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Comparing tryptophan:lysine ratios in dried distillers grains with solubles-based diets with and without a dried distillers grains with solubles withdrawal strategy on growth, carcass characteristics, and carcass fat iodine value of growing-finishing pigs

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Abstract

A total of 6,240 finishing pigs (DNA 600 × PIC 1050; initially 22.5 ± 1.00 kg), divided into two groups, were used in a 119 or 120 d study comparing increasing Trp:Lys ratio in diets containing dried distillers grains with solubles (DDGS) or a DDGS withdrawal strategy (removing all DDGS from the last phase before marketing) on growth performance and carcass fat iodine value (IV). Pigs were randomly allotted to one of seven dietary treatments with 30 to 36 pigs per pen and 26 replications per treatment. Diets were fed in four phases, approximately 23 to 44, 44 to 71, 71 to 100, and 100 kg to market. Diets included a control corn–soybean meal-based diet (no DDGS) formulated to a 19% standardized ileal digestibility (SID) Trp:Lys ratio, four diets with 30% DDGS fed in all four phases and formulated to provide SID Trp:Lys ratios of 16%, 19%, 22%, or 25%, and two DDGS withdrawal strategy diets: 19% SID Trp:Lys with 30% DDGS in phases 1 through 3 and then 0% DDGS in phase 4 with either a 19% or 25% Trp:Lys ratio. Overall, body weight (BW), average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (G:F) increased (linear, $P < 0.05$) as SID Trp:Lys ratio increased in diets with 30% DDGS fed in all phases. Simultaneously, hot carcass weight (quadratic, $P = 0.014$), carcass yield (quadratic, $P = 0.012$), and backfat depth (linear, $P = 0.040$) increased with increasing Trp:Lys ratio. Pigs fed the 19% SID Trp:Lys ratio withdrawal strategy diet had similar ADG and ADFI as those fed the control diet, the 25% Trp:Lys withdrawal diet, or the 30% DDGS diets with 25% Trp:Lys ratio throughout the study. Pigs fed the control diet had decreased ($P < 0.05$) carcass fat IV compared to pigs fed the DDGS diets throughout the study, with pigs fed the two DDGS withdrawal strategy diets intermediate. In summary, increasing the SID Trp:Lys ratio in diets with 30% DDGS resulted in a linear increase in ADG, ADFI, G:F, and BW but did not influence carcass fat IV, with most of the benefits observed as diets increased from 16% to 19% Trp:Lys. Removing DDGS from the diet in the last period reduced carcass fat IV and increased growth rate during the withdrawal period compared to pigs fed with 30% DDGS throughout, indicating value in a withdrawal strategy.

Lay Summary

Feeding high levels of dried distillers grains with solubles (DDGS) up to marketing has been found to have negative impacts on growth performance and carcass characteristics of finishing pigs, specifically carcass yield. High inclusion of DDGS has also been shown to increase iodine value (IV), a measurement of fat quality, due to increased deposition of unsaturated fatty acids. However, recent data suggested that when feeding finishing pigs diets containing DDGS, increasing the standardized ileal digestible Trp:Lys ratio well above the NRC requirement estimates can prevent or lessen some of these negative effects. This study compared removing DDGS from the final dietary phase with two levels of Trp:Lys ratio, commonly referred to as a withdrawal strategy, to increasing levels of Trp:Lys in diets containing 30% DDGS. The results of this study indicate that increasing the Trp:Lys ratio in diets containing DDGS to a 25% Trp:Lys ratio resulted in growth performance similar to the control diet and the withdrawal strategy, with most of the benefits observed when Trp:Lys is increased from a deficient to adequate status. However, feeding diets with DDGS up to market resulted in increased IV.

Key words: carcass characteristics, dried distillers grains with solubles, grow-finish pigs, lysine, tryptophan

Abbreviations: AA, amino acids; ADFI, average daily feed intake; ADG, average daily gain; BW, body weight; CP, crude protein; DDGS, dried distillers grains with solubles; HCW, hot carcass weight; IV, iodine value; LNAA, large neutral amino acids; NDF, neutral detergent fiber; NE, net energy; SID, standardized ileal digestibility

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Introduction

The effect of including dried distillers grains with solubles (DDGS) in swine diets has been evaluated since the 1940s (Fairbanks et al. 1944, 1945). DDGS have a higher fiber content and lower energy digestibility compared to corn (Stein and Shurson, 2009). Meloche et al. (2013) reported that the fat content of DDGS has decreased by 2% to 6% from the reported value of 10% by Stein and Shurson (2009) due to advancements in biorefining technologies and marketing of corn oil. Multiple studies have demonstrated that 30% DDGS can be included in grow-finish diets without negative effects on growth performance (Stein and Shurson, 2009; Rojo et al., 2016); however, the results have been inconsistent. Linneen et al. (2008) observed negative effects on growth performance at DDGS levels as low as 10% to 15% and Jacela et al. (2011) at levels at or above 20%. These differences can be attributed in part due to variations in the nutritional profile of DDGS because of different manufacturing processes (Belyea et al., 2004; Fantini et al., 2021).

Reductions in carcass yield when DDGS are included in diets are commonly observed due to the increased neutral detergent fiber (NDF) content leading to increased gut fill and weight of the intestinal tract (Coble et al., 2018; Soto et al., 2019; Agyekum et al., 2012). Fiber withdrawal strategies are defined as the replacement of high-fiber ingredients in finishing pig diets with low-fiber ingredients for a certain amount of time before marketing with the goal of reducing gut fill and improving carcass yield (Gonçalves et al., 2018). DDGS withdrawal strategies are commonly implemented in finishing diets to prevent negative impacts on iodine value (IV), belly firmness, and carcass yield (Xu et al., 2010). Fiber withdrawal strategies have been found to be effective from as short as 5 to 10 d (Asmus et al., 2014, Coble et al., 2018), whereas Gaines et al. (2007) observed that a 6-wk withdrawal period was needed to recover carcass yield losses due to high-fiber diets. However, diets containing DDGS or other sources of fiber are often less expensive than corn–soybean meal diets and consequently, a fiber withdrawal strategy will normally result in more expensive diets being fed.

