Grow-Finish Study 2

FINAL REPORT

Project Title:	Evaluate the Effects of Amino Acid Supplementation with Reduced Dietary Crude Protein on Performance and Carcass composition: GHG Mitigation Technology Evaluation: **Growing/Finishing Trial 2, Diets formulated on a NE basis**

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Key Words: P**aylean, Protein level, Swine, Growth performance, Carcass characteristics, Reduce nitrogen excretion, GHG mitigation**

Specific Objective

- Determine the impact on growth performance of diet formulation based on meeting the set point SID requirement of a limiting amino acid and sequentially adding feed grade amino acids to meet the Lys/AA SID ratio requirement for all indispensable amino acids in phase 1- 4 of growing/finishing.

- Determine the impact on growth performance, carcass composition and yield of diet formulation based on meeting the set point SID requirement of a limiting amino acid and sequentially adding feed grade amino acids to meet the Lys/AA SID ratio requirement for all indispensable amino acids in diets of finishing pigs fed Paylean during phase 5.

- Perform experimental validation of the effectiveness of reduced dietary nitrogen as a mitigation technology to support development of a robust and accurate process-based Life Cycle Analysis model of GHG emission from swine production systems.

- Provide data which will allow coupling this model with Life Cycle Cost Analysis.

- Utilize this model as an education and outreach tool for evaluation of the environmental footprint of swine production.

Justification

Nitrogen compounds from manure and urine are oxidized/reduced by soil and air, with some nitrogen being released into the atmosphere as nitrous oxide (N_2O). The greenhouse effect of N_2O is about 298 times that of CO_2; therefore, N_2O has the next largest impact on total global warming after CO_2 and methane. Maximizing feed grade amino acid use and reducing dietary crude protein in swine diets has been shown to dramatically reduce nitrogen excretion in both nursery and growing/finishing swine (Kerr and Easter, 1995; Kendall, 2000; Figueroa et al., 2002, Hinson, et al., 2009). However, there was variability in growth performance and carcass characteristics when reduced crude protein diets were fed (Dourmad et al., 1993; Kerr et al., 1995; Figueroa et al., 2002). The situation with Paylean is further complicated by FDA regulations requiring the feeding of a 16% crude protein diet with Paylean (Feed Additive Compendium, 2011), even though preliminary studies indicate that lower crude protein diets with appropriate added amino acids could potentially be fed to Paylean-fed pigs without compromising performance or carcass composition (DeCamp et al., 2001, Gaines et al., 2004) and may actually improve the yield reduction associated with increased dietary soybean meal needed to meet the minimum crude protein required (Gaines et al., 2004 and 2007). These studies suggest that the maximum level of crude protein reduction, in conjunction with the optimum amino acid inclusion rate, has not been sufficiently determined for widespread acceptance by the swine industry. In a recent study evaluating effects of lowering protein and adding feed grade amino acids, Apple et al., 2013, observed an improvement in growth performance at the lower levels of substitution, but decreased growth performance at the higher levels of amino acid substitution, and backfat increased at the higher levels of substitution. Results of this study were also consistent with other findings that reducing the crude protein content of grower and finisher diets elevates intramuscular fat content from 14 to 65% (Kerr et al., 1995; Nold et al., 1999; Teye et al., 2006); whereas the reductions in intramuscular fat content or marbling anecdotally associated with feeding Paylean are more than likely a response to dietary lysine levels in excess of 0.8% (Apple et al., 2007). In all these studies, diets were formulated on an ME basis and as soybean meal is reduced in diets, the Lys/NE is actually decreased which may explain some of the increase in fat deposition in pigs fed ME based diets formulated by decreasing soybean meal and including high levels of feed grade amino acids Therefore, we utilized wean-to-finish facilities at the University of Arkansas to develop a 5 phase feeding program with Paylean fed during the final 3-week phase to develop diets formulated on an NE basis that maximize use of feed grade amino acids and minimize crude protein without negatively impacting gain, carcass composition or quality. In addition, we will be able to ascertain if the proposed reductions in crude protein will increase the intramuscular fat content of the *longissimus* muscle when feed grade amino acids are used to ensure adequate SID amino acid ratio's for finishing pigs.

Procedures

The study was conducted at the University of Arkansas wean-to-finish facilities to establish the efficacy of using a **"Set Point SID requirement"** of sequential limiting amino acids and sequentially adding feed grade amino acids to meet the AA/Lys SID ratio as a means of establishing the practical limits of crude protein reduction and amino acid replacement without impacting growth performance, carcass composition or quality in growing and finishing pigs fed reduced protein diets that meet the ideal SID amino acid recommended ratio's. Diets were formulated starting with a control diet that approximates acceptable levels of amino acids currently used in industry, followed by sequentially formulating three additional dietary treatments, each based on the next limiting amino acid. Diets in this study were formulated on a constant NE basis within phase. DDGS was included in all diets. The highest level of crude protein reduction in each phase was formulated to meet the SID histidine requirement (except in cases where DDGS and corn provide His levels above the requirement) in diets containing no soybean meal. This experiments was carried out in accordance with the Protocol **#13060** for swine experiments issued by the University of Arkansas Interdepartmental Animal Care and Use Committee.

Grow/Finish Study:

A total of 216 PIC C-29 X PIC 380 pigs, at approximately 45 to 50 lbs. from the University of Arkansas Animal Science Swine Research Farm, were used for the study.

Allotment to Treatments:

The pigs were individually weighed and sorted at the completion of the nursery phase. To avoid the confounding effect of initial weight, the pigs were assigned to 9 blocks by weight as determined by the experimental facility (9 blocks of 24 pigs/block; University of Arkansas). There were a total of 9 replicates/treatment with pigs housed 6 pigs/pen. Sex within pen was balanced such that each pen was represented by equal numbers of each sex within pen. Pigs remained in the same pens throughout the experiment.

The study was conducted during each of five-phases of a five phase growing/finishing study. During phases 1 [50 to 90 lbs (23 to 41 kg)], 2 [90 to 130 lbs (41 kg to 59 kg)], 3 [130 lbs to 180 lbs (59.0 to 82.0 kg)]), 4 [180 lbs to 230 lbs (82.0 to 104.0 kg)], and 5, pigs were fed one of 4 treatments and 10 ppm of Paylean was fed during the final 3-week finishing phase [Phase 5, 230 to 280 lbs (104.0 to 127.0 kg)].

Treatments: Pigs were fed one of 4 dietary treatments.

***Treatment 1*:** Control: Conventional phase 1 through 5 diets that approximates acceptable levels of crystalline amino acids currently used in industry. The assumption is that most in the industry are comfortable utilizing Thr and Met levels that meet the suggested Thr/Lys ratio and Met/Lys ratio in diets formulated to meet the Trp/Lys requirement without added Trp. Therefore, control diets were formulated to meet the SID lysine requirement (Standardized Ileal Digestible Amino Acid Recommendations for Growing and Finishing swine, PIC Nutrient Specifications Manual, 2011) by adding feed grade Lys and set to meet the SID Trp ratio requirement (18.00 Trp/Lys ratio, PIC Nutrient Specification Manual, 2011) without adding feed grade Trp. This is referred to as the "**Trp Set Point"**. All other indispensable amino acids (Thr and Met) were added to meet the SID ideal amino acid ratio requirement to ensure that all indispensable amino acids were not deficient (PIC Nutrient Specification Manual, 2011). **Note that feed grade Trp was not added in any diet.**

***Treatment 2*:** Diets were formulated to meet the next limiting amino acid. In phase 1 and 5, the next limiting amino acid was Val while in phases 2, 3 and 4, the next limiting amino acid was Ile. This is referred to as the **"Val or Ile Set Point"**. Diets were formulated to meet the SID lysine requirement (Standardized Ileal Digestible Amino Acid Recommendations for Growing and Finishing swine, (PIC Nutrient Specifications Manual, 2011) by adding feed grade Lys and set to meet the SID Val or Ile ratio requirement (55.00 Ile/Lys ratio in phase 2, 3 and 4 or 65.00 Val/Lys in ratio in phase 1 and 5, PIC Nutrient Specifications Manual, 2011) without adding feed grade Ile or Val. All other indispensable amino acids were added (Trp, Thr in all phases, Met in all phases except phases 3 and 4) to meet the SID ideal amino acid ratio requirement to ensure that all indispensable amino acids are not deficient (PIC Nutrient Specification Manual, 2011). **Note that neither feed grade Val or Ile were not added in any phase.**

***Treatment 3*:** Diets were formulated to meet the next limiting amino acid. In phase 1 and 5, the next limiting amino acid was Ile while in phases 2, 3 and 4, the next limiting amino acid was Val. This is referred to as the **"Val and Ile Set Point"** Diets were formulated to meet the SID lysine requirement (Standardized Ileal Digestible Amino Acid Recommendations for Growing and Finishing swine, PIC Nutrient Specifications Manual, 2011) by adding feed grade Lys. All other indispensable amino acids were added (Phase 1 and 5, Met, Trp, Thr, and **Val** were added while in phases 2, 3, and 4, Met, Trp, Thr, and **Ile** were added) to meet the SID ideal amino acid ratio requirement to ensure that all indispensable amino acids were not deficient (PIC Nutrient Specification Manual, 2011). **Note that Val but not Ile was added in phases 1 and 5, and Ile but not Val was added in phase 2, 3, and 4.**

***Treatment 4*:** Diets were formulated to meet the next limiting amino acid, **His**. This is referred to as the **"His Set Point"**. Diets were formulated to meet the SID lysine requirement (Standardized Ileal Digestible Amino Acid Recommendations for Growing and Finishing swine, PIC Nutrient Specifications Manual, 2011) by adding crystalline Lys. All other indispensable amino acids were added (Thr, Met, Trp, Val, Ile) to meet the SID ideal amino acid ratio requirement to ensure that all indispensable amino acids are not deficient (PIC Nutrient Specification Manual, 2011). **Note that feed grade His was not added to any diets,**

