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Summary

A total of 1,080 pigs (PIC 337 × 1050; initially 58.4 ± 1.26 lb) were used in this 121-d experiment to determine the effects of added soybean meal (SBM) versus using an amino acid (AA) adjustment in diets with dried distillers grains with solubles (DDGS) on growth performance and carcass characteristics. Pens were randomly assigned to 1 of 4 dietary treatments in a completely randomized design. There were 27 pigs per pen and 10 replications per treatment. Treatments diets consisted of: 1) a control diet containing high SBM with no DDGS; 2) DDGS-based diet with a medium level of SBM; 3) DDGS-based diet with low SBM + Val, Ile, and Trp to equal levels as in diet 2; and 4) Treatment 3 but without the Val, Ile, and Trp adjustment (still meeting requirement estimates for all AA). Overall, from d 0 to 83, pigs fed the DDGS-based diets had decreased ADG ($P = 0.014$) compared to pigs fed the control diet. There was an improvement ($P < 0.05$) in feed efficiency for pigs fed the high SBM diet without DDGS as compared to pigs fed diets including DDGS and low levels of SBM with no AA adjustment, with the other two treatments intermediate. There was a tendency ($P = 0.074$) for a treatment difference in HCW between treatments. Pigs fed the high SBM diet without DDGS had increased HCW ($P = 0.018$) compared to pigs fed the three diets containing DDGS. There were no differences between treatments for percentage lean, loin depth, or backfat ($P > 0.10$). In conclusion, pigs fed diets containing no DDGS and higher levels of SBM had improved growth performance and HCW compared with pigs fed DDGS-based diets. When feeding diets containing DDGS, pigs fed without the AA adjustment had poorer overall feed efficiency ($P < 0.05$) than those fed the control diet with pigs fed the other two diets intermediate, showing the importance of the AA adjustment in maintaining performance.

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Introduction

It has been summarized that up to 30% DDGS can be fed without negative effects on pig performance.[2] However, feeding DDGS at an excessive inclusion rate can impair performance and carcass quality compared to corn-SBM-based diets.[2] A factor that could explain these discrepancies is differences in BCAA and/or Trp relationships in finishing pig diets.[3] Currently, DDGS and feed-grade amino acids are common replacements for SBM in swine diets. However, there is some speculation that branch chain amino acids (Val, Ile, and Leu; BCAA) and Trp (a large neutral amino acid) from SBM could be better utilized, are more economical, and will lead to increased pig performance compared to synthetic BCAAs, Trp, and DDGS.[4,5] Understanding if pigs' growth performance and carcass characteristics are comparable to those of pigs fed diets without DDGS and a high inclusion of SBM is thus warranted. Therefore, the objective of this study was to determine the difference in contribution of Val, Ile, and Trp from SBM versus feed-grade amino acids and DDGS on finishing pig performance and carcass characteristics.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research-finishing site in southwest Minnesota. The barn was mechanically ventilated and double-curtain-sided. Each pen was equipped with a 5-hole stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water. Pigs were provided 6.7 ft^2 of floor space per pig until 265 lb and then 7.9 ft^2 until the remaining pigs were marketed.

Animals and diets

A total of 1,080 pigs (PIC 337 × 1050; initially 58.4 ± 1.26 lb) were used in this 121-d experiment. Pens were randomly assigned to 1 of 4 dietary treatments in a completely randomized design. There were 27 pigs per pen and 10 replications per treatment. Treatments consisted of: 1) A control diet containing high SBM with no DDGS; 2) DDGS-based diet with a medium level of SBM; 3) DDGS-based diet with low SBM + (Val, Ile, and Trp) to equal levels in diet 2; and 4) Treatment 3 but without the Val, Ile, and Trp adjustment (still meeting requirement estimates for all AA). The AA adjustment more specifically included additional Val, Ile and Trp so that the individual AA ratios for Val:Lys, Ile:Lys, and Trp:Lys within treatment 3 (DDGS + low SBM) matched those of the medium SBM diet (Treatment 2) and the Ile+Val+Trp:Leu ratio was equal to that of the high SBM diet (control diet). Diets were formulated

[2] Stein, H. H and G. C. Shurson. 2009. Board-invited review: The use and application of distillers dried grains with solubles in swine diets, J Anim. Sci. 87(4):1292–1303. doi:10.2527/jas.2008-1290.