Tryptophan is an essential amino acid (AA) that is the second or third limiting AA in swine diets (Guzik et al., 2002). Tryptophan is a precursor for serotonin, which is a neuromodulator that regulates appetite, sleep, and stress (Wolf, 1974;Sève, 1999). DDGS have lower concentrations of Trp than soybean meal and since the DDGS partially replaces soybean meal in formulations, a higher level of synthetic Trp needs to be included to meet the pig's requirement (Naatjes et al., 2014; Gonçalves et al., 2018). Corn DDGS are three times higher in crude protein (CP) compared to corn, leading to a greater concentration of large neutral amino acids (LNAA; Salyer et al., 2013). LNAA compete with Trp for transport into the brain (Leathwood, 1987), suggesting a need for higher Trp levels in diets containing DDGS. Data have suggested that increasing dietary Trp concentrations to levels greater than the pig's current estimated requirement for growth can improve carcass yield and hot carcass weight (HCW; Nitikanchana, 2013; Salyer et al., 2013). Nitikanchana (2013) observed that increasing standardized ileal digestibility (SID) Trp:Lys from 16.5% to 20% increased carcass yield when DDGS were included in the diet at 20% or 40% all the way to marketing. Salyer et al. (2013) observed a linear improvement in HCW in pigs fed with SID Trp:Lys levels from 15% to 19.5% in diets with 30% DDGS. These improvements in carcass characteristics in pigs fed with diet containing DDGS suggest that increasing the Trp:Lys ratio in diets with DDGS could replace a DDGS withdrawal strategy by preventing some of the negative effect commonly seen when feeding DDGS up to market. However, no research has been conducted comparing high SID Trp:Lys ratios in diets with DDGS to a DDGS withdrawal strategy.

If a high SID Trp:Lys ratio can reduce or prevent carcass yield losses from feeding diets containing DDGS, then DDGS could be fed in grow-finish diets up to market, potentially reducing production costs. Therefore, the objective of this study was to determine the impact of feeding increasing SID Trp:Lys ratios in diets containing DDGS compared to withdrawal strategy on growth performance, carcass composition, and carcass fat IV in grow-finish pigs to determine if feeding increased Trp:Lys ratios could replace a withdrawal strategy. We hypothesized that increasing the Trp:Lys ratio in diets containing 30% DDGS all the way to market would improve carcass yield and HCW to levels equal to pigs fed a DDGS withdrawal strategy.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The trial was conducted at a commercial research finishing facility in Missouri (JBS, Fortuna, MO, USA). The barn was curtain-sided, and tunnel ventilated with a fully slatted concrete floor and deep-pit manure storage. Pens were 7.0 m × 3.6 m. Each pen was equipped with a one-sided wet-dry self-feeder to provide a minimum of 3.8 linear cm of feeder space per pig for ad libitum access to feed and water. Feed was delivered by a feeding system (DryExact Pro, Big Dutchman, Holland, MI, USA) that recorded daily feed additions.

Animals and diets

Two groups of finishing pigs totaling 6,240 pigs (DNA 600 × PIC 1050; initially 22.5 ± 1.01 kg) were used. Group 1 was on test for 119 d and group 2 for 120 d. Pens of pigs (30 to 36 pigs per pen) were randomly assigned to one of seven dietary treatments in a randomized complete block design with body weight (BW) serving as the blocking factor resulting in 26 replications per treatment. Dietary treatments were fed in four phases from approximately 23 to 44, 44 to 71, 71 to 100, and 100 kg to market (Tables 1 and 2). Treatments consisted of: a control corn–soy bean meal-based diet (no DDGS) formulated to a 19% SID Trp:Lys ratio, two DDGS withdrawal strategy diets: 19% SID Trp:Lys with 30% DDGS in phases 1 through 3 and then 0% DDGS in phase 4 with either a 19% or 25% Trp:Lys ratio, or four diets with 30% DDGS fed in all four phases and formulated to provide SID Trp:Lys ratios of 16%, 19%, 22%, or 25%.

All treatment diets were manufactured at a JBS Feed Mill (Centralia, MO, USA). To form the experimental diets, the diets with the lowest and highest Trp:Lys ratio with 30% DDGS inclusion, 16% and 25% Trp:Lys ratio, were manufactured first, then blended on farm to create the intermediate Trp:Lys ratio diets of 19% or 22%. The control diet, 16%, and 25% Trp:Lys ratio treatments were mixed at the feed mill for phases 1 to 3 diets. For phase 4, four complete diets were mixed at the feed mill, the control diet, the 16% Trp:Lys ratio diet, and the 25% Trp:Lys ratio with and without 30% DDGS. Ingredient nutrient values and their AA SID co-efficients were

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

	Phase 1			Phase 2		
DDGS, %:	0	30		0	30	
SID Trp:Lys, %:	19	16[2]	25	19	16	25
Ingredients, %						
Corn	69.79	50.72	50.66	79.28	56.73	56.69
Soybean meal	26.30	13.30	13.31	17.06	7.82	7.83
DDGS[3], 5.5% oil	–	30.00	30.00	–	30.00	30.00
Choice white grease	–	2.14	2.10	–	2.24	2.20
Calcium carbonate	1.40	1.26	1.26	1.26	1.17	1.17
Monocalcium P (21% P)	0.63	0.20	0.20	0.47	–	–
Salt	0.54	0.41	0.41	0.55	0.42	0.42
L-Lys[4]	0.87	1.55	1.55	0.94	1.34	1.34
Methionine hydroxy analog	0.14	0.08	0.08	0.10	0.01	0.01
L-Thr[5]	0.15	0.17	0.17	0.15	0.10	0.10
L-Trp	0.02	0.02	0.12	0.04	0.02	0.10
Mineral–vitamin premix[6]	0.15	0.15	0.15	0.15	0.15	0.15
Calculated analysis						
Standardized ileal digestibility (SID) amino acids, %						
Lys	1.11	1.11	1.11	0.91	0.91	0.91
His:Lys	40	38	38	39	41	41
Ile:Lys	60	56	56	57	59	59
Leu:Lys	129	148	148	134	168	168
Met:Lys	34	32	32	33	30	30
Met & Cys:Lys	57	57	57	57	58	58
Thr:Lys	62	62	62	62	62	62
Trp:Lys	19	16	25	19	16	25
Val:Lys	67	67	67	65	72	72
Total Lys, %	1.24	1.29	1.29	1.01	1.07	1.07
NE, kcal/kg	2,533	2,533	2,533	2,560	2,560	2,560
SID Lys:NE, g/Mcal	4.38	4.38	4.38	3.54	3.54	3.54
Ca, %	0.75	0.62	0.62	0.64	0.53	0.53
P, %	0.51	0.49	0.49	0.43	0.42	0.42
STTD[7] P, %	0.39	0.39	0.39	0.34	0.34	0.34
Analyzed values						
CP, %	19.31	19.50	23.81	14.56	16.59	17.28
DM, %	87.59	87.83	87.98	87.57	87.81	87.68
Free Trp, %	0.063	0.022	0.095	0.023	0.038	0.100

[1]Phases 1 and 2 were fed from 23 to 44 and 44 to 71 kg, respectively.
[2]The two diets containing 30% DDGS with either 16% or 25% SID Trp:Lys ratio were blended on farm to form the 19% and 22% SID Trp:Lys ratio diets.
[3]Dried distillers grains with solubles.
[4]Biolys liquid 32.5% Lys (Evonik, Essen, Germany).
[5]THR-PRO, 80% Thr (CJ Bio, Seoul, South Korea).
[6]Minerals and vitamins provided per kilogram of premix: 148,325 FTU phytase, 59 g Zn, 73 g Fe, 19 g Mn, 10 g Cu, 0.198 mg I, 198 mg Se, 2,204,634 IU vitamin A, 661,390 IU vitamin D, 19,595 IU vitamin E, 1,323 mg vitamin K, 13 mg vitamin B12, 19,482 mg Niacin, 11,023 pantothenic acid, and 3,307 mg riboflavin.
[7]Standardized total tract digestible.

derived from NRC (2012) and diets were formulated to meet or exceed NRC (2012) requirement estimates for growing-finishing pigs for their respective weight ranges except for the diet with a formulated SID Trp:Lys ratio of 16% with 30% DDGS fed in phases 1 through 4. Complete feed samples were analyzed for CP and DM (AOAC, 2006) at Ajinomoto Health & Nutrition North America, Inc. (Eddyville, IA, USA).

