Kansas State University
College of Agriculture

SWINE DAY
2026

The Apparent and Standardized Ileal Digestibility of Crude Protein and Amino Acids of Sorghum Produced in Different Regions of the United States fed to Growing Pigs

Walter G. Friesen[1], Diego A. Lopez [1], Jason C. Woodworth[2], Jordan T. Gebhardt[3], Matt D. Miesner[4], Chad B. Paulk[1]

Summary

An experiment was conducted to determine the apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of crude protein (CP) and amino acids (AA) in sorghum grain produced across the U.S. when fed to growing-finishing pigs. Five regionally based sources of sorghum were collected and fed to pigs as the sole source of dietary protein. Twelve barrows were surgically fitted with a T-cannula at the distal ileum and were randomly allotted to a replicated 6 × 6 Latin square with six diets and six periods, providing 12 replicates per treatment. Previously published values of basal endogenous losses were used to calculate the SID of CP and AA. Treatments consisted of diets containing corn; corn from Manhattan, KS (CKS), or sorghum sourced from varying locations; Trenton, NE (SNE); Leoti, KS (SKS1); Fowler, KS (SKS2); Brandon, CO (SCO); and Montgomery City, MO (SMO). There was an overall grain source effect ($P \leq 0.005$) for SID of His, Ile, Leu, Met, Phe, Trp, Val, Ala, Cys, Glu, Ser, and Tyr. Corn had increased ($P < 0.05$) SID of His compared with all sorghum sources. However, sorghum sources did not differ in SID of His. Corn and sorghum sourced from SMO had increased ($P < 0.05$) SID of Ile compared with SNE, with all other sorghum sources being intermediate. Corn and sorghum from SMO had increased ($P < 0.05$) SID of Leu compared with SNE and SCO, with remaining sources being intermediate. Corn had increased ($P < 0.05$) SID of Met compared with all sorghum sources. Sorghum sourced from SMO had increased ($P < 0.05$) SID of Met compared with SCO with all other sources being intermediate. Corn had increased ($P < 0.05$) SID of Phe compared with SNE and SCO. Sorghum from SMO had increased ($P < 0.05$) SID of Phe compared with SNE with remaining sources being intermediate. Corn had decreased ($P < 0.05$) SID of Trp compared with SKS1 and SMO. Sorghum from SMO had increased ($P < 0.05$) SID of Trp compared with SNE with SKS1, SKS2, and SCO being intermediate. Corn had increased ($P < 0.05$) SID of Val compared with SNE, SKS2, and SCO, but was similar to SKS1 and SMO. Sorghum sourced from SMO had the greatest ($P < 0.05$) SID of Val and SNE had the lowest, with the remaining sources being intermediate. The SID of CP and AA was within expected ranges for corn and sorghum; however, SNE generally had lower SID within the sorghum sources. The SID

[1] Department of Grain Science and Industry, Kansas State University.
[2] Department of Animal Sciences and Industry, Kansas State University.
[3] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University
[4] Department of Clinical Sciences, College of Veterinary Medicine, Kansas State University.

concentration of CP and most AA was generally reduced for sorghum from SMO due to the lower CP and AA content of the grain source compared with other sorghum sources. Consequently, the growing conditions of Missouri may provide lower total AA supply, but improved digestibility to pigs compared with other growing regions.

Keywords: amino acid digestibility, corn, grain growing region, sorghum

Introduction

As ingredient prices continue to increase, swine producers are using alternative feedstuffs to reduce diet cost. Sorghum is a cereal grain that serves as an economical alternative to corn due to its comparable nutritional value, making it a suitable primary grain source in swine diets. Sorghum has agronomical attributes, such as resistance to heat stress and drought, which make it favorable to produce in certain regions of the world, including Kansas. When properly balanced for digestible amino acids (AA) and phosphorus concentrations, sorghum can be a viable alternative to corn. However, traditional research determined grain sorghum to contain approximately 96% of the energy content of corn[5].

Over time, the nutritional value of sorghum has been enhanced through genetic selection of sorghum grains and by applying feed processing strategies. Sorghum has increased standardized ileal digestibility (SID) concentrations of essential AA, such as Ile, Leu, Phe, Trp, and Val compared with corn[6]. These digestible nutritional concentrations are important to consider when determining the feeding value of sorghum compared with corn, and how it is economically incorporated into swine diets. Although improvements in genetic selection of sorghum varieties have continued, there has been minimal research conducted to update the swine digestibility coefficients for sorghum grown in the U.S. Thus, the objective of the current experiment was to determine the SID of crude protein (CP) and AA of sorghum grain produced across the U.S. fed to growing pigs.