[3] Cemin, H. S., Tokach, M. D., Dritz, S. S., Woodworth, J. C., DeRouchey, J. M., & Goodband, R. D. 2019. Meta-regression analysis to predict the influence of branched-chain and large neutral amino acids on growth performance of pigs. J. Anim. Sci. *97*(6), 2505-2514.

[4] Eugenio, F. A., van Milgen, J., Duperray, J., Sergheraert, R., & Le Floc'h, N. 2023. Feeding pigs amino acids as protein-bound or in free form influences postprandial concentrations of amino acids, metabolites, and insulin. Animal. *17*(1), 100684. https://doi.org/10.1016/j.animal.2022.100684.

[5] Yen, J. T., B. J. Kerr, R. A. Easter, A. M. Parkhurst. 2004. Difference in rates of net portal absorption between crystalline and protein-bound lysine and threonine in growing pigs fed once daily, J. Anim. Sci. 82(4): 1079–1090. doi.10.2527/2004.8241079x.

using NRC (2012)[6] nutrient values for the ingredients and SID coefficients. Dietary treatments were fed in 4 phases. Phase 1 was fed from 60 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 to approximately 300 lb. All diets were fed in meal form and manufactured at the New Horizon Farms Feed Mill in Pipestone, MN. All diets were formulated to meet or exceed NRC (2012) requirement estimates for all nutrients. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) able to record feed amounts for individual pens. Complete diet samples were taken during each finishing phase and stored at -40°F until they were submitted for analysis of DM, CP, Ca, and P (Midwest Laboratories, Omaha, NE).

Pigs were weighed approximately every 14 days to determine ADG, ADFI, and F/G. On d 99, the 4 heaviest pigs in each pen were selected and marketed. These pigs were included in growth performance data but not in the final pen carcass data. On the last day of the trial, final pen weights were obtained, and the remaining pigs were tattooed with a pen identification number and transported to a U.S. Department of Agriculture-inspected packing plant (JBS Swift, Worthington, MN) for carcass data collection. Carcass measurements included HCW, loin depth, backfat, and percentage lean. Percentage lean was calculated from a plant proprietary equation. Carcass yield was calculated by dividing the pen average HCW by the pen average final live weight obtained at the farm.

Statistical analysis

Data were analyzed as a completely randomized design for one-way ANOVA using the lmer function from the lme4 package in R (version 3.5.2 (02-07-2018) with pen as the experimental unit and treatment considered the fixed effect for all performance criteria. Lean percentage, loin depth, and backfat depth considered HCW as a covariate in the model, and data were analyzed at a pen level. Besides comparing individual treatments, a contrast was used to compare the response to the control diet to the mean of the three diets containing DDGS. A Tukey multiple comparison adjustment was used to control Type I error rate. All results were considered significant with P-values ≤ 0.05 and considered marginally significant with P-values > 0.05 and ≤ 0.10.

Results and Discussion

During the grower phase, d 0 to 56, pigs fed high SBM diets with no DDGS had increased ADG ($P = 0.001$) and F/G ($P = 0.001$) compared to those fed diets containing DDGS (Table 5). On d 56, pigs fed high levels of SBM without DDGS had increased BW ($P < 0.05$) compared to pigs fed low levels of SBM with no additional AA, with pigs fed the other two treatments intermediate. However, during the finisher phase, d 56 to 121, there were no significant differences observed on any performance criteria ($P > 0.10$).

Overall, pigs fed DDGS-based diets had decreased ADG ($P = 0.014$) compared to pigs fed the corn-SBM control diet. Pigs fed the high SBM diet without DDGS had increased F/G ($P < 0.05$) compared to pigs fed low levels of SBM and no AA adjustment, with pigs fed the other two diets intermediate.

[6] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

For carcass characteristics, there was a tendency ($P = 0.074$) for a difference in HCW between treatments. Pigs fed the high SBM diet without DDGS had increased HCW ($P = 0.018$) compared to pigs fed diets containing DDGS. There were no statistically significant ($P > 0.10$) differences between treatment in any of the other carcass traits.