Pens of pigs were weighed using a pen scale, and feed disappearance was measured every 2 wk to determine average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (G:F). Feed disappearance was measured to determine ADFI by measuring the length between the top of the feed in the feeder to the feeder. This value was then put into a regression equation to determine the amount of feed in the feeder. Feed samples were collected for each treatment 3 to 5 d before and after a phase change. Pigs were sent to market in three marketing events, based on weight, with the heaviest pigs being marketed at marketing events

Table 2. Composition of phases 3 and 4 diets (as-fed basis)[1]

	Phase 3			Phase 4			
DDGS, %:	0	30		0		30	
SID Trp:Lys, %:	19	16[2]	25	19	25	16	25
Ingredients, %							
Corn	85.03	58.11	58.07	85.25	85.20	57.46	57.43
Soybean meal	11.74	6.65	6.65	11.67	11.68	7.64	7.64
DDGS[3], 5.5% oil	–	30.00	30.00	–	–	30.00	30.00
Choice white grease	–	2.52	2.48	–	–	2.48	2.45
Calcium carbonate	1.14	1.16	1.16	1.17	1.17	1.17	1.17
Monocalcium P (21% P)	0.26	–	–	0.34	0.34	–	–
Salt	0.56	0.42	0.42	0.56	0.56	0.42	0.42
L-Lys[4]	0.89	0.97	0.97	0.73	0.73	0.73	0.73
Methionine hydroxy analog	0.06	–	–	0.03	0.03	–	–
L-Thr[5]	0.14	0.02	0.02	0.12	0.12	–	–
L-Trp	0.04	0.02	0.07	0.03	0.07	–	0.05
Mineral–vitamin premix[6]	0.15	0.15	0.15	0.10	0.10	0.10	0.10
Calculated analysis							
Standardized ileal digestibility (SID) amino acids, %							
Lys	0.76	0.76	0.76	0.70	0.71	0.70	0.70
His:Lys	40	48	48	43	43	53	53
Ile:Lys	56	67	67	60	60	75	75
Leu:Lys	143	197	197	154	154	216	216
Met:Lys	32	34	34	31	31	38	38
Met & Cys:Lys	58	67	67	59	59	73	73
Thr:Lys	64	64	64	66	66	68	68
Trp:Lys	19	16	25	19	25	16	25
Val:Lys	66	84	83	71	71	92	92
Total Lys, %	0.85	0.92	0.92	0.80	0.80	0.87	0.87
NE, kcal/kg	2,579	2,579	2,579	2,579	2,579	2,579	2,579
SID Lys:NE, g/Mcal	2.94	2.94	2.94	2.73	2.73	2.73	2.73
Ca, %	0.55	0.52	0.52	0.57	0.57	0.53	0.53
P, %	0.36	0.42	0.42	0.38	0.38	0.42	0.42
STTD[7] P, %	0.29	0.34	0.34	0.26	0.26	0.30	0.30
Analyzed values							
CP, %	12.96	15.89	15.90	12.36	12.49	14.93	15.11
DM, %	87.54	88.24	88.46	87.78	88.20	87.95	87.41
Free Trp, %	0.041	0.007	0.069	0.047	0.075	0.008	0.054

[1]Phases 3 and 4 were fed from 71 to 100 and 100 kg to market, respectively.
[2]The two diets containing 30% DDGS with either 16% or 25% SID Trp:Lys ratio were blended on farm to form the 19% and 22% SID Trp:Lys ratio diets.
[3]Dried distillers grains with solubles.
[4]Biolys liquid, 32.5% Lys (Evonik).
[5]THR-PRO, 80% Thr (CJ Bio).
[6]Minerals and vitamins provided per kilogram of premix: 148,325 FTU phytase, 59 g Zn, 73 g Fe, 19 g Mn, 10 g Cu, 0.198 mg I, 198 mg Se, 2,204,634 IU vitamin A, 661,390 IU vitamin D, 19,595 IU vitamin E, 1,323 mg vitamin K, 13 mg vitamin B12, 19,482 mg Niacin, 11,023 pantothenic acid, and 3,307 mg riboflavin.
[7]Standardized total tract digestible.

1 and 2. Four weeks before the end of the experiment, 7 to 8 pigs per pen were marketed; 2 wk after the first marketing event, 10 to 12 pigs per pen were marketed, and the remaining pigs were marketed 2 wk after the second marketing event. Pigs on the two withdrawal treatments were fed the withdrawal diet for 16, 30, or 46 d before marketing events 1, 2, and 3, respectively. For each marketing event, 3 pigs per pen were chosen for fat sample collection that were approximately the average weight of the pigs marketed, tattooed with the pen number, and loaded separately on trucks with only pigs selected for fat sample collection. Sex was represented equally in pigs selected for fat sample collection. Fat samples were collected at the plant from the dorsal loin-butt junction after carcasses sat overnight in the cooler. A circular fat sample with a diameter of approximately 7.5 cm was taken. All fat samples were immediately frozen after collection and later analyzed for carcass fat IV using near infrared spectroscopy. Measurements of HCW, percentage

lean, loin depth, and backfat depth were measured on carcasses from all three marketing events of the second group of pigs (approximately 2,859 pigs). HCW, loin depth, and backfat depth were all measured at the plant on the production line. Percentage lean was calculated using proprietary plant equations. Carcass yield was calculated by dividing HCW by the pen average final live weight obtained at the farm.

Statistical analysis

The experimental data were analyzed for analysis of variance using the proc GLIMMIX procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC, USA). Pen was the experimental unit for all growth performance data. Response variables were analyzed using a linear mixed model. Treatment was a fixed effect and BW block a random effect. Pairwise comparisons were made between all treatments using a Tukey multiple comparison adjustment to control Type I error rate. Additionally, linear and quadratic orthogonal polynomial contrasts of equally spaced treatments were used to evaluate the effect of increasing SID Trp:Lys ratio (16% to 25% Trp:Lys ratio) in diets containing 30% DDGS up to marketing. Carcass data were analyzed using individual carcass observations and the statistical model incorporated pen as a random intercept to account for the subsampling of multiple observations within each experimental unit. HCW was used as a covariate for percentage lean, backfat depth, and loin depth. Results were considered significant at $P \leq 0.05$ and a tendency at $P > 0.05$ and $P \leq 0.10$.