Materials and methods

The protocols used in this experiment were approved by the Institutional Animal Care and Use Committee of Kansas State University (Manhattan, KS), and conducted in a totally enclosed, environmentally regulated facility at the Kansas State University Swine Teaching and Research Center in Manhattan, KS.

Grain Sourcing

Yellow corn was acquired locally from Mid Kansas Cooperative Association (Manhattan, KS; CKS). Approximately 4,000 lb of grain sorghum were collected from five separate locations of the U.S. to represent differing grain growing conditions. The locations were: Trenton, NE (SNE); Leoti, KS (SKS1); Fowler, KS (SKS2); Brandon, CO (SCO); and Montgomery City, MO (SMO). Nutrient content of grain sources used for this experiment were analyzed at a commercial laboratory and displayed in Table 1. Sorghum grain sources were considered equal, including nutrient coefficient values used for diet formulation6.

[5] Cromwell, G. L., T. S. Stahly, and J. R. Randolf. 1985. Grain sorghum and barley as alternative feed grains for growing-finishing swine. Kentucky Agric. Exp. Sta. Rep. 25-173. pp. 27

[6] Nutrient Requirements of Swine: Eleventh Revised Addition. 2012. National Academies Press, Washington, DC.

Amino acid digestibility

Dietary treatments were formulated to contain each individual grain source as the sole source of dietary protein provided to pigs (Table 2). All other nutrients were provided to meet or exceed requirements for pigs between 110 and 165 lb6. Titanium dioxide was included in all dietary treatments at a level of 0.5% as an indigestible marker for the calculation of apparent ileal digestibility (AID) and SID of CP and AA.

All diets were fed in meal form and dietary treatments were manufactured at the O.H. Kruse Feed Technology and Innovation Center in Manhattan, KS, in accordance with current good manufacturing practices. Grain sources were individually ground on a three-high RMS roller mill (RMS Model 924) achieving a target particle size of 650 μm (±50 μm). Grain particle size analysis was conducted according to the ANSI/ASAE S319.2 standard particle size analysis method7. Each dietary treatment was mixed using a 2,000-lb twin-shaft counterpoise mixer (Hayes and Stolz, model TRDB63-0152, Fort Worth, TX) for 180 s. After mixing, the mash feed was discharged and packaged in 50-lb bags, where every second bag was sampled using a probe to provide a composite mash feed sample for each dietary treatment.

A total of 12 barrows were surgically equipped with a T-cannula in the distal ileum and were individually housed in pens (4.0 ft × 4.0 ft) equipped with a self-feeder, nipple waterer, and a slatted floor. The 12 barrows (average initial BW: 144.45 ± 7.12 lb) were allotted to a replicated 6 × 6 Latin square with six periods of 7 d and six dietary treatments. Therefore, each diet was fed to two pigs in each period for a total of 12 replicate pigs per dietary treatment for the six periods. Pigs were fed 3.0 times the maintenance requirement for ME (i.e., 90 kcal/lb BW0.60; NRC, 2012)6 and had ad libitum access to water throughout the experiment. The daily feed allowance was divided and fed into two equal meals at 0800 and 1600 h.

The first 5 d of each period were considered the adaptation period to the diet. Ileal sample collection took place on d 6 and 7. Ileal samples were collected for 8 h by removing the lid of the cannula, attaching a plastic bag to the barrel of the cannula, and securing it with a plastic cable tie. The digesta flowing into the bag were collected every 30 min or every time the bag was full. Digesta samples were immediately stored at -4°F to prevent bacterial degradation of AA. Digesta samples were thawed, subsampled, lyophilized, and ground in preparation for laboratory analysis.

Samples of individual ingredients, diets, and ileal digesta were shipped to the Experiment Station Chemical Laboratories (University of Missouri, Columbia, MO) and analyzed for DM (method 930.15; AOAC, 2019)[8], nitrogen using the combustion method in a LECO analyzer (method 990.03; AOAC, 2019)8, and AA (method 982.30 E [a, b, c]; AOAC, 2019)8. The CP was calculated as nitrogen × 6.25. Diet and ileal digesta samples were also analyzed for titanium following the method described by Myers et al.[9]. Diet samples were also analyzed for ash (method 942.05; AOAC, 2019)8, crude fiber (method 978.10; AOAC, 2019)8, and crude fat (method 920.39; AOAC, 2019)8.

[7] Kalivoda, J. R., C. K. Jones, and C. R. Stark. 2017. Impact of varying analytical methodologies on grain particle size determination. J. Anim. Sci. 95:113–119. doi:10.2527/jas.2016.0966.