In summary, pigs fed diets containing no DDGS and higher levels of SBM had improved growth performance and HCW compared with pigs fed DDGS-based diets. When feeding diets containing DDGS, pigs fed without the AA adjustment had poorer overall feed efficiency ($P < 0.05$) than those fed the control diet with pigs fed the other two diets intermediate, showing the importance of the AA adjustment in maintaining performance. Diets containing DDGS with a medium level of SBM had slightly higher Leu:Lys ratios than the low SBM diets, which could help to explain the decreases in growth performance for this treatment.

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

SBM level:	High	Medium	Low	Low
Item, % AA adjustment:	No	No	Yes	No
Corn	61.03	44.24	49.15	49.38
Soybean meal	35.26	27.15	21.53	21.51
DDGS	--	25.00	25.00	25.00
Choice white grease	1.00	1.00	1.00	1.00
Monocalcium phosphate	0.50	--	0.05	0.05
Calcium carbonate	1.15	1.45	1.48	1.48
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine, 55%	0.29	0.47	0.72	0.72
DL-Met	0.07	--	0.06	0.06
L-Trp	--	0.02	0.05	0.04
L-Val	--	--	0.10	--
L-Ile	--	--	0.10	--
Thr[2]	0.05	0.03	0.13	0.13
Phytase[3]	0.05	0.05	0.05	0.05
Vitamin-trace mineral premix	0.10	0.10	0.10	0.10
Total, %	100	100	100	100
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lys	1.20	1.20	1.20	1.20
Ile:Lys	68	68	68	60
Leu:Lys	136	158	147	147
Met:Lys	31	29	31	31
Met and Cys:Lys	56	56	56	56
Thr:Lys	61	61	61	61
Trp:Lys	20.1	20.1	20.1	19.0
Val:Lys	73	77	77	69
His:Lys	44	46	41	41
Total Lys, %	1.35	1.41	1.40	1.40
NE, kcal/lb	1,205	1,149	1,150	1,148
SID Lys:NE, g/Mcal	4.52	4.74	4.73	4.74
STTD P, %	0.39	0.39	0.39	0.39
Chemical analysis, %				
DM	86.65	87.32	87.58	86.87
CP[4]	21.90	22.70	21.70	20.80
Ca	0.55	0.73	0.78	0.60
P	0.38	0.48	0.48	0.42

[1]Phase 1 was fed from approximately 50 to 100 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huevepharma, Sofia, Bulgaria) was included at 1,251 FTU/kg providing an estimated release of 0.15% STTD P.
[4]CP = crude protein.

Table 2. Diet composition (as-fed basis) Phase 2[1]

SBM level:	High	Medium	Low	Low
Item, % AA adjustment:	No	No	Yes	No
Corn	69.66	52.39	80.37	79.23
Soybean meal	26.68	19.07	17.24	17.32
DDGS	--	25.00	25.00	25.00
Choice white grease	1.00	1.00	1.00	1.00
Monocalcium phosphate	0.55	0.05	0.10	0.10
Calcium carbonate	1.08	1.38	1.40	1.40
Sodium chloride	0.05	0.05	0.05	0.05
Liquid lysine, 55%	0.29	0.44	0.66	0.66
DL-Met	0.05	--	0.02	0.02
L-Trp	--	0.02	0.05	0.04
L-Val	--	--	0.08	--
L-Ile	--	--	0.08	--
Thr[2]	0.05	0.01	0.10	0.10
Phytase[3]	0.05	0.05	0.05	0.05
Vitamin-trace mineral premix	0.10	0.10	0.10	0.10
Total, %	100	100	100	100
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lys	0.99	0.99	0.99	0.99
Ile:Lys	68	68	68	60
Leu:Lys	145	172	160	161
Met:Lys	32	31	30	30
Met and Cys:Lys	58	61	58	58
Thr:Lys	62	62	62	62
Trp:Lys	19.6	19.5	19.8	18.8
Val:Lys	74	80	80	72
His:Lys	45	48	43	43
Total Lys, %	1.12	1.18	1.17	1.17
NE, kcal/lb	1,205	1,149	1,150	1,148
SID Lys:NE, g/Mcal	3.73	3.91	3.91	3.91
STTD P, %	0.38	0.38	0.38	0.38
Chemical analysis, %				
DM	86.65	87.39	87.50	87.68
CP[4]	20.80	22.70	20.70	21.60
Ca	0.59	0.50	0.63	0.73
P	0.38	0.48	0.46	0.47