Note Concerning Paylean: During the final 3-week phase (Phase 5), pigs were fed Paylean with crude protein decreasing from 17.98 to 14.60 percent from Treatment 1 to Treatment 5. Diets were formulated to contain at least 3.37 Mcal/kg and 2.67 g SID Lys/Mcal NRC ME. Results of previous research at the University of Arkansas indicate that 3.30 Mcal/kg is sufficient energy for optimum ADG, G:F, and lean tissue deposition in pigs fed 10 ppm Paylean (Apple et. al., 2008). Similarly, the Lys/Mcal level was set based on previous research at the university of Arkansas evaluating Lys:ME ratio's from 1.7 to 3.1 (Apple et al., 2004). Results indicate that there is a linear increase in gain with increasing Lys:ME ratio during the initial two weeks of phase 5, but not for weeks 3 and 4 although the overall Lys:ME effect on gain was significant for the entire 4 week period (Linear, $P < 0.01$). However, marbling scores and intramuscular lipid content decreased linearly in longissimus muscle with increasing Lys:ME. Research by Webster et al. (2007) indicates that there is a quadratic and linear growth response to increasing levels of Lys from 0.80 to 1.40% dietary Lys in pigs fed Paylean, although the maximum response was at 1.2% dietary Lys. The diets used for this experiment are formulated to contain approximately 0.943% SID Lys which is slightly below the maximum response level observed by Webster et al. (2007), but is the level recommended by industry (PIC Nutrient Specifications Manual, 2011). This change was made to ensure that dietary lysine was not limiting lean tissue growth. **It should be noted that some of the treatments will be below the crude protein level of 16.00% stipulated for pigs fed Ractopamine Hydrochloride in the 2011 Feed Additive Compendium and a Memorandum has been filed in the study documentation file indicating that no effect on Paylean residues are expected.** A copy of the Memorandum is attached.

Diets Formulation, Requirements, Mixing and Sampling:

Dietary formulation were provided by the University of Arkansas. Diets were formulated to meet the average standardized ileal digestible lysine requirement (SID) for barrows and gilts (PIC Nutrient Specifications Manual, 2011). Diets were formulated to meet the SID amino acid ratio recommendations for lysine for growing and finishing gilts and barrows (PIC Nutrient Specifications Manual, 2011) for all phases of production, and are consistent with standard industry dietary ingredients. Dried distillers grains with solubles (DDGS) was included in all diets.

Diets for the growing/finishing study are presented in Tables 1, 2, 3, 4 and 5, for phases 1 through 5 respectively.

Measurements:
Individual pig weights and pen feed intake were collected in order to calculate average daily gain, feed intake, and gain-to-feed ratio by phase. Tenth rib (¾ midline) backfat measurements and LM depth was estimated at study initiation (36 randomly selected pigs) and all pigs at the end of each phase to allow estimation of carcass fat-free lean gain. Data were used to validate the animal physiology model and to estimate GHG emissions (DNDC model).

When the average of all blocks was approximately 280 lb. (12**7** kg), all pigs were individually weighed, tattooed, transported to, and harvested at, a commercial pork packing plant according to industry accepted procedures. Longissimus muscle (LM) and fat depths at the 10^{th} rib were measured on-line with a Fat-O-Meater probe and hot carcass weight was recorded for each pig/carcass. Right side loins were marked with edible-ink crayons with the particular carcass tattoo number, and identified loins were individually vacuum-packaged, boxed, and shipped under refrigeration to the University of Arkansas Red Meat Abattoir for additional data collection.

Upon arrival at the University of Arkansas Red Meat Abattoir, pH and temperature of each loin (longissimus muscle) were recorded. Then, the blade and sirloin sections were removed and discarded. The remaining center-cut loins were further processed into: 1) two 1-in-thick chops designated for 5 d of simulated retail display and oxidative rancidity production assay (TBARS on d 1 and 5 of display); 2) two 1-in-thick chops for Warner-Bratzler shear force determinations; 3) two 1.5-in-thick chops to be used for drip loss calculations; and 4) a 1-in-thick chop for intramuscular fat (IMF) content.

Housing:
Pigs were housed in a curtain-sided building with slatted floors, and each 4.9 × 9.8 feet (1.5 × 3.0-m) pen is equipped with a single-hole feeder and wean-to-finish waters for ad libitum access to diets and water. Ambient temperature was maintained according to SOP # 302.01. The minimum computer controlled temperature curve below was followed starting when pigs (approximately 50 lbs.) were moved into the barn:

Day	1	5	10	21	28	35	50	60	70	80
Temperature, °F	75.0	74.0	73.0	72.0	71.0	70.5	70.0	69.5	69.0	68.0

Animal care:
The pigs in this study were cared for according to typical commercial management procedures. This experiment was carried out in accordance with the Animal Care Protocol #10041 for swine experiments issued by the University of Arkansas Animal Care Committee. Any animal suffering from minor illness was reported to the Study Director and treated. All medical treatments were recorded. Any animal that died or became ill was weighed and removed from the study. An animal removal form was completed detailing the reason for removal, date, time and animal disposition.

Data analysis:

Performance and carcass composition data were analyzed as a randomized complete block design, with dietary treatment during phases 1 to 5 of the growing/finishing period as the lone fixed effect, blocks based on initial BW as the random effect, and pen as the experimental unit. The ANOVA was generated using the mixed models procedure of SAS (SAS Institute, Inc., Cary, NC). In addition, LM quality data was analyzed as a repeated measures, with day of simulated retail display (1, 2, 3, 4, and 5), as well as the treatment × day interaction, included in the model as fixed effects. Least squares means were calculated for all dependent variables, and mean separation was accomplished using *F*-protected, *t*-tests (PDIFF option).

Feed samples

Feed samples were obtained for each batch of feed mixed and sent to the swine research farm. These were accumulated for each phase, subsampled to one composite sample/treatment/phase, and shipped with proper identification of the ration number and batch size for estimation of amino acid composition.

Results:

Comparison of calculated and analyzed protein and amino acid values for phase 1, phase2, phase 3, phase 4 and phase 5 are in Tables 6 through 10, respectively. Analyzed values were similar to calculated values.

Overall performance in this study was very good. Overall treatment effects evaluating orthogonal contrasts of effects of dietary treatment over all treatments indicated that ADG decreased linearly with increasing dietary crystalline amino acids in Phase 3 (Table 11, $P < 0.05$), phase 4 ($P < 0.10$), phase 5 ($P < 0.01$) and overall ($P < 0.01$). Similarly, ADFI decreased linearly in phase 4 ($P < 0.05$), Phase 5 ($P < 0.01$) and overall ($P < 0.01$). Compared to pigs fed the control diet (Treatment 1), feed efficiency (G:F) in phase 1 increased in pigs fed increasing levels of feed grade amino acids at the lower inclusion levels (Treatment 2 and 3) before decreasing to the control level of efficiency at the highest level of inclusion (Treatment 4, Quadratic effect, $P < 0.05$). During phase 3, a small, but significant, decrease in G:F was observed with increasing level of feed grade amino acids (Linear effect, $P < 0.05$). For the overall study, however, a trend for increased G:F was observed (Linear effect, $P < 0.06$). BW increased at the end of phase 2 with increasing level of crystalline amino acids (Quadratic effect, $P < 0.06$). However, consistent with ADG, BW decreased with increasing dietary crystalline amino acids at the end of phase 3, 4 and 5 (Linear effect, $P < 0.05$, $P < 0.01$ and $P < 0.01$, respectively).

The effect of dietary amino acid inclusion on ultrasound backfat and loin depth are presented in Table 12. Increasing crystalline amino acids at the expense of CP increased backfat at the end of phase 1, phase 2, phase 3, and phase 4 (Linear effects, $P < 0.07$, $P < 0.01$, $P < 0.01$, and $P < 0.05$, respectively). However by the end of phase 5, pigs fed the highest level of crystalline amino acids actually had a reduced backfat compared to pigs fed the intermediary levels of crystalline amino acids resulting in a Quadratic effect, P < 0.05. Loin depth was similar among treatments at the end of all phases with the exception of phase 4 where a linear trend for decreasing loin depth was observed (Linear effect, P < 0.06).

As might be expected based on body weight, HCW (Table 13) decreased with increasing inclusion of dietary feed grade amino acids (Linear effect, P < 0.01). Adjusted carcass yield tended to increase with increasing dietary amino acids (Linear effect, P < 0.10), while adjusted percent lean, and loin depth were similar among the treatments (P > 0.37). Tenth rib backfat was lower in pigs fed diets formulated to the Val or Ile Set Point (Treatment 2) or the His Set Point (Treatment 4) when compared to those fed diets formulated to the Val/Ile Set Point (Treatment 3).

Diets were formulated to establish the efficacy of using a **"Set Point SID requirement"** of sequential limiting amino acids and sequentially adding feed grade amino acids to meet the AA/Lys SID ratio as a means of establishing the practical limits of crude protein reduction and amino acid replacement without impacting growth performance, carcass composition or quality in growing and finishing pigs fed reduced protein diets that meet the ideal SID amino acid recommended ratio's. The control diet (Treatment 1) was set at the "**Trp Set Point".** The next set point was to meet the next limiting amino acid compared to the control set at the **"Trp Set Point" This control diet met the Trp requirement without added feed grade Trp.** In phases 1 and 5, the next limiting amino acid was Val while in phases 2, 3 and 4, the next limiting amino acid was Ile. This is referred to as the **"Val or Ile Set Point"** (Treatment 2). **These diets were formulated to meet the Val or Ile requirement without adding either feed grade Val or Ile.** Pigs fed the initial reduced crude protein diets in each of the five phases of the study based on meeting the Val or Ile SID requirement without the addition of crystalline Val or Ile (**Val or Ile Set Point)** where the only additional amino acid added was Trp had similar ADG, BW, ADFI, and G:F when compared to those fed the control **Trp Set Point** diets formulated to meet industry standards for crystalline amino acid use (Table 11, Treatment 2 vs. Treatment 1). Overall performance during the growing/finishing period was also similar between pigs fed the control diet based on industry standard amino acid use (Trp Set Point, Treatment 1) and those fed diets formulated to the **Val or Ile Set Point** (Treatment 2) without adding crystalline Val or Ile. Scan backfat was increased at the end of phase 2 and 3 in pigs fed to the Val or Ile Set Point (Treatment 2) compared to those fed to the Trp Set Point (Treatment 1). This suggests that diets can be formulated to meet the limiting Val or Ile requirements from feedstuffs, add feed grade Lys to meet the Lys requirement and add feed grade Met, Thr and Trp based on the recommended ratio without impacting growth performance. However, ultrasound backfat increased during the earlier phases. Carcass composition including HCW, adjusted yield, loin depth, and Fat-O Meater BF was similar between the two treatments.