[8] AOAC. 2019. Official methods of analysis of AOAC int. 21st Ed. AOAC Int., Rockville, MD.

[9] 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.

The AID and SID of CP and AA were calculated[10]. The values for the basal endogenous losses of CP and AA used to calculate SID were obtained from Adeola et al.[11].

Statistical Analyses

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC) with pig as the experimental unit. Diet was the fixed effect and pig and period were random effects. Least squares 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

The chemical analysis of CKS, SNE, SKS1, SKS2, and SCO was within expected nutrient content ranges6. However, the crude fiber content was lower than expected in SNE, SKS1, and SCO. Furthermore, SMO was lower in crude fiber content and several AA such as Arg, Ile, Leu, Phe, Trp, and most dispensable AA.

There was no evidence of differences in AID of CP, Ile, Thr, Asp, and Ser (Table 3). There was an overall grain source effect ($P \leq 0.04$) for AID of DM, Arg, His, Leu, Lys, Met, Phe, Trp, Ala, Asp, Cys, and Glu. Corn had similar AID of DM compared with all sorghum sources. However, SMO had the greatest ($P < 0.05$) AID of DM and SNE, SKS2, and SCO were poorest, with SKS1 being intermediate. Corn had increased ($P < 0.05$) AID of Arg compared with SKS1 and SKS2; however, sorghum sources did not differ. Corn had increased ($P < 0.05$) AID of His compared with all sorghum sources. Sorghum sources did not differ in AID of His. Corn had increased ($P < 0.05$) AID of Leu compared with SNE and SCO. However, sorghum sources did not differ. Corn had increased ($P < 0.05$) AID of Lys compared with SNE and SKS1, while sorghum sources did not differ in AID of Lys. Corn had increased ($P < 0.05$) AID of Met compared with all sorghum sources, with no differences detected between sorghum sources. Although there was an overall treatment effect ($P = 0.040$) for AID of Phe, mean separation did not detect any differences among individual grain sources. Corn had decreased ($P < 0.05$) AID of Trp compared with SKS1, SKS2, SCO, and SMO. For sorghum sources, SKS1 and SMO had the greatest ($P < 0.05$) AID of Trp and SNE had the poorest with SKS2 and SCO being intermediate. Corn tended to have a numerically greater ($P = 0.07$) AID of Val compared with SNE, however, it was similar to remaining sorghum sources. Although there was an overall treatment effect ($P = 0.040$) for AID of Ala, mean separation did not detect any differences among individual grain sources. Corn had increased ($P < 0.05$) AID of Cys compared with each sorghum source. There were no differences in AID of Cys between sorghum sources. Corn had increased ($P < 0.05$) AID of Glu compared with SNE and SCO; however, sorghum sources did not differ in AID of Glu. Although there was a tendency for a treatment effect ($P = 0.068$) for AID of Tyr, mean separation did not detect separation among individual grain sources.

[10] Stein, H. H., M. F. Fuller, P. J. Moughan, B. Sève, R. Mosenthin, A. J. M. Jansman, J. A. Fernández, and C. F. M. De Lange. 2007. Definition of apparent, true, and standardized ileal digestibility of amino acids in pigs. Livest. Sci. 109:282–285. doi:10.1016/j.livsci.2007.01.019.