Results

From days 0 to 70, ADG and ADFI increased (linear, $P < 0.05$) as SID Trp:Lys ratio increased in diets containing 30% DDGS in all four phases (Table 3). During this period (days 0 to 70), three treatments were fed the same diet containing 30% DDGS with a 19% SID Trp:Lys ratio. Pigs fed these three treatments had similar ($P > 0.05$) ADG, ADFI, and G:F compared to each other and intermediate ADG between pigs fed the control corn–soybean meal-based diet and those fed the 16% SID Trp:Lys ratio with 30% DDGS. All pigs had similar ADFI, except for pigs fed with 19% SID Trp:Lys ratio withdrawal strategy diets being greater ($P < 0.05$) than pigs fed the 16% SID Trp:Lys ratio diet. Pigs fed with diets containing 19% SID Trp:Lys ratio with 30% DDGS had reduced ($P < 0.05$) G:F compared to pigs fed the control corn–soybean meal-based diet but were similar to all other treatments.

From day 70 to the end of the study (day 119 or 120), increasing the SID Trp:Lys ratio in diets containing 30% DDGS tended (linear, $P = 0.083$) to increase ADG and improved (linear, $P = 0.024$) G:F. Around day 70, the DDGS withdrawal strategy was implemented with pigs switched from 19% SID Trp:Lys with 30% DDGS to diets containing 19% or 25% SID Trp:Lys without DDGS. Pigs fed the 19% Trp:Lys ratio withdrawal diet had greater ($P < 0.05$) ADG and ADFI compared to those fed all other diets except for pigs fed the withdrawal diet with 25% Trp:Lys ratio in phase 4. Pigs fed the withdrawal diet with 25% SID Trp:Lys ratio had improved ($P < 0.05$) ADG compared to pigs fed with 30% DDGS diets with 16% or 19% SID Trp:Lys ratio and increased ADFI compared to pigs fed all diets containing 30% DDGS in phase 4. Pigs fed the control diet had a similar ($P > 0.05$) ADG and ADFI when compared to pigs fed all diets containing 30% DDGS in phase 4. No differences in G:F were observed between treatments.

Overall, ADG, ADFI, and G:F increased (linear, $P < 0.05$) with increasing SID Trp:Lys ratio for pigs fed diets with 30% DDGS throughout. For ADG, pigs fed the 19% Trp:Lys ratio withdrawal diet had greater ($P < 0.05$) ADG compared to pigs fed with 30% DDGS diets with 16%, 19%, or 22% Trp:Lys ratios. Pigs fed the 19% SID Trp:Lys withdrawal diet had greater ADFI ($P < 0.05$) than pigs fed the control diet or diets with 30% DDGS throughout with 16%, 19%, or 22% Trp:Lys ratios. All pigs fed diets containing 30% DDGS had a similar ($P > 0.05$) ADG and ADFI compared to pigs fed the control diet except pigs fed the 16% SID Trp:Lys ratio with 30% DDGS having a lower ($P < 0.05$) ADG. Pigs fed the control corn–soybean meal-based diet had increased ($P < 0.05$) G:F compared to all other treatments except for pigs fed the 19% Trp:Lys ratio withdrawal diet or pigs fed the 30% DDGS diet throughout with 25% Trp:Lys ratio.

Increasing SID Trp:Lys ratio in 30% DDGS diets increased (linear, $P < 0.001$) BW on day 70 and at the end of the study (day 119/120). Pigs fed the 25% SID Trp:Lys ratio withdrawal diet had similar ($P > 0.05$) BW to all other treatments on day 70 and 119/120, except for greater ($P < 0.05$) final BW than pigs fed the 16% Trp:Lys ratio. Pigs fed the 19% Trp:Lys withdrawal diet had greater ($P < 0.05$) BW than pigs fed the 30% DDGS diets containing 16% or 22% Trp:Lys ratio throughout. Pigs fed the control diet had a similar ($P > 0.05$) BW on day 119/120 to pigs on all other treatments except for a greater BW compared to pigs fed the 16% Trp:Lys ratio ($P < 0.05$).

No differences in BW were observed at the first marketing event of the study. For the second, third, and overall marketing events, BW increased (linear, $P < 0.001$) with increasing Trp:Lys ratio in 30% DDGS diets. Pigs fed the 19% Trp:Lys withdrawal diet had a greater BW ($P < 0.05$) than pigs fed 30% DDGS diets with 16% or 19% Trp:Lys ratio throughout during the second marketing event and pigs fed the 30% DDGS diet with 16% Trp:Lys ratio for the third marketing event. Overall, across all three marketing events, pigs fed the withdrawal diet with 19% Trp:Lys ratio had greater ($P < 0.05$) BW at market than pigs fed with 30% DDGS diets throughout with 16%, 19%, or 22% Trp:Lys ratio pigs fed the control diet had a similar ($P > 0.05$) BW at the marketing events 2 and 3 and overall to all other treatments, except greater then pigs fed diets with a 16% SID Trp:Lys ratio ($P < 0.05$).

No differences in carcass characteristics were observed at the first marketing event ($P > 0.05$; Table 4) except for a decrease (quadratic, $P = 0.047$) in carcass yield in pigs fed diets with increasing SID Trp:Lys ratio with 30% DDGS. The HCW and loin depth increased (quadratic, $P > 0.05$) in pigs as the SID Trp:Lys ratio increased as well as a tendency for an increase in percentage lean (quadratic, $P = 0.091$) and carcass yield (linear, $P = 0.068$) within marketing event 2. All pigs had a similar ($P > 0.05$) HCW within marketing event 2, except for pigs fed a 16% SID Trp:Lys ratio being lower ($P < 0.05$) than all other treatments.