The further reduction in crude protein (**Val and Ile Set Point,** Treatment 3) to meet the Ile requirement in phases 1 and 5 without adding feed grade Ile and the Val minimum requirement in phases 2, 3 and 4 without adding feed grade Val resulted in similar ADG and BW for each phase and for the overall study. Daily feed intake was also similar among the three treatments during phases 1, 2, 3, 4, and overall, however, ADFI was reduced in pigs fed diets formulated to a Val/Ile set point in phase 5 ($P < 0.05$). Feed efficiency (G:F) was improved in phase 1 in pigs fed diets formulated to the Val and Ile set point ($P < 0.05$), compared to those fed diets to meet the Trp Set Point (Treatment 1). Ultrasound backfat was higher at the end of phases 2, 3, 4, and 5 ($P < 0.05$) in pigs fed diets formulated to the Val and Ile set point ($P < 0.05$, Treatment 2)), compared to those fed diets to meet the Trp Set Point (Treatment 1). Carcass composition including HCW, adjusted yield, and loin depth were similar among the treatments. Backfat measured by Fat-O-Meater increased with the increased feed grade amino acid inclusion (Treatment 3 vs. Treatment 1, $P < 0.05$)

Further reduction in crude protein to the His Set Point (meeting the His Sid requirement without adding feed grade His) and adding back all amino acids to meet the SID Lys/AA ratios (Treatment 4) resulted in similar ADG in phase 1, and phase 2, but reduced ADG in phase 3 ($P < 0.10$), phase 5 ($P < 0.05$), and for the overall study ($P < 0.05$, phase 1 through 5) when compared to those fed the control Trp Set Point diets (Treatment 1) or fed to the Val or Ile (Treatment 2) or the Val and Ile Set Point (Treatment 3) diets. Similarly, ADFI was not impacted by decreasing crude protein and adding synthetic amino acids during phases 1, 2 and 3, however reducing crude protein to meet the His Set Point (Treatment 4) resulted in a reduction in feed intake during phase 4 ($P < 0.10$), phase 5 ($P < 0.05$) and for the overall study ($P < 0.05$) when compared to pigs fed either the control Trp Set Point diets (Treatment 1) or pigs fed to the Val or Ile (Treatment 2) or Val and Ile Set Point diets (Treatment 3). Interestingly, the further reduction in crude protein to the His Set Point did not impact G:F during any of the phases ($P > 0.11$). Ultrasound backfat was higher at the end of phases 2, and 3, but was lower at the end of phase 5 ($P < 0.05$) in pigs fed diets formulated to the His set point (Treatment 4), compared to those fed diets to meet the Trp Set Point (Treatment 1). HCW was lower in pigs fed to the His Set Point ($P < 0.05$, Treatment 4) compared to those fed to the Trp (Treatment 1) or to the Val or Ile Set Point (Treatment 2). Carcass composition including adjusted yield, and loin depth was similar among the treatments. However, backfat measured by Fat-O-Meater, was lower in pigs fed to the His Set Point (Treatment 4) compared to those fed to the Val and Ile Set Point ($P < 0.05$, Treatment 3).

Profitability (Return to feed cost only) of inclusion of feed grade amino acids at the expense of soybean meal was estimated based on ingredient prices and market hog prices on 5/21/14 (Table 14). Profitability was highest in pigs fed diets based on the SID Ile **or** Val set point (Treatment 2) and were still profitable in pigs fed diets to meet the SID Ile **and** Val set point (Treatment 3) compared to pigs fed the control diet which were formulated to meet standard feed grade amino acid use in swine diets. Profitability under these conditions in pigs fed diets to meet the SID His set point (Treatment 4) were reduced compared to control.

Increasing inclusion of AA at the expense of soybean meal had a dramatic effect on fatty acid composition in belly fat (Table 15), jowl subcutaneous fat (Table 16) and the fatty acid composition of the longissimus muscle (Table 17).

A linear increase in belly fat total saturated fatty acids (∑SFA, linear effect, P < 0.01), total monounsaturated fatty acids (∑MUFA, linear effect, P < 0.001), and a linear decrease in total polyunsaturated fatty acids (∑PUFA, linear effect, P < 0.001) was observed in pigs fed diets formulated with increasing feed grade amino acids at the expense of soybean meal going from a **Trp set point** in the control diet **to a His set point** in the highest inclusion of amino acids**.** This was also true for all the SFA with the exception of 15:0 and 17:0 where a small, linear decrease was observed (P < 01) and 18:0 where a quadratic increase was observed (P < 0.05). The individual MUFA ($16{:}1_c$, $18{:}1_c9$, and $18{:}1_c11$) responded similarly with a linear increase (P < 0.001) while $16{:}1_t$, and $18{:}1_t$ decreased linearly (P < 0.001) with increasing dietary amino acid inclusion. Both the polyunsaturated fatty acids ($18{:}2_N6$, AND $18{:}2_C9_T11$) responded similarly to the total PUFA with a linear decrease (P < 0.001) with increasing dietary amino acid inclusion. The net effect of these changes in fatty acid composition resulted in a reduction in calculated belly IV from 72.5 in pigs fed the control diet to 69.4 in pigs fed the highest inclusion of amino acids (linear effect, P < 0.001).

A similar response with increasing amino acid inclusion was observed for in jowl fat composition with ∑SFA (Linear increase, P < 0.10), ∑MUFA (Linear increase, P < 0.01), and ∑PUFA (Linear decrease, P < 0.001) in pigs fed diets formulated with increasing feed grade amino acids. Based on these changes in fatty acids, the calculated belly IV was reduced from 74.9 in pigs fed the control diet to 72.0 in pigs fed the highest inclusion of amino acids (linear effect, P < 0.001).

The pattern of increasing ∑MUFA (Linear increase, P < 0.001) and decreasing ∑PUFA (Linear decrease, P < 0.001) with increasing dietary amino acids was also observed in the LM. The calculated LM IV was reduced from 65.8 in pigs fed the control diet to 61.9 in pigs fed the highest inclusion of amino acids (linear effect, P < 0.001).

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Current Research on Similar Subject Matter

- Effects of L-carnitine supplementation on live performance, carcass characteristics and pork quality of growing-finishing pigs fed three levels of corn oil
    - Manuscript in preparation

- Effects of L-carnitine supplementation and dietary inclusion level of corn oil on the fatty acid composition of fat and muscle layers of fresh pork bellies
    - Manuscript in preparation

- Measuring the fatty acid composition and firmness variations in fresh pork bellies
    - Completed data analysis

Facilities and Equipment

- The Animal Science Department at the University of Arkansas has a 150 sow herd which supports a comprehensive research and teaching program. Facilities include farrowing for 40 sows, a 48 pen conventional nursery with capacity for 7 pigs/pen, a 36 pen off-site nursery with capacity for 7 pigs/pen, and four wean-to-finish rooms with a total of 144 pens and a capacity of 6 pigs/pen. The wean-to-finish facility includes twenty 3-ton feed bins, 3 auger-feeding carts, and a central sorting area for weighing pigs. The department also has a research feed mill with a 1 ton horizontal mixer.

- The Red Meat Research Abattoir has the capacity for slaughter and fabrication of all red-meat species, including a 10’ × 28’ chilling cooler, 20’ × 28’ holding cooler, a 42’ × 28’ fabrication room, and a 32’ × 12’ × 11’ walk-in freezer. Instrumental color will be measured with either of a Hunter MiniScan XE (Model 45/0-L), with a 1 inch aperture and or a Hunter MiniScan XE Plus (Model 45/0-L) with interchangeable apertures of 1 inch and ¼ inch. Visual panelists will be trained and tested against a Munsell 185 color evaluation system.

- The Meat Cookery Laboratory is equipped with a Blodgett forced-air convection oven, a gas-fired open-hearth grill, a Lincoln air impingement oven, and a Pro-max Panini grill. Objective tenderness measurement may be evaluated using an Instron Universal Testing Machine (Instron Corp) with a Warner-Bratzler shear force or Allo-Kramer shear force attachments, whereas belly firmness will be measured with a blunt-tipped, 1.27-cm-diamter puncture probe attachment. For sensory measurement, a trained panel is available, in addition to a sensory facility with individual booths and adjustable lighting.

Table 1. Composition of Phase 1 diets.