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

There was no evidence of differences for SID of CP between any of the grain sources (Table 4). There was an overall grain source effect ($P \leq 0.005$) for SID of His, Ile, Leu, Lys, Met, Phe, Trp, Val, Ala, Cys, Glu, Ser, and Tyr. Corn tended to have a numerically greater ($P = 0.094$) SID of Arg compared with SKS2; however, it was similar to remaining sorghum sources. Corn had increased ($P < 0.05$) SID of His compared with all sorghum sources. However, sorghum sources did not differ in SID of His. Corn and SMO had increased ($P < 0.05$) SID of Ile compared with SNE, with all other sorghum sources being intermediate. Corn and SMO had increased ($P < 0.05$) SID of Leu compared with SNE and SCO with remaining sorghum sources being intermediate. Corn and SMO tended to have numerically increased ($P = 0.053$) SID of Lys compared with SNE but were similar to the remaining sources. Corn had increased ($P < 0.05$) SID of Met compared with all sorghum sources. Sorghum sourced from SMO had increased ($P < 0.05$) SID of Met compared with SCO with all other sources being intermediate. Corn had increased ($P < 0.05$) SID of Phe compared with SNE and SCO. Sorghum from SMO had increased ($P < 0.05$) SID of Phe compared with SNE with remaining sources being intermediate. SMO tended to have numerically increased ($P = 0.051$) SID of Thr compared with SNE but was similar to corn and the remaining sorghum sources. Corn had decreased ($P < 0.05$) SID of Trp compared with SKS1 and SMO. Sorghum from SMO had increased ($P < 0.05$) SID of Trp compared with SNE with SKS1, SKS2, and SCO being intermediate. Corn had increased ($P < 0.05$) SID of Val compared with SNE, SKS2, and SCO, but was similar to SKS1 and SMO. Sorghum sourced from SMO had the greatest ($P < 0.05$) SID of Val and SNE had the poorest, with the remaining sources being intermediate. Corn was similar to all sorghum sources in SID of Ala; however, SMO had increased ($P < 0.05$) SID of Ala compared with SNE and SCO, with remaining sources being intermediate. Corn and SMO tended to have numerically increased ($P = 0.062$) SID of Asp compared with SNE but were similar to the remaining sources. Corn had increased ($P < 0.05$) SID of Cys compared with SNE, SKS2, and SCO; however, sorghum sources did not differ. Corn and SMO had increased ($P < 0.05$) SID of Glu compared with SNE and SCO, with remaining sorghum sources being intermediate. Corn had increased ($P < 0.05$) SID of Ser compared with SNE but was similar to the remaining sources. Sorghum sourced from SMO had increased ($P < 0.05$) SID of Ser compared with SNE and SKS2, with SKS1 and SCO being intermediate. Corn and SMO had increased ($P < 0.05$) SID of Tyr compared with SNE and SCO, with SKS1 and SKS2 being intermediate.

The SID coefficient and total CP and AA content were used to calculate the concentration of SID CP and AA for each cereal grain. There was an overall effect ($P < 0.001$) of cereal grain on concentration of SID CP and AA (Table 5). Corn had decreased ($P < 0.05$) concentration of SID CP compared with SNE, SKS1, SKS2, and SCO. Sorghum sources SNE, SKS1, SKS2, and SCO had increased ($P < 0.05$) concentration of SID CP compared with SMO. Corn had increased ($P < 0.05$) concentration of SID Arg compared with SNE, SKS1, SKS2, and SMO. There were no differences in concentration of SID Arg between sorghum sources. Corn had increased ($P < 0.05$) concentration of SID His compared with SNE, SKS1, SCO, and SMO. Sorghum from SKS2 had increased ($P < 0.05$) concentration of SID His compared with SKS1 and SMO while SKS1 had increased ($P < 0.05$) concentration of SID His compared with SMO. Corn had decreased ($P < 0.05$) concentration of SID Ile compared with all sorghum sources. Sorghum sourced from SKS2 had the greatest ($P < 0.05$) concentration of SID Ile, and SMO had the lowest ($P < 0.05$) concentration of SID Ile, with SNE, SKS1, and SKS2 being intermediate. Corn had decreased ($P < 0.05$) concentration of SID Leu compared