During marketing event 3, HCW and carcass yield (quadratic, $P < 0.05$) as well as backfat depth (linear, $P = 0.003$) increased in pigs fed diets containing 30% DDGS with an increasing SID Trp:Lys ratio. A tendency for a decrease (quadratic, $P = 0.070$) in percentage lean was also observed as Trp:Lys ratio increased in the diet. Pigs fed diets with a 16% SID Trp:Lys ratio had a lower ($P < 0.05$) HCW than all

Table 3. Effects of Trp:Lys ratios and dried distillers grains with solubles (DDGS) withdrawal strategies on growth performance of growing finishing pigs[1]

DDGS[2]:	0	30% to 0% withdrawal		30% throughout				SEM	*P*-value		
SID Trp:Lys, %[2]:	19	19	19-25	16	19	22	25		Treatment	Linear[3]	Quadratic[3]
Item											
BW, kg											
Day 0	22.5	22.5	22.5	22.5	22.5	22.5	22.5	0.20	0.999	0.972	0.787
Day 70	96.2^{a}	95.8^{a}	94.6^{a,b}	93.5^{b}	95.0^{a,b}	94.9^{a,b}	96.0^{a}	0.61	<0.001	<0.001	0.591
Day 119/120	134.7^{a,b}	136.4^{a}	134.4^{a,b}	129.5^{c}	133.6^{a,b}	132.7^{b,c}	134.9^{a,b}	1.10	<0.001	<0.001	0.252
Market weight, kg											
First cut (day 91/92)[4]	131.6	131.5	130.0	131.2	130.8	130.6	130.7	0.81	0.728	0.576	0.729
Second cut (day 105)[5]	136.3^{a,b}	137.6^{a}	135.6^{a,b}	132.7^{c}	134.3^{b,c}	135.3^{a,b,c}	136.1^{a,b}	0.93	< 0.001	< 0.001	0.524
Third cut (day 119/120)[6]	134.7^{a}	136.4^{a}	134.4^{a}	129.5^{b}	133.6^{a}	133.1^{a}	134.8^{a}	1.16	< 0.001	< 0.001	0.146
Overall[7,8]	134.7^{a,b}	135.8^{a}	133.9^{a,b}	131.2^{c}	133.3^{b,c}	133.4^{b,c}	134.3^{a,b}	0.66	< 0.001	< 0.001	0.309
Day 0 to 70											
ADG, kg	1.05^{a}	1.04^{a,b}	1.02^{b,c}	1.01^{c}	1.03^{a,b,c}	1.03^{a,b,c}	1.04^{a,b}	0.01	< 0.001	< 0.001	0.489
ADFI, kg	2.54^{a,b}	2.56^{a}	2.53^{a,b}	2.49^{b}	2.54^{a,b}	2.53^{a,b}	2.56^{a}	0.02	0.016	0.002	0.571
G:F	0.413^{b}	0.407^{a}	0.404^{a}	0.403^{a}	0.405^{a}	0.405^{a}	0.406^{a}	< 0.01	< 0.001	0.113	0.801
Day 70 to 119/120											
ADG, kg	1.03^{b,c}	1.07^{a}	1.06^{a,b}	1.01^{c}	1.01^{c}	1.02^{b,c}	1.03^{b,c}	0.01	<0.001	0.083	0.806
ADFI, kg	3.41^{b,c}	3.55^{a}	3.49^{a,b}	3.39^{c}	3.40^{c}	3.39^{c}	3.40^{c}	0.03	<0.001	0.696	0.889
G:F	0.304	0.303	0.303	0.299	0.298	0.302	0.303	0.02	0.078	0.024	0.496
Overall											
ADG, kg	1.04^{a,b}	1.05^{a}	1.03^{a,b}	1.01^{c}	1.02^{b,c}	1.02^{b,c}	1.04^{a,b}	0.01	<0.001	0.001	0.699
ADFI, kg	2.84^{b,c}	2.90^{a}	2.86^{a,b}	2.80^{c}	2.84^{b,c}	2.83^{b,c}	2.85^{a,b,c}	0.02	<0.001	0.020	0.655
G:F	0.367^{b}	0.363^{a,b}	0.361^{a}	0.360^{a}	0.361^{a}	0.363^{a}	0.364^{a,b}	<0.01	<0.001	0.005	0.922
Removals, %											
Removals, %	2.4	3.0	3.9	2.9	2.9	3.4	3.2	0.73	0.629	0.579	0.827
Mortality, %	1.6	1.5	0.9	1.3	0.8	1.1	0.7	0.42	0.480	0.293	0.948
Total removals, %	3.9	4.5	4.8	4.2	3.7	4.6	3.9	0.81	0.889	0.971	0.929

[a,b,c]Means in the same row that do not have a common superscript differ ($P < 0.05$).
[1]A total of 6,240 pigs (initially 22.5 kg) were used with 30 to 36 pigs per pen and 26 replications per treatment.
[2]Pigs were either fed diets containing 0% DDGS with 19% standardized ileal digestible (SID) Trp:Lys ratio from days 0 to 119/120, 30% DDGS from days 0 to 70 and 0% DDGS from days 70 to 119/120 with SID Trp:Lys ratios of 19% from days 0 to 119/120 or 19% from days 0 to 70 and 25% SID Trp:Lys from days 70 to 119/120, or fed 30% DDGS from days 0 to 119/120 with levels of SID Trp:Lys ratio of 16%, 19%, 22%, and 25%, respectively.
[3]Linear and quadratic contrasts included treatments containing 30% DDGS and a SID Trp:Lys ratio of 16%, 19%, 22%, and 25%, respectively.
[4]6 to 9 pigs per pen were marketed on day 84/92.
[5]10 to 12 pigs per pen were marketed on day 98/105.
[6]9 to 15 pigs per pen were marketed on day 119/120.
[7]Weighted average of pig marketed on days 84/92, 98/105, and 119/120 by pen.
[8]The DDGS withdrawal diet was fed for 16, 30, or 46 d before marketing event 1, 2, or 3, respectively.

other treatments. Pigs fed the corn–soybean meal control diet had the highest carcass yield, significantly greater ($P < 0.05$) than pigs fed the 25% SID Trp:Lys withdrawal diet and SID Trp:Lys of 16% or 22% with 30% DDGS throughout. Percentage lean and loin depth were lower ($P < 0.05$) for pigs fed 16%, 19%, or 25% Trp:Lys ratio with 30% DDGS, compared to the control diet. Backfat depth was similar ($P > 0.05$) across all treatments, except pigs fed a 16% SID Trp:Lys ratio being lower ($P < 0.05$) than pigs fed both withdrawal strategies.

Overall, HCW and carcass yield increased (quadratic, $P < 0.05$) in pigs fed diets with an increasing Trp:Lys ratio going from 16% to 25% with 30% DDGS inclusion as well as backfat depth (linear, $P = 0.040$). The greatest increase in HCW was observed as SID Trp:Lys increased from 16% to 19% with a further increase as the ratio increased from 22% to 25%. Overall, pigs fed the 16% Trp:Lys ratio had reduced HCW ($P < 0.05$) compared to pigs fed all other treatments. Pigs fed diets with a 16% SID Trp:Lys ratio had a similar carcass yield to pigs fed the withdrawal strategy diet with a 25% SID Trp:Lys ratio and the 22% or 25% Trp:Lys ratio diets with 30% DDGS. All other treatments had a greater carcass yield when compared to pigs fed the 16% SID Trp:Lys diets. Pigs fed the withdrawal strategy diet with a 19% Trp:Lys ratio or diets with 22 or 25% Trp:Lys ratio with 30% DDGS had a lower ($P < 0.05$) percentage lean compared to pigs fed the control diet with all other treatments being similar to each other. Pigs fed the control diet had greater overall loin depth ($P < 0.05$) except for pigs fed the withdrawal strategy diets with increased SID Trp:Lys in phase 4 or pigs fed the 22% SID Trp:Lys ratio diet throughout.