University of Arkansas	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
PIC C29 x PIC380 2013 Reduced CP G_F	Formulated to meet SID Trp Req.		Formulated to meet SID Val Req.		Formulated to meet SID ILE Req.		Formulated to meet SID His Req.	
Ingredients	lb	%	lb	%	lb	%	lb	%
Corn, Aji	1020.6	51.03	1134.1	56.70	1158.9	57.94	1273.6	63.68
SBM, Aji	472.5	23.63	365.0	18.25	341.0	17.05	230.0	11.50
CDDGS, Aji	400.0	20.00	400.0	20.00	400.0	20.00	400.0	20.00
Fat (Darling, Yellow Grease)	52.00	2.60	38.50	1.93	35.50	1.78	20.00	1.00
Mono-Calcium phosphate	3.20	0.16	4.00	0.20	4.30	0.22	5.60	0.28
Limestone, 2012 NRC	25.00	1.250	25.50	1.275	25.60	1.280	25.95	1.298
Sodium chloride	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500
Copper Sulfate	2.00	0.100	2.00	0.100	2.00	0.100	2.00	0.100
L-Lysine	7.00	0.350	10.24	0.512	10.97	0.549	14.32	0.716
DL-Methionine	0.64	0.032	1.54	0.077	1.74	0.087	2.68	0.134
L-Threonine	1.64	0.082	3.11	0.156	3.44	0.172	4.96	0.248
L-Tryptophan	0.00	0.000	0.58	0.029	0.70	0.035	1.30	0.065
L-Valine	0.00	0.000	0.00	0.000	0.40	0.020	2.23	0.112
L-Isoleucine	0.00	0.000	0.00	0.000	0.00	0.000	1.89	0.095
Mineral Premix (NB-8534)	2.00	0.10	2.00	0.10	2.00	0.10	2.00	0.10
Vitamin Premix (NB-6508)	2.50	0.13	2.50	0.13	2.50	0.13	2.50	0.13
Ronozyme P CT	0.37	0.02	0.37	0.02	0.37	0.02	0.37	0.02
Ethoxiquin (Quinguard)	0.60	0.03	0.60	0.03	0.60	0.03	0.60	0.03
Tylan-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paylean-9	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
NSNG NE (Mcal/lb)	1.148		1.148		1.148		1.148	
CP (%)	20.640		18.825		18.433		16.678	
SID Lysine (%)	1.070	1.071	1.070	1.063	1.070	1.061	1.070	1.053
Available P (%)	0.200	0.300	0.196	0.300	0.197	0.300	0.197	0.300
Avail P (%) with phytase	0.306		0.302		0.302		0.302	
Ca (%)	0.606	0.600	0.605	0.600	0.606	0.600	0.606	0.600
g SID Lysine/Mcal NE	4.23		4.23		4.23		4.23	
SID Met:Lys	29.74		31.80		32.25		34.41	
SID M+C:Lys	55.05	55	55.04	55	55.02	55	55.03	55
SID Thr:Lys	65.03	65	65.04	65	65.03	65	65.03	65
SID Trp:Lys	18.02	18	18.05	18	18.01	18	18.03	18
SID Ile:Lys	65.26	55	56.92	55	55.04	55	55.05	55
SID Val:Lys	72.98	65	65.02	65	65.03	65	65.03	65
SID Leu:Lys	148.12	100	136.72	100	134.13	100	122.28	100
SID His:Lys	42.39	32	37.83	32	36.80	32	32.08	32
SID Arg:Lys	103.81	40	89.53	40	86.31	40	71.54	40
SID Phe:Lys	79.40	60	70.51	60	68.50	60	59.29	60
SID Phe+Tyr:Lys	138.44	94	123.60	94	120.25	94	104.87	94
Ca/AP	3.02		3.08		3.08		3.08	
Ca/aP with phytase	1.98		2.00		2.00		2.00	

Table 2. Composition of Phase 2 diets.

University of Arkansas	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
PIC C29 x PIC380	Formulated to meet SID Trp Req.		Formulated to meet SID ILE Req.		Formulated to meet SID Val Req.		Formulated to meet SID His Req.	
2013 Reduced CP G_F								
Ingredients	lb	%	lb	%	lb	%	lb	%
Corn, Aji	972.5	48.62	1130.2	56.51	1152.3	57.62	1270.1	63.51
SBM, Aji	318.0	15.90	169.5	8.48	148.0	7.40	34.0	1.70
CDDGS, Aji	600.0	30.00	600.0	30.00	600.0	30.00	600.0	30.00
Fat (Darling, Yellow Grease)	57.00	2.85	38.50	1.93	36.00	1.80	20.00	1.00
Calcium phosphate (monocalcium)	0.00	0.00	0.60	0.03	1.00	0.05	2.30	0.12
Limestone, 2012 NRC	25.80	1.290	26.80	1.340	26.70	1.335	27.20	1.360
Sodium chloride	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500
Copper Sulfate	2.00	0.100	2.00	0.100	2.00	0.100	2.00	0.100
L-Lysine	6.68	0.334	11.16	0.558	11.80	0.590	15.26	0.763
DL-Methionine	0.00	0.000	0.34	0.017	0.52	0.026	1.49	0.075
L-Threonine	0.58	0.029	2.61	0.131	2.90	0.145	4.47	0.224
L-Tryptophan	0.00	0.000	0.80	0.040	0.91	0.046	1.52	0.076
L-Valine	0.00	0.000	0.00	0.000	0.00	0.000	1.88	0.094
L-Isoleucine	0.00	0.000	0.00	0.000	0.36	0.018	2.30	0.115
Trace Mineral Premix (NB-8534)	3.00	0.15	3.00	0.15	3.00	0.15	3.00	0.15
Vitamin Premix (NB-6508)	3.00	0.15	3.00	0.15	3.00	0.15	3.00	0.15
Ronozyme P CT	0.37	0.02	0.37	0.02	0.37	0.02	0.37	0.02
Ethoxiquin (Quinguard)	0.60	0.03	0.60	0.03	0.60	0.03	0.60	0.03
Tylan-40	0.50	0.03	0.50	0.03	0.50	0.03	0.50	0.03
Paylean-9	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
NSNG NE (Mcal/lb)	1.159		1.159		1.159		1.159	
CP (%)	19.382		16.852		16.498		14.697	
SID Lysine (%)	0.905	0.905	0.905	0.896	0.905	0.895	0.905	0.888
Available P (%)	0.185	0.280	0.175	0.280	0.176	0.280	0.176	0.280
Avail P (%) with phytase	0.291		0.281		0.282		0.282	
Ca (%)	0.582	0.580	0.582	0.580	0.581	0.580	0.583	0.580
g SID Lysine/Mcal NE	3.54		3.54		3.54		3.54	
SID Met:Lys	31.11		29.53		30.02		32.64	
SID M+C:Lys	59.97	55	55.01	55	55.02	55	55.02	55
SID Thr:Lys	65.01	65	65.02	65	65.02	65	65.02	65
SID Trp:Lys	18.04	18	18.08	18	18.06	18	18.04	18
SID Ile:Lys	68.70	55	55.06	55	55.05	55	55.02	55
SID Val:Lys	79.93	65	66.93	65	65.06	65	65.01	65
SID Leu:Lys	173.96	100	155.34	100	152.69	100	138.18	100
SID His:Lys	46.31	32	38.86	32	37.79	32	32.02	32
SID Arg:Lys	105.60	38	82.27	38	78.91	38	60.91	38
SID Phe:Lys	86.66	60	72.13	60	70.04	60	58.80	60
SID Phe+Tyr:Lys	154.89	94	130.64	94	127.17	94	108.39	94
Ca/AP	3.15		3.33		3.29		3.31	
Ca/aP with phytase	2.00		2.08		2.06		2.07	

Table 3. Composition of Phase 3 diets.

University of Arkansas	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
PIC C29 x PIC380	Formulated to meet SID Trp Req.		Formulated to meet SID ILE Req.		Formulated to meet SID Val Req.		Formulated to meet SID His Req.	
2013 Reduced CP G_F								
Ingredients	lb	%	lb	%	lb	%	lb	%
Corn, Aji	1191.7	59.58	1319.9	65.99	1358.4	67.92	1461.5	73.08
SBM, Aji	258.5	12.93	137.5	6.88	100.8	5.04	0.0	0.00
CDDGS, Aji	450.0	22.50	450.0	22.50	450.0	22.50	450.0	22.50
Fat (Darling, Yellow Grease)	53.00	2.65	38.00	1.90	33.00	1.65	20.00	1.00
Calcium phosphate (monocalcium)	0.00	0.00	1.55	0.08	2.00	0.10	3.10	0.16
Limestone, 2012 NRC	25.00	1.250	25.35	1.268	25.45	1.273	25.80	1.290
Sodium chloride	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500
Copper Sulfate	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
L-Lysine	5.70	0.285	9.35	0.468	10.45	0.523	13.50	0.675
DL-Methionine	0.00	0.000	0.00	0.000	0.20	0.010	1.05	0.053
L-Threonine	0.39	0.020	2.04	0.102	2.54	0.127	3.92	0.196
L-Tryptophan	0.00	0.000	0.64	0.032	0.84	0.042	1.38	0.069
L-Valine	0.00	0.000	0.00	0.000	0.00	0.000	1.66	0.083
L-Isoleucine	0.00	0.000	0.00	0.000	0.62	0.031	2.34	0.117
Trace Mineral Premix (NB-8534)	2.00	0.10	2.00	0.10	2.00	0.10	2.00	0.10
Vitamin Premix (NB-6508)	2.50	0.13	2.50	0.13	2.50	0.13	2.50	0.13
Ronozyme P CT	0.37	0.02	0.37	0.02	0.37	0.02	0.37	0.02
Ethoxiquin (Quinguard)	0.60	0.03	0.60	0.03	0.60	0.03	0.60	0.03
Tylan-40	0.25	0.01	0.25	0.01	0.25	0.01	0.25	0.01
Paylean-9	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
NSNG NE (Mcal/lb)	1.176		1.176		1.176		1.176	
CP (%)	16.755		14.683		14.079		12.482	
SID Lysine (%)	0.772	0.772	0.772	0.765	0.772	0.763	0.772	0.758
Available P (%)	0.157	0.260	0.158	0.260	0.159	0.260	0.158	0.260
Avail P (%) with phytase	0.263		0.264		0.264		0.264	
Ca (%)	0.548	0.540	0.548	0.540	0.548	0.540	0.548	0.540
g SID Lysine/Mcal NE	2.98		2.98		2.98		2.98	
SID Met:Lys	32.17		28.88		29.18		31.86	
SID M+C:Lys	62.23	55	55.72	55	55.05	55	55.01	55
SID Thr:Lys	65.05	65	65.03	65	65.04	65	65.01	65
SID Trp:Lys	18.06	18	18.02	18	18.05	18	18.04	18
SID Ile:Lys	69.06	56	56.03	56	56.03	56	56.04	56
SID Val:Lys	81.23	65	68.81	65	65.06	65	65.02	65
SID Leu:Lys	179.04	100	161.25	100	155.90	100	140.90	100
SID His:Lys	47.30	32	40.18	32	38.03	32	32.06	32
SID Arg:Lys	106.50	36	84.22	36	77.48	36	58.83	36
SID Phe:Lys	87.77	60	73.89	60	69.70	60	58.06	60
SID Phe+Tyr:Lys	155.64	94	132.47	94	125.49	94	106.06	94
Ca/AP	3.49		3.46		3.45		3.47	
Ca/aP with phytase	2.08		2.08		2.07		2.08	

Table 4. Composition of Phase 4 diets.

