001
Leu	78.54[c]	82.03[b]	83.92[ab]	85.06[a]	0.988	0.001
Lys	81.22	82.25	81.66	82.69	0.989	0.436
Met	86.16	86.19	87.63	88.12	0.885	0.027
Phe	77.75[c]	80.40[bc]	82.40[ab]	83.63[a]	1.020	0.001
Thr	72.71[b]	75.89[a]	76.93[a]	78.58[a]	1.046	0.001
Trp	84.82	85.13	86.19	86.69	0.995	0.225
Val	74.56[b]	77.33[ab]	78.91[a]	80.29[a]	1.173	0.001
Mean	79.24[c]	81.46[bc]	82.81[ab]	83.90[a]	0.939	0.001
Dispensable AA						
Ala	74.80[c]	78.90[b]	81.12[ab]	82.16[a]	1.204	0.001
Asp	72.68[c]	74.96[bc]	77.09[ab]	78.30[a]	1.040	0.001
Cys	63.05[b]	63.16[b]	65.69[ab]	69.19[a]	1.462	0.002
Glu	77.72[c]	79.36[bc]	81.29[ab]	82.99[a]	1.050	0.001
Gly	68.96[b]	70.89[ab]	72.91[ab]	75.62[a]	1.670	0.011
Ser	79.39[c]	81.94[b]	83.66[ab]	84.82[a]	0.922	0.001
Tyr	80.56[c]	82.95[b]	84.50[ba]	85.72[a]	0.898	0.001
Mean	79.20[c]	81.51[bc]	83.53[ab]	85.12[a]	1.060	0.001
Total AA	79.22[c]	81.49[bc]	83.19[ab]	84.55[a]	0.984	0.001

[a-c]Means within a row lacking a common superscript letter are different ($P < 0.05$).
[1]A total of 12 barrows (DNA 200 x 400; initial BW: 99.10 ± 5.95 lb.) were used in this experiment. Each pig was allotted to a 4 x 4 Latin Square design with four dietary treatments and four periods for a total of 12 replicate pigs per treatment.
[2]Values for standardized ileal digestibility were obtained with the correction of apparent ileal digestibility values for basal endogenous losses of each individual AA and CP. These values were obtained from Adeola, 2016 (g/kg of DMI): CP, 17.28; Arg, 0.59; His, 0.17; Ile 0.30; Leu, 0.50; Lys, 0.40; Met, 0.11; Phe, 0.32; Thr, 0.52; Trp, 0.13; Val, 0.46; Ala, 0.57; Asp 0.75; Cys, 0.17; Glu, 0.94; Gly, 1.46; Ser, 0.65; Tyr, 0.35.

Table 4. Digestible energy (DE), metabolizable energy (ME), and apparent total tract digestibility (ATTD) of gross energy (GE) in experimental diets[1]

		Conditioning time, s				
Item	**Mash**	**30**	**60**	**180**	**SEM**	***P*** <
DE, kcal/lb	1,723[b]	1,712[b]	1,779[a]	1,704[b]	11.39	0.001
DE, kcal/lb of DM[1]	1,960[b]	1,958[b]	2,034[a]	1,947[b]	13.00	0.001
ME, kcal/lb	1,646[b]	1,643[b]	1,699[a]	1,628[b]	17.18	0.001
ME, kcal/lb of DM	1,873[b]	1,878[b]	1,943[a]	1,860[b]	19.62	0.001
ATTD of GE, %	86.18[b]	88.38[a]	88.38[a]	88.06[a]	0.59	0.001
ATTD of DM, %	86.76	87.79	87.42	87.50	0.32	0.135

[a-b]Means within a row lacking a common superscript letter are different ($P < 0.05$).
[1]A total of 12 barrows (DNA 200 x 400; initial BW: 75.2 ± 2.27 lb.) were used in this experiment. Each pig was allotted to a 4 x 3 Balanced Incomplete Latin Square design with four dietary treatments and three periods for a total of nine replicate pigs per treatment.