with all sorghum sources except for SMO. Sorghum from SKS2 had the greatest ($P < 0.05$) concentration of SID Leu and SMO had the lowest ($P < 0.05$) concentration of SID Leu, with remaining sources being intermediate. Corn had increased ($P < 0.05$) concentration of SID Lys compared with each sorghum source. Sorghum from SKS1 had increased ($P < 0.05$) concentration of SID Lys compared with SNE and SMO, with all other sources being intermediate. Corn had increased ($P < 0.05$) concentration of SID Met compared with each sorghum source. Sorghum from SNE and SKS2 had increased ($P < 0.05$) concentration of SID Met compared with SKS1, SCO, and SMO, with SKS1 having increased ($P < 0.05$) concentration of SID Met compared with SCO and SMO, and SCO having increased ($P < 0.05$) concentration of SID Met compared with SMO. Corn had decreased ($P < 0.05$) concentration of SID Phe compared with all sorghum sources except for SMO. Sorghum sourced from SKS2 had the greatest ($P < 0.05$) concentration of SID Phe and SMO had the lowest ($P < 0.05$) concentration of SID Phe, with the remaining sources being intermediate. Corn had decreased ($P < 0.05$) concentration of SID Trp compared with all sorghum sources. Sorghum from SKS2 had the greatest ($P < 0.05$) concentrations of SID Trp while SNE had the poorest ($P < 0.05$), with all other sources being intermediate. Corn had decreased ($P < 0.05$) concentration of SID Val compared with SNE, SKS1, SKS2, and SCO, but was similar to SMO. Sorghum from SKS2 had the greatest ($P < 0.05$) concentration of SID Val and SMO had the lowest ($P < 0.05$) concentration of SID Val, with remaining sources being intermediate. Corn had decreased ($P < 0.05$) concentration of SID Ala compared with all sorghum sources. Sorghum sourced from SKS2 had the greatest ($P < 0.05$) concentration of SID Ala and SMO had the lowest ($P < 0.05$) concentration of SID Ala with SNE, SKS1, and SCO being intermediate. Corn had decreased ($P < 0.05$) concentration of SID Asp compared with SNE, SKS1, SKS2, and SCO, but was similar to SMO. Sorghum from SKS2 had the greatest ($P < 0.05$) concentration of SID Asp and SMO had the lowest ($P < 0.05$) concentration of SID Asp. Corn had increased ($P < 0.05$) concentration of SID Cys compared with SKS1 and SMO but was similar to the other sources. Sorghum from SNE, SKS2, and SCO had increased ($P < 0.05$) concentration of SID Cys compared with SKS1 and SMO. Corn had decreased ($P < 0.05$) concentration of SID Glu compared with SNE, SKS1, SKS2 and SCO, but was similar to SMO. Sorghum sourced from SKS2 had the greatest ($P < 0.05$) concentration of SID Glu, and SMO had the lowest ($P < 0.05$) concentration of SID Glu. Corn had decreased ($P < 0.05$) concentration of SID Ser compared with all sorghum sources except SMO. Sorghum from SKS2 had the greatest ($P < 0.05$) concentration of SID Ser, and SMO had the lowest ($P < 0.05$) concentration of SID Ser. Corn had decreased ($P < 0.05$) concentration of SID Tyr compared with SNE, SKS1, SKS2, and SCO but was similar compared with SMO. Sorghum sourced from SKS2 had the greatest ($P < 0.05$) concentration of SID Tyr, and SMO had the lowest ($P < 0.05$) concentration of SID Tyr.

Conclusions

The corn and most sorghum sources used in this study were generally consistent with expected proximate and AA values, apart from sorghum sources having lower fiber content and, specifically, SMO having lower AA content.

Corn exhibited increased SID Arg, His, Lys, and Met concentration, but decreased SID CP and all other AA concentration compared with sorghum sources. Digestibility coefficients varied among sorghum sources, with SNE generally having lower digestibility coefficients than the others. Across sorghum sources, concentration of SID CP and

AA values varied, with SKS2 generally having greater concentrations of SID AA. For sorghum, the reduced nutrient content of the SMO source resulted in lower concentrations of SID CP and AA. The SMO source exhibited digestibility coefficients generally greater than the other sources, indicating that differences in SID concentration were primarily driven by differences in nutrient composition rather than digestibility values. Consequently, the growing conditions of Missouri may provide lower total AA supply to pigs than other regions, but improved digestibility compared with other growing regions. This emphasizes the need for nutrient characterization of sorghum when using various sources to formulate swine diets.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Chemical composition of grain sources (as-fed basis)[1]

		Grain sorghum sources[2]				
Item, %[3]	CKS	SNE	SKS1	SKS2	SCO	SMO
DM	88.14	87.98	87.41	88.08	90.21	88.02
CP	7.62	9.35	8.87	9.81	9.36	7.14
Ether extract	3.42	2.69	3.12	2.88	3.01	2.85
Crude fiber	1.58	1.63	1.78	1.95	1.64	1.38
Ash	1.25	1.26	1.36	1.47	1.40	1.33
Indispensable AA						
Arg	0.36	0.34	0.34	0.35	0.35	0.30
His	0.22	0.23	0.20	0.23	0.22	0.18
Ile	0.27	0.38	0.36	0.40	0.38	0.29
Leu	0.89	1.25	1.15	1.34	1.22	0.89
Lys	0.27	0.22	0.23	0.24	0.24	0.21
Met	0.17	0.17	0.15	0.16	0.14	0.12
Phe	0.37	0.49	0.47	0.53	0.49	0.38
Thr	0.27	0.31	0.29	0.33	0.30	0.25
Trp	0.05	0.06	0.06	0.07	0.06	0.06
Val	0.38	0.49	0.45	0.50	0.49	0.37
Dispensable AA						
Ala	0.57	0.85	0.79	0.91	0.84	0.63
Asp	0.51	0.62	0.60	0.67	0.63	0.49
Cys	0.17	0.19	0.16	0.19	0.18	0.15
Glu	1.42	1.99	1.88	2.13	1.95	1.44
Gly	0.31	0.31	0.30	0.31	0.31	0.26
Ser	0.33	0.39	0.38	0.42	0.38	0.31
Tyr	0.24	0.30	0.28	0.31	0.29	0.23

[1] Approximately 4,000 lb of grain sorghum were collected from five separate locations of the US to represent differing grain growing conditions.