University of Arkansas	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
PIC C29 x PIC380	Formulated to meet SID Trp Req.		Formulated to meet SID ILE Req.		Formulated to meet SID Val Req.		Formulated to meet SID His Req.	
2013 Reduced CP G_F								
Ingredients	lb	%	lb	%	lb	%	lb	%
Corn, Aji	1355.4	67.77	1475.6	73.78	1502.9	75.15	1600.8	80.04
SBM, Aji	235.0	11.75	121.5	6.08	95.0	4.75	0.0	0.00
CDDGS, Aji	315.0	15.75	315.0	15.75	315.0	15.75	315.0	15.75
Fat (Darling, Yellow Grease)	50.00	2.50	36.00	1.80	33.00	1.65	20.00	1.00
Calcium phosphate (monocalcium)	1.20	0.06	2.50	0.13	2.80	0.14	3.90	0.20
Limestone, 2012 NRC	22.25	1.113	22.65	1.133	22.70	1.135	23.00	1.150
Sodium chloride	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500
Copper Sulfate	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
L-Lysine	5.06	0.253	8.48	0.424	9.27	0.464	12.14	0.607
DL-Methionine	0.00	0.000	0.00	0.000	0.10	0.005	0.91	0.046
L-Threonine	0.40	0.020	1.95	0.098	2.31	0.116	3.61	0.181
L-Tryptophan	0.00	0.000	0.61	0.031	0.75	0.038	1.26	0.063
L-Valine	0.00	0.000	0.00	0.000	0.00	0.000	1.57	0.079
L-Isoleucine	0.00	0.000	0.00	0.000	0.45	0.023	2.06	0.103
Trace Mineral Premix (NB-8534)	2.00	0.10	2.00	0.10	2.00	0.10	2.00	0.10
Vitamin Premix (NB-6508)	2.50	0.13	2.50	0.13	2.50	0.13	2.50	0.13
Ronozyme P CT	0.37	0.02	0.37	0.02	0.37	0.02	0.37	0.02
Ethoxiquin (Quinguard)	0.60	0.03	0.60	0.03	0.60	0.03	0.60	0.03
Tylan-40	0.25	0.01	0.25	0.01	0.25	0.01	0.25	0.01
Paylean-9	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
NSNG NE (Mcal/lb)	1.187		1.187		1.187		1.187	
CP (%)	14.994		13.051		12.611		11.109	
SID Lysine (%)	0.697	0.697	0.697	0.691	0.697	0.690	0.697	0.685
Available P (%)	0.146	0.250	0.146	0.250	0.146	0.250	0.146	0.250
Avail P (%) with phytase	0.251		0.251		0.251		0.251	
Ca (%)	0.501	0.500	0.501	0.500	0.501	0.500	0.501	0.500
g SID Lysine/Mcal NE	2.67		2.67		2.66		2.66	
SID Met:Lys	32.22		28.81		28.74		31.61	
SID M+C:Lys	62.62	55	55.87	55	55.02	55	55.06	55
SID Thr:Lys	65.04	65	65.05	65	65.06	65	65.05	65
SID Trp:Lys	18.04	18	18.06	18	18.06	18	18.07	18
SID Ile:Lys	68.56	55	55.05	55	55.07	55	55.03	55
SID Val:Lys	80.88	65	68.00	65	65.01	65	65.03	65
SID Leu:Lys	178.20	100	159.76	100	155.51	100	139.91	100
SID His:Lys	47.32	32	39.94	32	38.23	32	32.01	32
SID Arg:Lys	106.75	34	83.63	34	78.26	34	58.83	34
SID Phe:Lys	87.17	60	72.77	60	69.43	60	57.31	60
SID Phe+Tyr:Lys	152.76	94	128.73	94	123.16	94	102.93	94
Ca/AP	3.44		3.44		3.44		3.44	
Ca/aP with phytase	1.99		2.00		1.99		1.99	

Table 5. Composition of Phase 5 diets.

University of Arkansas	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
PIC C29 x PIC380	Formulated to meet SID Trp Req.		Formulated to meet SID Val Req.		Formulated to meet SID ILE Req.		Formulated to meet SID His Req.	
2013 Reduced CP G_F								
Ingredients	lb	%	lb	%	lb	%	lb	%
Corn, Aji	1273.2	63.66	1359.3	67.96	1385.1	69.25	1488.9	74.44
SBM, Aji	432.5	21.63	350.5	17.53	326.0	16.30	225.0	11.25
CDDGS, Aji	200.0	10.00	200.0	10.00	200.0	10.00	200.0	10.00
Fat (Darling, Yellow Grease)	47.00	2.35	37.00	1.85	33.50	1.68	20.00	1.00
Calcium phosphate (monocalcium)	0.00	0.00	1.00	0.05	1.30	0.07	2.50	0.13
Limestone, 2012 NRC	21.60	1.080	21.85	1.093	21.90	1.095	22.15	1.108
Sodium chloride	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500
Copper Sulfate	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
L-Lysine	6.00	0.300	8.48	0.424	9.23	0.462	12.28	0.614
DL-Methionine	1.24	0.062	1.93	0.097	2.14	0.107	3.00	0.150
L-Threonine	2.20	0.110	3.32	0.166	3.66	0.183	5.05	0.253
L-Tryptophan	0.00	0.000	0.45	0.023	0.58	0.029	1.12	0.056
L-Valine	0.00	0.000	0.00	0.000	0.41	0.021	2.08	0.104
L-Isoleucine	0.00	0.000	0.00	0.000	0.00	0.000	1.72	0.086
Trace Mineral Premix (NB-8534)	2.00	0.10	2.00	0.10	2.00	0.10	2.00	0.10
Vitamin Premix (NB-6508)	2.50	0.13	2.50	0.13	2.50	0.13	2.50	0.13
Ronozyme P CT	0.37	0.02	0.37	0.02	0.37	0.02	0.37	0.02
Ethoxiquin (Quinguard)	0.60	0.03	0.60	0.03	0.60	0.03	0.60	0.03
Tylan-40	0.25	0.01	0.25	0.01	0.25	0.01	0.25	0.01
Paylean-9	0.50	0.025	0.50	0.025	0.50	0.025	0.50	0.025
NSNG NE (Mcal/lb)	1.167		1.167		1.167		1.167	
CP (%)	17.981		16.596		16.198		14.599	
SID Lysine (%)	0.952	0.953	0.952	0.947	0.952	0.946	0.952	0.939
Available P (%)	0.139	0.240	0.139	0.240	0.140	0.240	0.140	0.240
Avail P (%) with phytase	0.245		0.245		0.245		0.245	
Ca (%)	0.506	0.500	0.506	0.500	0.506	0.500	0.505	0.500
g SID Lysine/Mcal NE	3.70		3.70		3.70		3.70	
SID Met:Lys	32.80		34.57		35.10		37.33	
SID M+C:Lys	58.04	58	58.02	58	58.02	58	58.05	58
SID Thr:Lys	68.05	68	68.03	68	68.03	68	68.06	68
SID Trp:Lys	18.01	18	18.06	18	18.05	18	18.04	18
SID Ile:Lys	64.42	55	57.24	55	55.07	55	55.08	55
SID Val:Lys	71.88	65	65.02	65	65.03	65	65.05	65
SID Leu:Lys	144.39	100	134.55	100	131.57	100	119.43	100
SID His:Lys	42.00	32	38.07	32	36.89	32	32.05	32
SID Arg:Lys	103.92	34	91.64	34	87.94	34	72.82	34
SID Phe:Lys	78.03	60	70.37	60	68.06	60	58.62	60
SID Phe+Tyr:Lys	133.76	94	120.98	94	117.13	94	101.38	94
Ca/AP	3.64		3.63		3.63		3.61	
Ca/aP with phytase	2.07		2.07		2.06		2.06	

Table 6. Analyzed amino acids composition in G/F phase 1 diet.

Treatment	1		2		3		4	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	20.64	21.06	18.83	19.61	18.43	19.17	16.68	17.05
Total Lysine (%)	1.24	1.27	1.23	1.26	1.22	1.24	1.21	1.23
Total Met (%)	0.37	0.39	0.39	0.42	0.39	0.40	0.41	0.43
Total Threonine (%)	0.85	0.89	0.84	0.87	0.84	0.85	0.82	0.82
Total Tryptophan (%)	0.23	0.24	0.22	0.23	0.22	0.23	0.22	0.22
Total Isoleucine (%)	0.82	0.85	0.72	0.78	0.70	0.77	0.69	0.75
Total Valine (%)	0.94	1.01	0.85	0.94	0.84	0.95	0.83	0.94
Total Leucine (%)	1.83	1.93	1.69	1.85	1.66	1.83	1.52	1.64
Total Histidine (%)	0.53	0.55	0.48	0.50	0.46	0.49	0.41	0.43
Total Arginine (%)	1.23	1.29	1.07	1.16	1.03	1.14	0.87	0.95
Total Phenylalanine (%)	0.99	1.04	0.88	0.96	0.86	0.95	0.75	0.81

Table 7. Analyzed amino acids composition in G/F phase 2 diet.