[1]Phase 2 was fed from approximately 100 to 160 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huevepharma, Sofia, Bulgaria) was included at 1,251 FTU/kg providing an estimated release of 0.15% STTD P.
[4]CP = crude protein.

Table 3. Diet composition (as-fed basis) Phase 3[1]

SBM level:	High	Medium	Low	Low
Item, % AA adjustment:	**No**	**No**	**Yes**	**No**
Corn	75.68	62.23	65.89	66.08
Soybean meal	20.93	14.46	10.27	10.26
DDGS	--	20.00	20.00	20.00
Choice white grease	1.00	1.00	1.00	1.00
Monocalcium phosphate	0.45	--	0.05	0.05
Calcium carbonate	0.98	1.25	1.28	1.28
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine, 55%	0.25	0.39	0.58	0.58
DL-Met	0.03	--	--	--
L-Trp	0.02	0.03	0.06	0.03
L-Val	--	--	0.08	--
L-Ile	--	--	0.08	--
Thr[2]	0.05	0.02	0.10	0.10
Phytase[3]	0.03	0.03	0.03	0.03
Vitamin-trace mineral premix	0.10	0.10	0.10	0.10
Total, %	100	100	100	100
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lys	0.83	0.83	0.83	0.83
Ile:Lys	69	69	69	60
Leu:Lys	157	182	170	170
Met:Lys	32	33	30	31
Met and Cys:Lys	60	64	60	60
Thr:Lys	64	64	64	64
Trp:Lys	21.3	21.4	21.5	18.6
Val:Lys	77	82	82	74
His:Lys	47	49	45	45
Total Lys, %	0.95	0.99	0.98	0.98
NE, kcal/lb	1,207	1,163	1,164	1,162
SID Lys:NE, g/Mcal	3.12	3.24	3.24	3.24
STTD P, %	0.32	0.32	0.32	0.32
Chemical analysis, %				
DM	85.14	85.45	85.40	85.17
CP[4]	16.10	19.70	19.00	18.90
Ca	0.53	0.57	0.56	0.64
P	0.42	0.45	0.42	0.43

[1]Phase 3 was fed from approximately 160 to 220 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huevepharma, Sofia, Bulgaria) was included at 626 FTU/kg providing an estimated release of 0.12% STTD P.
[4]CP = crude protein.

Table 4. Diet composition (as-fed basis) Phase 4[1]

SBM level:	High	Medium	Low	Low
Item, % AA adjustment:	**No**	**No**	**Yes**	**No**
Corn	77.65	67.00	72.92	73.19
Soybean meal	19.63	14.96	8.36	8.34
DDGS	--	15.00	15.00	15.00
Choice white grease	1.00	1.00	1.00	1.00
Monocalcium phosphate	0.35	--	0.10	0.13
Calcium carbonate	0.93	1.15	1.15	1.15
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine, 55%	0.14	0.24	0.54	0.54
DL-Met	--	--	0.02	0.02
L-Trp	--	0.01	0.05	0.03
L-Val	0.03	--	0.11	--
L-Ile	0.14	--	0.12	--
Thr[2]	0.03	0.01	0.12	0.12
Phytase[3]	0.03	0.03	0.03	0.03
Vitamin-trace mineral premix	0.10	0.10	0.10	0.10
Total, %	100	100	100	100
Calculated analysis				
Standard ileal digestible (SID) amino acids, %				
Lys	0.74	0.74	0.74	0.74
Ile:Lys	75	75	75	60
Leu:Lys	172	194	172	172
Met:Lys	31	35	33	33
Met and Cys:Lys	63	69	63	63
Thr:Lys	67	67	67	67
Trp:Lys	21.0	21.0	21.3	18.7
Val:Lys	84	88	88	74
His:Lys	51	54	45	45
Total Lys, %	0.85	0.89	0.87	0.87
NE, kcal/lb	1,209	1,176	1,117	1,174
SID Lys:NE, g/Mcal	2.78	2.85	2.85	2.86
STTD P, %	0.30	0.30	0.30	0.29
Chemical analysis, %				
DM	86.28	85.88	86.00	85.48
CP[4]	12.50	17.80	13.80	14.50
Ca	0.58	0.62	0.56	0.59
P	0.36	0.34	0.33	0.36