[2] Yellow corn Manhattan, KS (CKS); Sorghum Trenton, NE (SNE); Sorghum Leoti, KS (SKS1); Sorghum Fowler, KS (SKS2); Sorghum Brandon, CO (SCO); and Sorghum Montgomery City, MO (SMO).

[3] Grain sources were analyzed in duplicate at Experiment Station Chemical Laboratories (University of Missouri, Columbia, MO).

Table 2. Composition of experimental diets (as-fed basis)[1]

		Grain sorghum sources[2]				
Item, %	CKS	SNE	SKS1	SKS2	SCO	SMO
Corn	96.47	---	---	---	---	---
Sorghum	---	96.54	96.54	96.54	96.54	96.54
Monocalcium phosphate, 21% P	1.33	1.25	1.25	1.25	1.25	1.25
Calcium carbonate	0.90	0.91	0.91	0.91	0.91	0.91
Sodium chloride	0.50	0.50	0.50	0.50	0.50	0.50
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.15	0.15	0.15	0.15	0.15	0.15
Titanium dioxide	0.50	0.50	0.50	0.50	0.50	0.50
Total	100.00	100.00		100.00	100.00	100.00
Analyzed composition[3], %						
DM	88.69	88.74	87.08	88.96	90.61	87.92
CP	7.49	9.05	8.68	9.47	8.89	6.76
Ether extract	2.91	2.62	2.46	2.68	2.99	2.19
Crude fiber	1.72	1.79	2.30	1.97	1.82	1.69
Ash	3.75	3.78	4.09	4.01	4.08	3.78
Indispensable AA						
Arg	0.38	0.35	0.32	0.35	0.34	0.30
His	0.22	0.23	0.20	0.22	0.21	0.16
Ile	0.27	0.38	0.36	0.38	0.36	0.28
Leu	0.86	1.19	1.14	1.22	1.15	0.81
Lys	0.29	0.24	0.22	0.25	0.25	0.22
Met	0.18	0.17	0.14	0.16	0.14	0.11
Phe	0.37	0.49	0.46	0.50	0.47	0.35
Thr	0.28	0.32	0.29	0.32	0.31	0.25
Trp	0.06	0.07	0.08	0.07	0.08	0.07
Val	0.39	0.49	0.45	0.48	0.47	0.36
Dispensable AA						
Ala	0.55	0.82	0.78	0.85	0.80	0.57
Asp	0.53	0.61	0.59	0.64	0.63	0.46
Cys	0.17	0.18	0.16	0.17	0.17	0.13
Glu	1.41	1.93	1.87	1.97	1.85	1.32
Gly	0.32	0.31	0.28	0.31	0.30	0.26
Ser	0.34	0.39	0.36	0.40	0.37	0.29
Tyr	0.27	0.34	0.31	0.33	0.31	0.25

[1] Diets were formulated such that grain sources were the sole source of dietary protein. Sorghum sources were considered equal while all other nutrients were provided to meet recommendations for growing pigs, 110 to 165 lb (NRC, 2012)6.

[2] Yellow corn Manhattan, KS (CKS); Sorghum Trenton, NE (SNE); Sorghum Leoti, KS (SKS1); Sorghum Fowler, KS (SKS2); Sorghum Brandon, CO (SCO); and Sorghum Montgomery City, MO (SMO).

[3] Dietary treatments were analyzed in duplicate at Experiment Station Chemical Laboratories (University of Missouri, Columbia, MO)

Table 3. The AID coefficient of DM, CP, and AA in experimental diets[1]