Treatment	1		2		3		4	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	19.38	20.41	16.85	17.15	16.50	16.68	14.70	14.69
Total Lysine (%)	1.08	1.10	1.06	1.09	1.06	1.05	1.05	1.04
Total Met (%)	0.33	0.35	0.32	0.33	0.32	0.33	0.34	0.35
Total Threonine (%)	0.75	0.77	0.73	0.73	0.73	0.70	0.72	0.71
Total Tryptophan (%)	0.20	0.19	0.19	0.19	0.19	0.20	0.19	0.19
Total Isoleucine (%)	0.75	0.79	0.61	0.65	0.61	0.64	0.60	0.65
Total Valine (%)	0.89	0.96	0.76	0.82	0.74	0.80	0.73	0.78
Total Leucine (%)	1.83	1.92	1.64	1.72	1.61	1.70	1.47	1.53
Total Histidine (%)	0.50	0.52	0.42	0.43	0.41	0.42	0.36	0.36
Total Arginine (%)	1.08	1.16	0.86	0.92	0.83	0.86	0.65	0.70
Total Phenylalanine (%)	0.93	0.99	0.78	0.82	0.76	0.80	0.64	0.68

Table 8. Analyzed amino acids composition in G/F phase 3 diet.

Treatment	1		2		3		4	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	16.75	17.25	14.68	14.92	14.08	14.22	12.48	12.94
Total Lysine (%)	0.92	0.94	0.91	0.93	0.90	0.94	0.89	0.92
Total Met (%)	0.29	0.30	0.27	0.28	0.27	0.27	0.29	0.29
Total Threonine (%)	0.64	0.66	0.63	0.63	0.62	0.63	0.61	0.71
Total Tryptophan (%)	0.17	0.18	0.17	0.16	0.17	0.16	0.16	0.15
Total Isoleucine (%)	0.64	0.70	0.53	0.58	0.53	0.59	0.52	0.51
Total Valine (%)	0.77	0.84	0.66	0.74	0.63	0.71	0.62	0.69
Total Leucine (%)	1.61	1.69	1.45	1.56	1.40	1.51	1.27	1.33
Total Histidine (%)	0.43	0.45	0.37	0.39	0.36	0.38	0.31	0.33
Total Arginine (%)	0.93	0.98	0.75	0.78	0.69	0.74	0.54	0.60
Total Phenylalanine (%)	0.80	0.86	0.68	0.73	0.64	0.70	0.54	0.60

Table 9. Analyzed amino acids composition in G/F phase 4 diet.

Treatment	1		2		3		4	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	14.99	15.81	13.05	13.00	12.61	13.43	11.11	11.37
Total Lysine (%)	0.83	0.85	0.81	0.71	0.81	0.80	0.80	0.77
Total Met (%)	0.27	0.26	0.24	0.23	0.24	0.24	0.26	0.25
Total Threonine (%)	0.57	0.59	0.56	0.55	0.56	0.56	0.55	0.53
Total Tryptophan (%)	0.15	0.15	0.15	0.13	0.15	0.14	0.15	0.13
Total Isoleucine (%)	0.57	0.63	0.47	0.50	0.47	0.45	0.46	0.44
Total Valine (%)	0.69	0.75	0.59	0.64	0.56	0.61	0.55	0.60
Total Leucine (%)	1.44	1.51	1.29	1.35	1.26	1.31	1.14	1.21
Total Histidine (%)	0.39	0.41	0.33	0.35	0.32	0.34	0.27	0.29
Total Arginine (%)	0.84	0.89	0.67	0.72	0.63	0.68	0.48	0.53
Total Phenylalanine (%)	0.71	0.79	0.60	0.66	0.57	0.64	0.48	0.55

Table 10. Analyzed amino acids composition in G/F phase 5 diet.

Treatment	1		2		3		4	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	17.98	18.03	16.60	16.87	16.20	16.52	14.60	15.98
Total Lysine (%)	1.09	1.18	1.08	1.18	1.08	1.14	1.07	1.15
Total Met (%)	0.35	0.36	0.37	0.37	0.37	0.36	0.39	0.39
Total Threonine (%)	0.78	0.79	0.77	0.79	0.76	0.74	0.75	0.75
Total Tryptophan (%)	0.20	0.20	0.20	0.19	0.20	0.20	0.19	0.18
Total Isoleucine (%)	0.72	0.76	0.64	0.68	0.62	0.67	0.61	0.84
Total Valine (%)	0.82	0.87	0.74	0.79	0.74	0.80	0.73	0.81
Total Leucine (%)	1.58	1.66	1.48	1.54	1.44	1.52	1.31	1.47
Total Histidine (%)	0.46	0.48	0.42	0.45	0.41	0.43	0.36	0.39
Total Arginine (%)	1.09	1.13	0.96	1.03	0.93	0.98	0.77	0.85
Total Phenylalanine (%)	0.86	0.96	0.78	0.88	0.75	0.89	0.65	0.75

Table 11. Effect of increasing crystalline amino acids in grower/finisher pigs fed diets formulated on a NE basis on growth performance, LS means.

	Treatment					*P* – Value			
	1	2	3	4	SEM	Trt	Linear[3]	Quadratic	Cubic
BW, kg									
Initial	20.7	20.7	20.7	20.7	0.7	0.8857			
End of P 1	46.8	47.0	47.2	46.5	1.1	0.3801	0.5965	0.1148	0.6235
End of P 2	58.0[xy]	58.0[xy]	58.6[x]	57.2[y]	1.2	0.0894	0.2475	0.0599	0.1696
End of P 3	85.9[a]	85.9[a]	85.8[a]	83.6[b]	1.5	0.0483	0.0240	0.0841	0.7833
End of P 4	106.2[a]	105.9[a]	105.7[a]	102.6[b]	1.5	0.0112	0.0044	0.0611	0.8394
End of P 5	134.5[a]	133.8[a]	133.6[a]	128.3[b]	1.9	0.0039	0.0009	0.0930	0.7798
ADG, kg/d									
P 1	0.930	0.939	0.944	0.922	0.019	0.3909	0.5604	0.1198	0.6734
P 2	1.020	1.005	1.044	0.969	0.025	0.2185	0.2202	0.2151	0.2243
P 3	1.164[x]	1.164[x]	1.131[xy]	1.101[y]	0.022	0.0896	0.0248	0.3617	0.4092
P 4	0.957	0.953	0.947	0.902	0.022	0.2756	0.0973	0.2980	0.9614
P 5	1.093[a]	1.072[a]	1.075[a]	0.989[b]	0.031	0.0449	0.0090	0.2930	0.7203
Overall[2]	1.034[a]	1.028[a]	1.026[a]	0.978[b]	0.013	0.0037	0.0009	0.0926	0.7922
ADFI, kg/d									
P 1	1.545	1.525	1.486	1.517	0.029	0.2167	0.2629	0.1958	0.2046
P 2	2.386	2.478	2.492	2.373	0.066	0.2850	0.9860	0.0581	0.8123
P 3	2.882	2.889	2.886	2.801	0.053	0.3578	0.1868	0.2326	0.8531
P 4	3.136[x]	3.147[x]	3.084[xy]	2.964[y]	0.054	0.0661	0.0245	0.1611	0.5667
P 5	3.218[a]	3.127[ab]	3.062[b]	2.839[c]	0.052	0.0002	<0.0001	0.3493	0.7660
Overall[2]	2.620[a]	2.606[a]	2.569[a]	2.472[b]	0.038	0.0043	0.0007	0.2236	0.6120
G:F									
P 1	0.602[a]	0.615[ab]	0.636[b]	0.609[a]	0.008	0.0318	0.4412	0.0173	0.0834
P 2	0.428	0.409	0.420	0.409	0.010	0.3205	0.1270	0.6984	0.3187
P 3	0.404	0.403	0.393	0.393	0.005	0.1165	0.0463	0.9650	0.1581
P 4	0.306	0.303	0.307	0.305	0.007	0.9440	0.9440	0.9553	0.5493
P 5	0.335	0.343	0.351	0.348	0.007	0.3470	0.1545	0.3464	0.5415
Overall[2]	0.384	0.393	0.399	0.396	0.004	0.0889	0.0588	0.1045	0.4690

[a,b,c] Means with superscript different significant differ ($P < 0.05$).

[x,y,z] Means with superscript different trend differ ($P < 0.10$).

1. Proc IML was used to generate coefficient for orthogonal contrast by using L-lysine supplementation level from each treatment for each phase.
2. Coefficient used for orthogonal contrast is generated based on L-lysine supplementation level from finisher phase 3

Table 12. . Effect of increasing crystalline amino acids in grower/finisher pigs fed diets formulated on a NE basis on ultrasound backfat and loin thickness, LS means.

	Treatment					*P* - Value			
	1	2	3	4	SEM	Trt	Linear[1]	Quadratic	Cubic
Backfat[2], mm									
Initial[3]	0.251	0.237	0.257	0.256	0.017	0.8216			
End of P 1	0.779	0.786	0.829	0.839	0.030	0.2111	0.0671	0.9743	0.2809
End of P 2	0.887[a]	1.004[b]	0.987[b]	1.056[b]	0.041	0.0039	0.0005	0.4006	0.4320
End of P 3	1.133[a]	1.263[b]	1.364[b]	1.374[b]	0.048	0.0016	0.0003	0.2620	0.2661
End of P 4	1.562[a]	1.660[ab]	1.740[b]	1.675[ab]	0.044	0.0420	0.0384	0.0813	0.2456
End of P 5	1.959[ab]	2.021[a]	2.023[a]	1.831[b]	0.060	0.0450	0.0679	0.0252	0.8657
Loin thickness[2], mm									
Initial[3]	1.707	1.637	1.651	1.747	0.081	0.7294			
End of P 1	3.243	3.318	3.342	3.193	0.061	0.2528	0.5403	0.0611	0.7232
End of P 2	3.500	3.570	3.613	3.525	0.070	0.5068	0.7203	0.1719	0.6156
End of P 3	4.359	4.371	4.354	4.309	0.057	0.8221	0.4743	0.5428	0.9123
End of P 4	4.755[x]	4.761[x]	4.765[x]	4.593[y]	0.054	0.0964	0.0559	0.0956	0.7395
End of P 5	5.426	5.458	5.393	5.341	0.065	0.5030	0.2341	0.5140	0.4781

[a,b,c] Means with superscript different significant differ (*P* < 0.05).