Pigs fed diets that contained 30% DDGS throughout the study had greater ($P < 0.05$) IV for all three marketing events, as well as overall, than the control or DDGS withdrawal treatments (Table 5). Pigs fed either of the two withdrawal treatments, which contained 30% DDGS from phases 1 to 3 and then 0% in phase 4, had greater ($P < 0.05$) IV than pigs fed the control diet. There was a tendency ($P = 0.057$) for a linear increase in IV from pigs within the third marketing event as the Trp:Lys ratio increased in diets containing 30% DDGS.

Table 4. Effects of Trp:Lys ratios and dried distillers grains with solubles (DDGS) withdrawal strategies on carcass characteristics of growing finishing pigs[1]

DDGS, %[2]:	0	30% to 0% withdrawal		30% throughout				SEM	*P*-value[3]		
SID Trp:Lys, %[2]:	19	19	19 to25	16	19	22	25		Treatment	Linear[4]	Quadratic[4]
Item											
Marketing event 1											
HCW, kg	93.5	92.3	92.2	93.4	93.8	93.1	93.3	0.90	0.786	0.764	0.895
Carcass yield, %	71.4	71.2	70.9	70.8	71.1	71.1	70.3	0.74	0.135	0.205	0.047
Lean, %[5]	53.1	52.4	52.8	52.5	52.5	52.6	52.6	0.20	0.241	0.574	0.876
Loin depth, cm[5]	6.20	5.97	6.11	6.03	6.06	6.09	6.08	0.07	0.448	0.549	0.758
Back fat depth, cm[5]	1.94	2.02	1.99	2.01	2.02	2.04	2.02	0.03	0.443	0.801	0.533
Marketing event 2											
HCW, kg	95.7^{a}	96.6^{a}	94.7^{a}	90.8^{b}	94.3^{a}	96.3^{a}	96.7^{a}	0.85	<0.001	<0.001	0.022
Carcass yield, %	72.0	71.9	71.4	71.2	71.6	71.9	71.7	0.75	0.088	0.068	0.199
Lean, %[5]	52.8	52.4	52.7	52.5	53.0	52.7	52.7	0.18	0.155	0.706	0.091
Loin depth, cm[5]	6.00	5.90	5.98	5.81	6.02	5.98	5.95	0.06	0.110	0.138	0.029
Back fat depth cm[5]	1.88	1.95	1.90	1.88	1.83	1.91	1.89	0.01	0.323	0.509	0.639
Marketing event 3											
HCW, kg	100.4^{a}	101.2^{a}	98.8^{a}	93.3^{b}	99.3^{a}	98.9^{a}	101.1^{a}	1.06	<0.001	<0.001	0.024
Carcass yield, %	73.0^{a}	72.6^{a,b}	72.1^{b,c}	71.6^{c}	72.7^{a,b}	72.0^{b,c}	72.2^{a,b,c}	0.01	<0.001	0.177	0.043
Lean, %[5]	53.2^{a}	52.6^{a,b}	52.5^{b}	53.1^{a,b}	52.5^{b}	52.6^{a,b}	52.4^{b}	0.15	<0.001	<0.001	0.070
Loin depth, cm[5]	6.40^{a}	6.26^{a,b}	6.23^{a,b}	6.19^{b}	6.11^{b}	6.24^{a,b}	6.13^{b}	0.05	<0.001	0.831	0.809
Back fat depth cm[5]	1.93^{a,b}	2.03^{a}	2.04^{a}	1.86^{b}	1.96^{a,b}	2.01^{a,b}	2.02^{a,b}	0.04	0.007	0.003	0.181
Overall[6]											
HCW, kg	97.1^{a}	97.7^{a}	95.8^{a}	92.4^{b}	96.3^{a}	96.6^{a}	97.6^{a}	0.80	<0.001	<0.001	0.014
Carcass yield, %	72.3^{a}	72.0^{a,b}	71.6^{b,c}	71.3^{c}	72.0^{a,b}	71.8^{a,b,c}	71.7^{a,b,c}	0.16	<0.001	0.192	0.012
Lean, %[5]	53.0^{a}	52.5^{b}	52.6^{a,b}	52.7^{a,b}	52.7^{a,b}	52.6^{b}	52.6^{b}	0.11	<0.001	0.259	0.868
Loin depth, cm[5]	6.21^{a}	6.07^{b}	6.11^{a,b}	6.02^{b}	6.07^{b}	6.11^{a,b}	6.06^{b}	0.03	0.004	0.277	0.119
Back fat depth, cm[5]	1.92	2.00	1.98	1.91	1.93	1.98	1.97	0.02	0.019	0.040	0.372

[a,b,c]Means in the same row that do not have a common superscript differ ($P < 0.05$).
[1]A total of 3,055 pigs (initially 22.5 kg) were used with 30 to 36 pigs per pen and 13 replications per treatment to collect carcass data.
[2]Pigs were either fed diets containing 0% DDGS with 19% standardized ileal digestible (SID) Trp:Lys ratio from days 0 to 119/120, 30% DDGS from days 0 to 70 and 0% DDGS from days 70 to 119/120 with SID Trp:Lys ratios of 19% from days 0 to 119/120 or 19% from days 0 to 70 and 25% SID Trp:Lys from days 70 to 119/120, or fed 30% DDGS from days 0 to 119/120 with levels of SID Trp:Lys ratio of 16%, 19%, 22%, and 25%, respectively.
[3]Treatment × marketing event for HCW and percentage lean ($P < 0.05$), back fat depth ($P = 0.054$), and carcass yield and loin depth ($P > 0.10$). Dose–response interaction, linear SID Trp:Lys × day, for HCW, percentage lean, and back fat depth ($P < 0.05$), carcass yield and loin depth ($P > 0.10$).
[4]Linear and quadratic contrasts included treatments containing 30% DDGS and a SID Trp:Lys ratio of 16%, 19%, 22%, and 25%, respectively.
[5]Adjusted using HCW as a covariate.
[6]Weighted average of carcass characteristics for the overall study.