	Grain sorghum sources[2]							
Item, %	CKS	SNE	SKS1	SKS2	SCO	SMO	SEM	*P* =
DM	77.5^{ab}	75.3^{b}	77.2^{ab}	75.1^{b}	74.4^{b}	80.1^{a}	1.09	0.001
CP	46.7	48.1	50.4	50.0	50.0	47.1	3.50	0.621
Indispensable AA								
Arg	59.9^{a}		48.3^{b}	47.4^{b}	50.8^{ab}	50.3^{ab}	4.83	0.036
His	75.4^{a}	66.2^{b}	68.3^{b}	68.4^{b}	68.3^{b}	67.1^{b}	1.42	0.001
Ile	68.6	66.9	70.1	69.5	67.5	69.2	1.33	0.161
Leu	81.2^{a}	76.5^{b}	79.8^{ab}	79.8^{ab}	77.0^{b}	79.4^{ab}	1.10	0.001
Lys	66.1^{a}	57.3^{b}	59.5^{b}	60.8^{ab}	62.0^{ab}	62.4^{ab}	2.29	0.001
Met	81.6^{a}	72.2^{b}	73.3^{b}	73.7^{b}	70.1^{b}	73.0^{b}	1.36	0.001
Phe[†]	74.3	70.7	74.2	74.3	71.6	73.7	1.36	0.040
Thr	55.0	52.9	55.9	56.2	56.8	56.8	2.28	0.541
Trp	74.4^{c}		81.5^{a}	79.6^{ab}	80.5^{ab}	81.4^{a}	1.19	0.001
Val	72.6^{x}	68.7^{y}	71.7^{xy}	70.9^{xy}	70.0^{xy}	71.1^{xy}	1.21	0.070
Dispensable AA								
Ala[†]	70.1	69.9	72.9	73.2	70.5	72.4	1.51	0.038
Asp	62.6	59.1	63.0	63.1	63.1	61.1	1.88	0.188
Cys	70.6^{a}	62.2^{b}	65.2^{b}	64.3^{b}	65.1^{b}	62.8^{b}	1.57	0.001
Glu	79.2^{a}	75.1^{b}	78.2^{ab}	77.8^{ab}	75.4^{b}	77.4^{ab}	1.12	0.003
Ser	68.2	65.8	68.2	68.3	67.4	66.9	1.84	0.493
Tyr[‡]	72.0	68.3	71.5	70.8	68.5	71.4	1.52	0.068

[a-c] Means within a row lacking a common superscript are different (P < 0.05).

[x-y] Means within a row lacking a common superscript tended to differ (P < 0.10).

[1] Effect of grain source location on AID of CP and AA (n = 12).

[2] Yellow corn Manhattan, KS (CKS); Sorghum Trenton, NE (SNE); Sorghum Leoti, KS (SKS1); Sorghum Fowler, KS (SKS2); Sorghum Brandon, CO (SCO); and Sorghum Montgomery City, MO (SMO).

[†] Overall treatment effect detected (P < 0.05); however, pairwise comparisons were not significant after Tukey adjustment.

[‡] A tendency for an overall treatment effect was detected (P < 0.10); however, pairwise comparisons were not significant after Tukey adjustment.

Table 4. The SID of CP and AA in experimental diets[1]

		Grain sorghum sources[2]						
Item, %	CKS	SNE	SKS1	SKS2	SCO	SMO	SEM	*P* =
CP	67.2	65.0	67.7	66.3	67.6	69.6	3.50	0.691
Indispensable AA								
Arg	74.1^{x}	65.7^{xy}	64.6^{xy}	62.7^{y}	66.7^{xy}	68.2^{xy}	4.83	0.094
His	83.7^{a}	74.1^{b}	77.3^{b}	76.7^{b}	76.9^{b}	78.1^{b}	1.44	0.001
Ile	78.4^{a}	74.0^{b}	77.5^{ab}	76.5^{ab}	75.1^{ab}	78.8^{a}	1.33	0.005
Leu	86.4^{a}	80.2^{c}	83.7^{ab}	83.5^{abc}	80.9^{bc}	84.9^{a}	1.10	0.001
Lys	78.5^{x}	72.0^{y}	75.7^{xy}	75.0^{xy}	76.8^{xy}	78.8^{x}	2.29	0.053
Met	86.6^{a}	77.5^{bc}	79.5^{bc}	79.4^{bc}	76.5^{c}	81.0^{b}	1.36	0.001
Phe	81.6^{a}	76.2^{c}	79.8^{abc}	79.7^{abc}	77.5^{bc}	81.2^{ab}	1.36	0.002
Thr	70.9^{xy}	67.0^{y}	71.2^{xy}	70.4^{xy}	71.7^{xy}	74.8^{x}	2.28	0.051
Trp	89.2^{c}	89.7^{bc}	93.1^{ab}	92.4^{abc}	92.6^{abc}	94.9^{a}	1.19	0.001
Val	84.1^{a}	77.8^{c}	81.4^{abc}	80.1^{bc}	79.7^{bc}	83.3^{ab}	1.21	0.001
Dispensable AA								
Ala	79.7^{ab}	76.4^{b}	79.6^{ab}	79.5^{ab}	77.3^{b}	81.6^{a}	1.51	0.005
Asp	75.9^{x}	70.9^{y}	74.9^{xy}	74.3^{xy}	74.7^{xy}	76.4^{x}	1.88	0.062
Cys	81.0^{a}	72.1^{b}	76.5^{ab}	74.8^{b}	75.7^{b}	76.9^{ab}	1.57	0.001
Glu	84.9^{a}	79.2^{b}	82.4^{ab}	81.9^{ab}	79.8^{b}	83.4^{a}	1.12	0.001
Ser	86.7^{ab}	82.0^{c}	85.1^{abc}	84.1^{bc}	84.4^{abc}	88.5^{a}	1.84	0.001
Tyr	85.4^{a}	78.9^{b}	82.7^{ab}	81.6^{ab}	80.2^{b}	85.7^{a}	1.52	0.001