[x,y,z] Means with superscript different trend differ (*P* < 0.10).

1. Proc IML was used to generate coefficient for orthogonal contrast by using L-lysine supplementation level from each treatment for each phase.
2. 10th rib Backfat and loin depth were measured from individual by ultrasound technique at phase change, and the end of study.
3. 10th rib Backfat and loin depth data from three pigs per pen were collected, and served as covariance for analysis of subsequence ultrasound backfat and loin depth data.

Table 13. . Effect of increasing crystalline amino acids in grower/finisher pigs fed diets formulated on a NE basis on carcass composition, LS means.

	Treatment					*P* - Value			
	1	2	3	4	SEM	Trt	Linear[2]	Quadratic	Cubic
HCW, kg	97.9[a]	98.5[a]	96.9[ab]	94.6[b]	1.01	0.0173	0.0066	0.1330	0.3123
Yield, %	72.94	73.34	73.24	73.92	0.73	0.7749	0.3185	0.8798	0.8240
Lean, %	53.11	53.07	52.61	53.34	0.28	0.3116	0.6053	0.1667	0.2386
Loin depth, mm	63.70	63.43	63.42	62.71	0.78	0.8298	0.3740	0.8238	0.9259
Backfat, mm	19.52[ab]	19.27[a]	20.95[b]	19.01[a]	0.55	0.0722	0.6220	0.1183	0.0339
Adjusted[1]									
Yield, %	72.75	73.01	73.25	74.43	0.79	0.3901	0.0970	0.5608	0.9601
Lean, %	53.15	53.14	52.61	53.23	0.29	0.3770	0.9200	0.2546	0.1986
Loin depth, mm	63.50	63.07	63.43	63.27	0.78	0.9790	0.8840	0.8689	0.7218
Backfat, mm	19.44[ab]	19.11[a]	20.96[b]	19.25[a]	0.57	0.0761	0.9813	0.1929	0.0250

[a,b,c] Means with superscript different significant differ ($P < 0.05$).

1. Hot carcass weight is served as covariance for data analysis
2. Coefficient used for orthogonal contrast is generated based on L-lysine supplementation level from finisher phase

Table 14. Profitability of AA during grower-finisher period

	Trt 1, Control	Trt 2 Val or Ile Set Point	Trt 3 Val and Ile Set Point	Trt 4 His Set Point
Feed ingredient Cost, $/pig	83.41	79.11	78.67	83.26
Carcass value, $/pig[1]	243.31	244.80	240.82	235.10
Total Profit[2], $/pig	159.89	165.69	162.15	151.84
Economic value[3], $/pig	0	5.79	2.25	-8.05

[1]Calculated based on carcass weight on each treatment and market price on 5/21/14.
[2]Note that this is feed ingredient cost only, and does not include other costs (Total Profit = carcass value - feed ingredient cost).
[3]Total Profit Value Difference between Trt 1 vs. Trt 2, 3, or 4.

Table 15. Effects of feed-grade AA supplementation in reduced CP (RCP) diets on the fatty acid composition of belly fat layers

	Treatments[1]					Belly fat layer[2]				*P*-value[3]				
	Ctrl	RCP1	RCP2	RCP3	SEM	Outer	Mid	Inter	SEM	TRT	LAY	T×L	Lin	Quad
ΣSFA	$34.11^{\mathbf{B}}$	34.79^{A}	35.31^{A}	35.00^{A}	0.255	31.93^{C}	34.83^{B}	37.65^{A}	0.227	**0.003**	**<0.001**	0.280	**0.006**	**0.023**
10:0	0.060^{D}	0.065^{C}	0.072^{B}	0.078^{A}	0.0020	0.056^{B}	0.075^{A}	0.077^{A}	0.0018	**<0.001**	**<0.001**	0.308	**<0.001**	0.881
12:0	0.067^{D}	0.070^{C}	0.073^{B}	0.077^{A}	0.0011	0.063^{C}	0.072^{B}	0.080^{A}	0.0010	**<0.001**	**<0.001**	0.150	**<0.001**	0.682
14:0	1.24^{C}	1.30^{B}	1.33^{B}	1.36^{A}	0.016	1.26^{C}	1.29^{B}	1.38^{A}	0.015	**<0.001**	**<0.001**	0.271	**<0.001**	0.221
15:0	0.072^{A}	0.067^{B}	0.062^{C}	0.063^{BC}	0.0020	0.070^{A}	0.062^{B}	0.066^{B}	0.0017	**<0.001**	**0.001**	0.518	**<0.001**	**0.055**
16:0	21.13^{C}	21.61^{B}	21.99^{A}	22.06^{A}	0.147	20.43^{C}	21.76^{B}	22.91^{A}	0.130	**<0.001**	**<0.001**	0.418	**<0.001**	**0.091**
17:0	0.44^{A}	0.43^{AB}	0.39^{C}	0.40^{BC}	0.114	0.44^{A}	0.40^{B}	0.40^{B}	0.010	**0.002**	**0.008**	0.294	**0.002**	0.211
18:0	10.88^{AB}	11.05^{AB}	11.19^{A}	10.75^{B}	0.138	9.41^{C}	10.97^{B}	12.54^{A}	0.124	**0.057**	**<0.001**	0.360	0.412	**0.014**
20:0	0.20	0.20	0.21	0.21	0.002	0.21^{B}	0.21^{A}	0.19^{C}	0.002	0.494	**<0.001**	0.899	0.251	0.714
ΣMUFA	43.03^{B}	43.26^{B}	44.25^{A}	44.99^{A}	0.327	45.31^{A}	44.82^{A}	41.51^{B}	0.296	**<0.001**	**<0.001**	0.208	**<0.001**	0.514
16:1t	0.056^{A}	0.050^{B}	0.042^{C}	0.033^{D}	0.0014	0.049^{A}	0.045^{B}	0.042^{B}	0.0012	**<0.001**	**0.001**	**0.024**	**<0.001**	0.519
16:1c	1.85^{C}	1.94^{C}	2.10^{B}	2.31^{A}	0.053	2.11^{A}	2.08^{A}	1.96^{B}	0.051	**<0.001**	**0.002**	0.883	**<0.001**	0.194
Σ18:1t	0.65^{A}	0.61^{B}	0.51^{C}	0.43^{D}	0.012	0.56	0.54	0.55	0.010	**<0.001**	0.162	0.626	**<0.001**	0.151

Table 15. CONTINUED

18:1c9	36.39^{B}	36.64^{B}	37.44^{A}	37.94^{A}	0.255	38.18^{A}	38.04^{A}	35.09^{B}	0.227	**<0.001**	**<0.001**	0.195	**<0.001**	0.760
18:1c11	3.26^{C}	3.22^{C}	3.37^{B}	3.49^{A}	0.048	3.54^{A}	3.33^{B}	3.15^{C}	0.044	**<0.001**	**<0.001**	0.129	**<0.001**	**0.063**
20:1	0.82	0.79	0.79	0.79	0.009	0.88^{A}	0.80^{B}	0.72^{C}	0.008	0.100	**<0.001**	0.352	**0.022**	0.342
ΣPUFA	21.61^{A}	20.76^{B}	19.30^{C}	18.84^{C}	0.345	21.47^{A}	19.20^{B}	19.72^{B}	0.310	**<0.001**	**<0.001**	0.132	**<0.001**	0.316
18:2n6	18.96^{A}	18.33^{A}	17.05^{B}	16.78^{B}	0.314	18.87^{A}	16.95^{B}	17.52^{B}	0.283	**<0.001**	**<0.001**	0.116	**<0.001**	0.336
18:2c9t11	0.141^{A}	0.128^{B}	0.121^{C}	0.109^{D}	0.0017	0.140^{A}	0.124^{B}	0.110^{C}	0.0016	**<0.001**	**<0.001**	0.862	**<0.001**	0.379
ΣCLA	0.19^{A}	0.17^{B}	0.16^{C}	0.14^{D}	0.004	0.19^{A}	0.16^{B}	0.13^{C}	0.004	**<0.001**	**<0.001**	0.896	**<0.001**	0.114
18:3n3	0.98^{A}	0.85^{B}	0.76^{C}	0.64^{D}	0.013	0.85^{A}	0.78^{B}	0.79^{B}	0.012	**<0.001**	**<0.001**	0.198	**<0.001**	0.266
20:2	0.83^{A}	0.81^{A}	0.76^{B}	0.76^{B}	0.013	0.91^{A}	0.76^{B}	0.70^{C}	0.011	**<0.001**	**<0.001**	0.750	**<0.001**	0.262
20:3n6	0.13^{A}	0.12^{A}	0.12^{B}	0.11^{B}	0.002	0.13^{A}	0.11^{B}	0.11^{B}	0.002	**<0.001**	**<0.001**	0.439	**<0.001**	0.834
20:3n3	0.14^{A}	0.12^{B}	0.11^{C}	0.09^{D}	0.002	0.14^{A}	0.11^{B}	0.10^{C}	0.003	**<0.001**	**<0.001**	0.797	**<0.001**	0.128
20:4	0.27^{A}	0.26^{AB}	0.26^{B}	0.25^{B}	0.004	0.27^{A}	0.25^{B}	0.26^{A}	0.004	**0.030**	**0.003**	0.166	**0.005**	0.379
22:5	0.071^{A}	0.062^{B}	0.058^{C}	0.051^{D}	0.0010	0.064^{A}	0.057^{C}	0.060^{B}	0.0017	**<0.001**	**<0.001**	0.218	**<0.001**	0.146
Other FA	1.27^{A}	1.21^{B}	1.16^{C}	1.18^{BC}	0.016	1.31^{A}	1.16^{B}	1.14^{B}	0.014	**<0.001**	**<0.001**	0.707	**<0.001**	**0.008**
ΣUFA	64.64^{A}	64.02^{B}	63.55^{B}	63.83^{B}	0.246	66.78^{A}	64.03^{B}	61.23^{C}	0.219	**0.007**	**<0.001**	0.271	**0.010**	**0.031**
PUFA: SFA	0.64^{A}	0.61^{B}	0.55^{C}	0.55^{C}	0.013	0.68^{A}	0.55^{B}	0.53^{B}	0.011	**<0.001**	**<0.001**	0.334	**<0.001**	0.135

Table 15 CONTINUED

IV	72.5^{A}	71.26^{B}	69.2^{C}	69.4^{C}	0.42	74.0^{A}	70.0^{B}	68.1^{C}	0.372	**<0.001**	**<0.001**	0.139	**<0.001**	**0.083**

[1]Ctrl = control diets; RCP1 = …

[2]Outer = outer s.c. layer; Mid = middle and inner s.c. layer; and Inter = intermuscular fat.