Discussion

Research has suggested that increasing the Trp:Lys ratio in diets containing DDGS fed to grow-finish pigs can reduce the negative impacts on growth performance and carcass characteristics commonly seen when feeding diets with DDGS up to market (Nitikanchana, 2013; Salyer et al., 2013; Clizer, 2021). Like our study, Clizer (2021) observed linear increases in ADG, ADFI, and final BW when pigs were fed 40% DDGS diets with the SID Trp:Lys ratio increasing from 15% to 25%. Salyer et al. (2013) also observed a linear improvement in ADG, ADFI, and final BW of pigs as the SID Trp:Lys ratio increased from 14% to 18% of Lys in diets containing 30% DDGS. However, Nitikanchana (2013) observed that pigs fed a standard corn–soybean meal-based diet had better growth performance compared to pigs fed diets with an increasing Trp:Lys ratio from 15% to 21% of Lys in diets with 30% DDGS. This is in contrast to our findings herein where pigs fed a standard corn–soybean meal-based diet had similar growth performance to pigs fed diets with 30% DDGS with a 19%, 22%, or 25% Trp:Lys ratio. In a second experiment, Nitikanchana (2013) observed that increasing the SID Trp:Lys ratio from 15% to 21% of Lys in diets with 30% DDGS had no effect on growth performance of pigs. However, none of the other reported studies compared increasing SID Trp:Lys ratios to a DDGS withdrawal strategy for finishing pigs.

When evaluating the SID Trp:Lys ratio in standard corn–soybean meal-based diets with no DDGS for pigs, other research has reported improvements in ADG, ADFI, and G:F as the ratio is increased. Quant et al. (2012) observed a linear improvement in ADG, ADFI, and G:F for pigs from 25 to 50 kg as dietary Trp increased from 12.8% to 17.9% of Lys and Liu et al. (2019) observed a quadratic increase in ADG, ADFI, and G:F as the SID Trp:Lys ratio increased from 15% to 25% in diets fed to pigs from 80 to 110 kg. In another study, Ma et al. (2015) found a quadratic improvement in ADG and G:F as Trp:Lys ratio increased from 12% to 24%, respectively when pigs were 89 to 121 kg in gilts.

Table 5. Effects of Trp:Lys ratios and dried distillers grains with solubles (DDGS) withdrawal strategies on carcass fat iodine value of growing finishing pigs[1]

DDGS, %[2]:	0	30% to 0% withdrawal		30% throughout				SEM	*P*-value[3]		
SID Trp:lys, %[2]:	19	19	19-25	16	19	22	25		Treatment	Linear[4]	Quadratic[4]
Item											
Iodine value, %											
Number of pigs	76	72	73	75	70	80	74	–	–	–	–
Marketing event 1	64.7[a]	72.9[b]	73.5[b]	75.4[c]	75.8[c]	75.5[c]	75.6[c]	0.47	< 0.001	0.824	0.741
Number of pigs	73	74	72	71	73	68	76	–	–	–	–
Marketing event 2	64.0[a]	70.8[b]	71.4[b]	76.1[c]	75.3[c]	75.7[c]	75.2[c]	0.37	< 0.001	0.117	0.589
Number of pigs	52	48	63	58	55	51	52	–	–	–	–
Marketing event 3	63.9[a]	70.3[b]	70.8[b]	76.1[c]	76.8[c]	77.3[c]	77.3[c]	0.49	< 0.001	0.057	0.422
Overall[5]	63.1[a]	71.2[b]	71.8[b]	76.0[c]	75.8[c]	75.3[c]	75.9[c]	0.25	< 0.001	0.798	0.515

[a,b,c]Means in the same row that do not have a common superscript differ ($P < 0.05$).
[1]A total of 6,240 pigs (initially 22.5 kg) were used with 30 to 36 pigs per pen and 26 replications per treatment. Fat samples were collected from the dorsal loin-butt junction and were immediately frozen and later analyzed for iodine value using near infrared spectroscopy.
[2]Pigs were either fed diets containing 0% DDGS with 19% standardized ileal digestible (SID) Trp:Lys ratio from days 0 to 119/120, 30% DDGS from days 0 to 70 and 0% DDGS from days 70 to 119/120 with SID Trp:Lys ratios of 19% from days 0 to 119/120 or 19% from days 0 to 70 and 25% SID Trp:Lys from days 70 to 119/120, or fed 30% DDGS from days 0 to 119/120 with levels of SID Trp:Lys ratio of 16%, 19%, 22%, and 25%, respectively.
[3]Treatment × marketing event, $P < 0.001$. Dose–response interaction, linear SID Trp:Lys × day, $P = 0.028$.
[4]Linear and quadratic contrasts included treatments containing 30% DDGS and a SID Trp:Lys ratio of 16%, 19%, 22%, and 25%, respectively.
[5]Weighted average of carcass fat iodine value by pen.

The improvements in feed intake and growth performance of pigs when the Trp:Lys ratio was increased could be explained by the increase in the Trp:LNAA ratio. LNAA, including Val, Ile, Leu, Thr, Tyr, and Phe, compete with Trp for transport across the blood brain barrier because they share a common transport mechanism (Leathwood, 1987; Henry et al., 1992; Pardridge, 1998). Furthermore, DDGS contribute significant amounts of Leu, Met, and Thr to the diet, which has been found to have a negative effect on Trp uptake by the brain (Sainio et al., 1996; Sève, 1999). Liu et al. (2019) suggested that the Trp requirement for swine fed diets with DDGS is increased due to the greater LNAA concentration. Corn proteins are also generally low in Trp (Stein, 2007) which creates metabolic problems with the Trp:LNAA ratio and Trp uptake by the brain. Salyer et al. (2013) reported that Trp to LNAA ratio of 3.1% or below can negatively affect growth performance of pigs. Tryptophan has been found to have a positive effect on feed intake (Russell et al., 1983; Sève et al., 1991; Batterham et al., 1994). This impact is suggested to be a result of Trp effects on the appetite regulating hormones, serotonin, insulin, and ghrelin (Le Floc'h and Sève, 2007; Zhang et al., 2007). Tryptophan is a precursor for serotonin, which has been shown to play a role in appetite regulation (Wolf, 1974;Sève, 1999), which could explain the linear increase in ADFI as the Trp level increased in our study. Henry et al. (1996) observed that excess protein in relation to Trp can cause a decrease in feed intake and growth performance due to a decrease in serotonin production. The results indicate that as the concentration of LNAA in the diet increases, the level of dietary Trp should also be increased.

Salyer et al. (2013) and Clizer (2021) observed increases in HCW of pigs as the Trp:Lys ratio increased, similar to the findings of our study. Nitikanchana (2013) observed a tendency for an increase in swine carcass yield as the Trp:Lys ratio increased. However, only two levels of Trp, 16.5% or 20%, were used with diets containing 0%, 20%, or 40% DDGS. The increase in carcass yield observed when increasing the Trp level in diets with DDGS reported in the literature could be explained by the finding of Ponter et al. (1994). Ponter et al. (1994) reported that increasing Trp increased gastric emptying causing a decrease in intestinal weight and increasing carcass yield. In our study, a quadratic effect was observed for carcass yield with the greatest improvement in yield between pigs fed diets with 16% SID Trp:Lys to pigs fed a 19% ratio with a slight decrease going up to 22% or 25% SID Trp:Lys ratio.