$^{a-c}$ Means within a row lacking a common superscript are different (P < 0.05).

$^{x-y}$ Means within a row lacking a common superscript tended to differ (P < 0.10).

[1] Effect of grain source location on SID of CP and AA (n = 12).

[2] Yellow corn Manhattan, KS (CKS); Sorghum Trenton, NE (SNE); Sorghum Leoti, KS (SKS1); Sorghum Fowler, KS (SKS2); Sorghum Brandon, CO (SCO); and Sorghum Montgomery City, MO (SMO).

Table 5. The SID concentration of CP and AA in experimental diets[1]

		Grain sorghum sources[2]						
Item, %	CKS	SNE	SKS1	SKS2	SCO	SMO	SEM	*P*, <
CP	5.106^{b}	6.081^{a}	6.011^{a}	6.505^{a}	6.345^{a}	4.947^{b}	0.3087	0.001
Indispensable AA								
Arg	0.267^{a}	0.223^{b}	0.219^{b}	0.219^{b}	0.234^{ab}	0.204^{b}	0.0165	0.001
His	0.184^{a}	0.171^{b}	0.155^{c}	0.176^{ab}	0.169^{b}	0.141^{d}	0.0030	0.001
Ile	0.208^{d}	0.281^{b}	0.279^{b}	0.306^{a}	0.285^{b}	0.228^{c}	0.0050	0.001
Leu	0.767^{d}	1.003^{b}	0.962^{c}	1.119^{a}	0.988^{bc}	0.754^{d}	0.0125	0.001
Lys	0.212^{a}	0.159^{d}	0.174^{bc}	0.180^{bc}	0.184^{b}	0.165^{cd}	0.0053	0.001
Met	0.147^{a}	0.137^{b}	0.119^{c}	0.127^{b}	0.107^{d}	0.097^{e}	0.0020	0.001
Phe	0.302^{c}	0.373^{b}	0.375^{b}	0.422^{a}	0.380^{b}	0.308^{c}	0.0062	0.001
Thr	0.191^{cd}	0.208^{bc}	0.206^{bc}	0.233^{a}	0.215^{ab}	0.187^{d}	0.0067	0.001
Trp	0.045^{d}	0.054^{c}	0.056^{bc}	0.064^{a}	0.056^{bc}	0.057^{b}	0.0007	0.001
Val	0.315^{d}	0.381^{bc}	0.367^{c}	0.401^{a}	0.390^{ab}	0.308^{d}	0.0059	0.001
Dispensable AA								
Ala	0.454^{d}	0.650^{b}	0.629^{b}	0.723^{a}	0.650^{b}	0.513^{c}	0.0115	0.001
Asp	0.387^{c}	0.440^{b}	0.450^{b}	0.500^{a}	0.471^{ab}	0.373^{c}	0.0111	0.001
Cys	0.138^{a}	0.137^{a}	0.123^{b}	0.142^{a}	0.136^{a}	0.115^{b}	0.0027	0.001
Glu	1.205^{c}	1.577^{b}	1.548^{b}	1.745^{a}	1.556^{b}	1.120^{c}	0.0198	0.001
Ser	0.286^{c}	0.320^{b}	0.323^{b}	0.354^{a}	0.321^{b}	0.274^{c}	0.0069	0.001
Tyr	0.205^{c}	0.237^{b}	0.232^{b}	0.253^{a}	0.233^{b}	0.197^{c}	0.0042	0.001

$^{a-e}$ Means within a row lacking a common superscript letter are different (P < 0.05).

[1] Effect of grain source location on SID concentration of CP and AA (n = 12). Values for SID concentration were calculated by multiplying the analyzed CP and AA content by the determined SID coefficient.

[2] Yellow corn Manhattan, KS (CKS); Sorghum Trenton, NE (SNE); Sorghum Leoti, KS (SKS1); Sorghum Fowler, KS (SKS2); Sorghum Brandon, CO (SCO); and Sorghum Montgomery City, MO (SMO).