[3]Probability values for main effect of RCP diets (TRT); main effect of belly fat layer (LAY); RCP × belly fat layer (T × L); and linear (LIN) and

quadratic (QUAD) effects of RCP diets.

[A – D]Within a row and main effect, least squares means lacking a common superscript letter differ, $P < 0.05$.

Table 16. Effects of feed-grade AA supplementation in reduced CP (RCP) diets on the fatty acid composition of jowl subcutaneous fat

	Treatments[1]					*P*-value[2]		
	Ctrl	RCP1	RCP2	RCP3	SEM	TRT	LIN	QUAD
ΣSFA	30.55	31.46	31.16	31.47	0.338	0.214	**0.085**	0.359
10:0	0.057^{B}	0.059^{B}	0.063^{AB}	0.068^{A}	0.0022	**0.005**	**<0.001**	0.643
12:0	0.060^{B}	0.063^{AB}	0.064^{AB}	0.068^{A}	0.0017	**0.030**	**0.003**	0.847
14:0	1.21^{B}	1.26^{AB}	1.25^{B}	1.31^{A}	0.020	**0.008**	**0.001**	0.922
15:0	0.069	0.065	0.062	0.062	0.0027	0.231	**0.062**	0.444
16:0	19.83^{B}	20.37^{AB}	20.29^{AB}	20.62^{A}	0.194	**0.056**	**0.010**	0.510
17:0	0.41	0.40	0.39	0.38	0.016	0.590	0.207	0.629
18:0	8.73	9.06	8.85	8.77	0.174	0.574	0.995	0.272
20:0	0.18	0.19	0.19	0.19	0.004	0.605	0.435	0.385
ΣMUFA	46.80^{B}	46.95^{B}	47.91^{AB}	48.46^{A}	0.442	**0.041**	**0.009**	0.757
16:1t	0.052^{A}	0.048^{A}	0.045^{B}	0.035^{C}	0.0013	**<0.001**	**<0.001**	**0.063**
16:1c	2.15^{B}	2.20^{B}	2.34^{AB}	2.57^{A}	0.103	**0.035**	**0.006**	0.446
Σ18:1t	0.58^{A}	0.55^{A}	0.49^{B}	0.40^{C}	0.015	**<0.001**	**<0.001**	0.178
18:1c9	39.27^{B}	39.37^{B}	40.13^{AB}	40.41^{A}	0.352	**0.081**	**0.022**	0.905

Table 16 CONTINUED

18:1c11	3.80^{B}	3.86^{B}	3.99^{AB}	4.11^{A}	0.080	**0.048**	**0.008**	0.794
20:1	0.94	0.92	0.92	0.93	0.024	0.922	0.789	0.533
ΣPUFA	21.26^{A}	20.28^{AB}	19.61^{BC}	18.77^{C}	0.406	**0.002**	**<0.001**	0.712
18:2n6	18.43^{A}	17.69^{AB}	17.11^{BC}	16.51^{C}	0.371	**0.008**	**0.001**	0.712
18:2c9t11	0.152^{A}	0.138^{B}	0.138^{B}	0.120^{C}	0.0033	**<0.001**	**<0.001**	0.734
ΣCLA	0.22^{A}	0.21^{A}	0.21^{A}	0.19^{B}	0.006	**0.004**	**<0.001**	0.679
18:3n3	0.96^{A}	0.83^{B}	0.78^{C}	0.65^{D}	0.016	**<0.001**	**<0.001**	0.726
20:2	0.94^{A}	0.91^{AB}	0.88^{B}	0.87^{B}	0.018	**0.055**	**0.009**	0.726
20:3n6	0.144^{A}	0.136^{AB}	0.136^{AB}	0.128^{B}	0.0031	**0.011**	**0.001**	0.804
20:3n3	0.153^{A}	0.135^{B}	0.125^{C}	0.106^{D}	0.0025	**<0.001**	**<0.001**	0.674
20:4	0.28	0.27	0.27	0.26	0.007	0.299	**0.087**	0.927
22:5	0.075^{A}	0.066^{B}	0.067^{B}	0.055^{C}	0.0016	**<0.001**	**<0.001**	0.531
Other FA	1.41	1.34	1.34	1.31	0.035	0.274	**0.068**	0.545
ΣUFA	68.06	67.23	67.52	67.24	0.320	0.246	**0.104**	0.374
PUFA:SFA	0.70^{A}	0.65^{B}	0.63^{BC}	0.60^{C}	0.017	**0.003**	**<0.001**	0.515
IV	74.9^{A}	73.3^{B}	73.0^{B}	72.0^{B}	0.48	**0.003**	**<0.001**	0.443

[1]Ctrl = control diets; RCP1 = …

[2]Probability values for main effect of RCP diets (TRT), as well as the linear (LIN) and quadratic (QUAD) effects of RCP diets.

[A – D]Within a row and main effect, least squares means lacking a common superscript letter differ, $P < 0.05$.

Table 17. Effects of feed-grade AA supplementation in reduced CP (RCP) diets on the fatty acid composition of the LM

	Treatments[1]					*P*-value[2]		
	Ctrl	RCP1	RCP2	RCP3	SEM	TRT	LIN	QUAD
ΣSFA	35.66	36.14	36.20	36.29	0.447	0.757	0.334	0.647
10:0	0.094^{B}	0.102^{A}	0.101^{A}	0.101^{A}	0.0025	**0.038**	**0.045**	**0.035**
12:0	0.079	0.083	0.080	0.079	0.0018	0.365	0.868	0.152
14:0	1.18	1.25	1.25	1.25	0.031	0.302	0.154	0.215
15:0	0.057	0.053	0.053	0.060	0.0055	0.750	0.703	0.324
16:0	22.43	22.81	22.95	23.00	0.288	0.498	0.171	0.520
17:0	0.32^{A}	0.30^{AB}	0.28^{B}	0.28^{B}	0.013	**0.089**	**0.024**	0.533
18:0	11.44	11.45	11.38	11.43	0.187	0.994	0.952	0.914
20:0	0.166	0.167	0.164	0.162	0.0052	0.924	0.621	0.745
ΣMUFA	40.73^{C}	42.76^{BC}	44.57^{AB}	46.03^{A}	0.821	**0.001**	**<0.001**	0.568
16:1c	2.56^{C}	2.76^{BC}	3.02^{AB}	3.13^{A}	0.099	**0.001**	**<0.001**	0.493
Σ18:1t	0.36^{A}	0.34^{A}	0.29^{B}	0.26^{C}	0.009	**<0.001**	**<0.001**	0.807
18:1c9	32.92^{C}	34.57^{BC}	35.94^{AB}	37.03^{A}	0.676	**0.002**	**<0.001**	0.539

Table 17. CONTINUED

18:1c11	4.28^{C}	4.47^{BC}	4.69^{AB}	4.96^{A}	0.096	**<0.001**	**<0.001**	0.893
20:1	0.60	0.62	0.63	0.65	0.017	0.244	**0.046**	0.894
ΣPUFA	22.10^{A}	19.61^{AB}	17.79^{BC}	16.25^{C}	1.025	**0.003**	**<0.001**	0.513
18:2n6	17.03^{A}	15.10^{AB}	13.65^{BC}	12.46^{C}	0.729	**0.001**	**<0.001**	0.472
18:2c9t11	0.090^{A}	0.077^{B}	0.077^{B}	0.070^{C}	0.0021	**<0.001**	**<0.001**	**0.062**
ΣCLA	0.108	0.093	0.095	0.105	0.0076	0.392	0.852	**0.094**
18:3n3	0.49^{A}	0.42^{B}	0.37^{C}	0.30^{D}	0.011	**<0.001**	**<0.001**	0.536
20:2	0.46^{A}	0.43^{AB}	0.38^{BC}	0.36^{C}	0.017	**0.001**	**<0.001**	0.595
20:3n6	0.39	0.35	0.33	0.31	0.023	0.140	**0.025**	0.611
20:3n3	0.089^{A}	0.067^{B}	0.059^{B}	0.052^{B}	0.0075	**0.005**	**0.001**	0.216
20:4	3.09	2.79	2.57	2.40	0.239	0.234	**0.050**	0.714
20:5	0.109^{A}	0.091^{AB}	0.088^{AB}	0.074^{B}	0.0077	**0.031**	**0.004**	0.713
22:5	0.30^{A}	0.25^{AB}	0.22^{B}	0.19^{B}	0.021	**0.010**	**0.001**	0.627
22:6	0.110^{A}	0.099^{AB}	0.088^{AB}	0.078^{B}	0.0089	**0.093**	**0.015**	0.867
Other FA	1.56	1.52	1.48	1.47	0.063	0.773	0.331	0.770
ΣUFA	62.83	62.37	62.36	62.28	0.413	0.779	0.370	0.622

Table 17. CONTINUED

PUFA:SFA	0.63[A]	0.55[AB]	0.49[BC]	0.45[C]	0.035	**0.009**	**0.001**	0.558
IV	65.8[A]	64.0[AB]	62.9[BC]	61.9[C]	0.67	**0.003**	**<0.001**	0.431

[1]Ctrl = control diets; RCP1 = …
[2]Probability values for main effect of RCP diets (TRT), as well as the linear (LIN) and quadratic (QUAD) effects of RCP diets.
[A – D]Within a row and main effect, least squares means lacking a common superscript letter differ, $P < 0.05$.