DDGS withdrawal strategies can be used to improve growth or carcass performance of late finishing pigs. Lerner et al. (2020b) observed an increase in ADG, ADFI, and G:F as the withdrawal period of DDGS in swine diets increased from 0 to 76 d. One experiment by Lerner et al. (2020a) observed that as the length of the fiber withdrawal strategy increased from 0 to 25 d, ADFI increased. However, in a second experiment by Lerner et al. (2020a), no differences in ADFI were found as the withdrawal period increased from 0 to 35 d. Coble et al. (2017) observed that pigs fed a diet containing 30% DDGS had a lower ADFI compared to pigs fed 0% DDGS. This is in contrast to the findings of our study, where pigs fed diets containing 30% DDGS had a similar ADFI to pigs fed the corn–soybean meal-based diets. However, pigs fed the withdrawal strategy diet with a 19% SID Trp:Lys ratio had greater ADG and ADFI compared to pigs fed diets with 30% DDGS with 16%, 19%, or 22% SID Trp:Lys ratio. Other studies have observed no differences in ADFI, ADG, or G:F in pigs fed varying lengths of a fiber withdrawal strategy vs. no fiber withdrawal (Coble et al., 2018; Lerner et al., 2020a). Rojo et al. (2016) observed that DDGS can be included in the diet fed to pigs at 30% without negative effects on growth performance. The results of our study illustrate the positive benefits of a DDGS withdrawal strategy for finishing pigs. The results of this study also illustrate the importance of increasing Trp levels in swine diets containing 30% DDGS for both growth performance and carcass characteristics.

A regression analysis by Soto et al. (2019) observed that increasing the withdrawal period increased carcass yield. However, the response is dependent on NDF concentration suggesting that a greater withdrawal period is needed when NDF concentration is increased in the diet. Coble et al. (2017) and Lerner et al. (2020a) observed a linear reduction in carcass yield as the dietary fiber withdrawal period of pigs decreased. However, other studies observed no differences in carcass yield regardless of the DDGS level in swine diets before marketing (Coble et al., 2018). The current study observed no differences in carcass yield when comparing pigs fed the corn–soybean meal-based diet and withdrawal strategy diets. However, pigs fed the 16% SID Trp:Lys ratio had a lower carcass yield compared to pigs fed the corn–soybean meal-based diet and withdrawal strategy with a 19% SID Trp:Lys ratio, indicating the importance of feeding adequate Trp levels when including DDGS in the diet. Differences in carcass yield were not observed between treatments until the third marketing event when pigs on the withdrawal strategy diets had been fed a corn–soybean meal diet for 46 d. These results indicate that pigs can be fed diets with 30% DDGS up to market without negative effects on carcass yield when dietary Trp levels are 19% of Lys or higher. This is in contrast with the findings of Rojo et al. (2016) who observed a linear reduction in carcass yield as the DDGS level increased from 0% to 30%.

High-fiber diets have been found to have negative impacts on HCW. Pigs fed a high DDGS diet up to market had a 5 kg lower HCW compared to pigs placed on a fiber withdrawal strategy 76 d before market (Lerner et al., 2020b). In another study, pigs fed a high-fiber diet throughout the grow-finish period had a 4.3 kg lighter HCW compared to pigs fed the low-fiber corn soybean meal-based diet (Coble et al., 2018). In the study herein, pigs fed a 19% SID Trp:Lys ratio diet with 30% DDGS had roughly a 1 kg reduction in HCW compared to pigs fed the standard corn soybean meal-based diet or pigs fed the 19% dietary SID Trp:Lys fiber withdrawal strategy. A quadratic improvement in HCW was observed as the SID Trp:Lys ratio increased, with pigs fed the highest SID Trp:Lys ratio, 25%, having a 5 kg greater HCW compared to pigs fed diets with a 16% SID Trp:Lys ratio. The biggest improvement in HCW was observed when the Trp:Lys ratio increased from 16% to 19% Trp:Lys ratio.

Multiple studies have investigated the effects of a DDGS withdrawal period and high vs. low dietary inclusion DDGS levels on carcass fat IV (Nemechek et al., 2015; Coble et al., 2018; Lerner et al., 2020a). IV is a measure of the unsaturated fatty acid content in fat (Nemechek et al., 2015) with a higher IV indicating more unsaturated fatty acid and lower quality fat. Nemechek et al. (2015), Coble et al. (2018), and Lerner et al. (2020a) all observed an increase in carcass IV as the fiber withdrawal period decreased. The increase in IV due to the inclusion of DDGS is because of the high unsaturated fatty acid content in DDGS (NRC, 2012). This agrees with the results of the current study. The decrease in IV in pigs fed the standard corn–soybean meal-based diet compared to pigs fed the withdrawal strategy diet and diets with 30% DDGS throughout can be attributed to the lower unsaturated fatty acid content of the diet. In the present study, increasing the SID Trp:Lys ratio in diets with 30% DDGS had no effect on carcass IV.

Conclusion

In summary, ADG, ADFI, G:F, and BW of pigs increased linearly as SID Trp:Lys ratio increased from 16% to 25% in diets containing 30% DDGS fed from 22.5 kg to marketing with the greatest improvement in growth performance going from deficient levels, 16% Trp:Lys ratio, to adequate levels, 19% Trp:Lys ratio. Pigs fed either of the two DDGS withdrawal strategy diets had similar ADG and ADFI compared to pigs fed diets with a 25% Trp:Lys ratio with 30% DDGS throughout. Furthermore, HCW quadratically increased as the SID Trp:Lys increased up to 25% in diets containing 30% DDGS. Pigs fed the control diet or the 19% SID Trp:Lys ratio withdrawal strategy diet had a greater carcass yield than pigs fed the diet with 16% SID Trp:Lys ratio but were not different to all other pigs fed diets with 30% DDGS throughout. Pigs fed the diet without DDGS had the lowest carcass fat IV, and pigs fed a DDGS-withdrawal strategy diet had a lower IV than pigs fed diets containing 30% DDGS throughout the entire study. These results demonstrate the value of withdrawing DDGS in the diet before market on carcass IV and the importance of feeding adequate Trp, above a 16% Trp:Lys ratio, in diets containing DDGS. Pigs fed the highest level of Trp in this experiment, 25% Trp:Lys ratio, with 30% DDGS had similar overall growth performance to pigs fed the withdrawal strategy diets and the control corn soybean meal-based diet. However, feeding a high SID Trp:Lys ratio alone does not replace a DDGS withdrawal strategy when considering IV.

Supplementary Data

Supplementary data are available at *Journal of Animal Science* online.

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Conflict of interest statement

The authors declare no real or perceived conflicts of interest.

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