[1]Phase 4 was fed from approximately 220 to 300 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huevepharma, Sofia, Bulgaria) was included at 626 FTU/kg providing an estimated release of 0.12% STTD P.
[4]CP = crude protein.

Table 5. Effects of SBM levels and AA adjustment in diets with or without DDGS on finishing pig performance and carcass characteristics[1]

SBM Level[2]:	High	Medium	Low	Low			
AA Adjustment[3]:	No	No	Yes	No		*P* =	
DDGS[4]:	No	Yes	Yes	Yes	SEM	Treatment	Control vs. DDGS[5]
BW, lb							
d 0	58.4	58.4	58.5	58.4	1.26	0.999	0.977
d 56	170.7[a]	163.9[ab]	164.4[ab]	162.2[b]	2.20	0.050	0.007
d 121	305.8	297.7	302.8	297.8	2.65	0.100	0.044
Grower (d 0-56)							
ADG, lb	2.00[a]	1.86[b]	1.86[b]	1.84[b]	0.029	0.001	< 0.001
ADFI, lb	4.29	4.16	4.15	4.16	0.058	0.264	0.050
F/G	2.15[b]	2.23[a]	2.23[a]	2.27[a]	0.020	0.001	< 0.001
Finisher (d 56-121)							
ADG, lb	2.14	2.12	2.19	2.17	0.024	0.189	0.409
ADFI, lb	6.89	6.91	7.06	7.08	0.073	0.167	0.143
F/G	3.23	3.26	3.22	3.27	0.034	0.717	0.586
Overall (d 0 to 121)							
ADG, lb	2.07	1.99	2.03	2.01	0.020	0.060	0.014
ADFI, lb	5.63	5.57	5.64	5.66	0.057	0.716	0.859
F/G	2.72[b]	2.79[ab]	2.78[ab]	2.82[a]	0.023	0.031	0.007
Carcass characteristics[6]							
HCW, lb	227.9	220.8	224.0	221.5	2.03	0.074	0.018
Carcass yield, %	73.3	73.0	73.2	73.1	0.003	0.940	0.639
Lean, %	56.24	56.34	56.03	56.19	0.222	0.788	0.853
Loin depth, in.	2.63	2.58	2.56	2.60	0.025	0.187	0.066
Back fat depth, in.	0.69	0.67	0.69	0.68	0.012	0.749	0.584

[a-c]Means within row with different superscripts differ ($P < 0.05$).
[1]A total of 1,080 pigs (initial BW 58.4 of ± 1.26 lb) were used in a 121-d finisher trial with 27 pigs per pen and 10 pens per treatment.
[2]SBM levels ranged from 21.51 (low) to 35.26% (high) in phase 1, 17.24 to 26.68% in phase 2, 10.26 to 20.93% in phase 3, and 8.34 to 19.63% in phase 4.
[3] The AA adjustment more specifically included adding additional Val, Ile, and Trp so that the individual AA ratios for Val:Lys, Ile:Lys, and Trp:Lys within treatment 3 (DDGS + low SBM) matched those of the medium SBM diet and the Ile+Val+Trp:Leu ratio was equal to that of the high SBM diet.
[4]DDGS included in medium and low SBM diets at 25% in phases 1 and 2, 20% in phase 3, and 15% in phase 4.
[5]Contrast comparing the response of pigs fed diets without DDGS compared to the mean of the response of pigs fed diets with DDGS.
[6]In the analysis for backfat depth, lean, and loin, HCW was used as a covariate in the model.