

Nonruminant Nutrition: Amino Acids and Energy

658 Influence of net energy content of the diet on productive performance and carcass merit of gilts, boars, and immunocastrated males fed barley-based diets and slaughtered at 119 kg of BW. L. Cámara¹, M. Romero¹, M. P. Serrano¹, J. L. Sánchez², E. Alcázar², and G. G. Mateos*¹, ¹Departamento de Producción Animal, Universidad Politécnica de Madrid, Madrid, Spain, ²SAT Vallehermoso S.A., Ciudad Real, Spain.

In total, 540 crossbred pigs with an initial BW of 28.5 ± 4.1 kg were used to investigate the effects of increasing the level of NE of barley based diets (2.450, 2.410, 2.370, 2.330, and 2.290 Mcal/kg) on growth performance and carcass and meat quality traits of gilts, boars, and immunocastrated males (IMC) slaughtered at 119 kg BW. The IMC pigs were immunized against GnRF with Improvac at 90 and 143 d of age (18 and 71 d on trial). Each treatment (5 × 3) was replicated 3 times (12 pigs per pen). Gilts, boars, and IMC pigs responded similarly to NE concentration of the diet. For the entire experimental period, an increase in NE concentration of the diet improved linearly NE intake ($P < 0.05$), ADG ($P < 0.05$), and feed efficiency ($P < 0.001$) but ADFI and NE efficiency (g of ADG/Mcal NE intake) were not affected. Backfat depth (linear, $P < 0.05$, quadratic; $P = 0.078$), fat at m. *Gluteus medius* (linear, $P < 0.05$), and trimmed ham yield (linear, $P < 0.05$) increased as the NE concentration of the diet increased but carcass yield was not affected. The IMC pigs had higher ADFI ($P < 0.001$) and ADG ($P < 0.05$) than gilts and boars. Net energy efficiency was higher for boars than for gilts with IMC being intermediate ($P < 0.001$). Carcass and loin yields were higher for gilts than for boars and IMC ($P < 0.001$). Backfat depth ($P < 0.01$) and fat at m. *Gluteus medius* ($P < 0.001$) were higher for gilts and IMC than for boars. The results indicate that an increase in NE concentration of the diet improved growth performance and increased the amount of fat carcass independent of gender. The IMC pigs had higher ADG, backfat, fat at m. *Gluteus medius*, intramuscular fat, and similar carcass and primal cut yields than boars. The use of diets with NE content above 2.330–2.370 Mcal/kg is recommended for the production of pigs destined to the dry cured industry because of its beneficial effects on growth performance, backfat depth, and intramuscular fat that improved the quality of the final products.

Key Words: growth performance and carcass merit of pigs, immunocastration, net energy

659 Influence of increasing levels of lysine in the diet on growth performance and carcass quality of entire and immunocastrated females. L. Cámara¹, M. P. Serrano¹, A. López², J. M. González², F. Ortín², and G. G. Mateos*¹, ¹Departamento de Producción Animal, UPM, Ciudad Universitaria, Madrid, Spain, ²Piensos Jiménez S.L., Lorca, Murcia, Spain.

In total, 320 crossbred pigs (70 d of age) were used to study the influence of increasing levels of standardized ileal digestible lysine (Lysd) in the diet on growth performance and carcass and meat quality of gilts and immunocastrated gilts (IMG). The IMG were immunized against GnRF at 89 and 161 d of age. The feeding program consisted of 3 periods with 5 dietary Lysd levels used within each period. Diets within period were formulated to have the same net energy (NE) content (2,470 kcal/kg) but differed in Lysd concentration (control diet and ± 5% and ± 10% over the control diet). The Lysd concentration of the control diets was 1.01% from 70 to 89 d of age, 0.95% from 89 to 140 d of age, and 0.83% from 140 to 185 d of age. All the other indispensable amino acids were

formulated on an ideal protein bases. Each treatment was replicated 4 times and the experimental unit was the pen for all traits (8 pigs each for growth performance variables and 4 carcasses chosen at random for carcass and meat quality traits). From 70 to 89 d of age, ADFI was similar for pigs fed diets with -5% to +5% Lysd and decreased with -10% (linear, $P = 0.088$; quadratic, $P = 0.003$). Pigs fed -10% Lysd diet had worse G:F than pigs fed -5% to +10% Lysd diets (linear, $P < 0.001$; quadratic, $P = 0.010$). From 161 to 185 d of age, IMG had higher ADFI ($P < 0.001$) and ADG ($P = 0.023$) than gilts. Cumulatively, neither Lysd content of the diet nor immunocastration of gilts had any influence on growth performance of the pigs. Immunocastrated gilts tended ($P = 0.073$) to have higher fresh ham yield than gilts but none of the other carcass quality variables measured, were affected by Lysd content of the diet or immunocastration of the gilts. An increase in Lysd concentration in the diet increased protein content (linear, $P = 0.0185$) and reduced (linear, $P = 0.0373$) fat content of the meat measured at m. *Longissimus dorsi*. It is concluded that, under the conditions of the current experiment, the use of 1.01%, 0.86%, and 0.74% digestible Lys is recommended in each of the 3 feeding periods considered, in diets containing 2,470 kcal NE/kg.

Key Words: carcass quality of pigs, digestible lysine, immunocastration

660 The standardized ileal digestible (SID) tryptophan to lysine ratio to optimize performance of 25 to 50 kg pigs fed low protein diets. G. Zhang¹, S. Qiao¹, and J. K. Htoo*², ¹China Agricultural University, Beijing, China, ²Evonik Industries AG, Hanau, Germany.

Published data about the optimal SID Trp:Lys ratios for growing pigs fed low CP, AA-supplemented diets are rather inconsistent. Two 35-d experiments were conducted to estimate the optimal SID Trp:Lys in 25–50 kg pigs under commercial conditions. In Exp. 1, 144 pigs (Landrace × Large White; initial BW of 25.3 kg) were used to identify a diet deficient in Lys. Pigs were fed either a corn, soybean meal based high CP (18.6%) diet with 1.02% SID Lys or one of 2 low CP diets (14.6% CP but supplemented with Lys, Thr, Met, Thr, Trp, Val and Ile) to contain 0.90 or 1.02% SID Lys, respectively. All diets were formulated to contain 2400 kcal/kg NE and AA except Lys were adequate. Each diet was assigned to 6 pens with 4 barrows and 4 gilts per pen. The ADG (688 g/d) of pigs fed the low CP diet containing 0.90% SID Lys was lower ($P < 0.05$) than that of pigs fed the diet containing 1.02% SID Lys with a high (758 g/d) or low (747 g/d) CP content confirming that 0.90% SID Lys was deficient for these pigs. In Exp. 2, 300 pigs (same genetic and BW as used in Exp. 1) were allotted to 5 diets with 5 barrows and 5 gilts per pen and 6 replicates per treatment. Diets 1 to 5 contained SID Trp content of 0.12, 0.14, 0.17, 0.20 and 0.23%, respectively and the same suboptimal SID Lys level of 0.90% (dietary SID Trp:Lys of 13, 16, 19, 22 and 25%). The ADG increased linearly ($P < 0.05$) as the SID Trp:Lys increased while a linear effect of ADFI ($P < 0.05$) and a quadratic effect of FCR ($P < 0.05$) were observed. The d 36 plasma Trp concentration was highest ($P < 0.05$) at 25% SID Trp:Lys while plasma urea N concentration was lowest ($P < 0.05$) at 22% SID Trp:Lys. The SID Trp:Lys to optimize ADG, FCR and plasma urea N were 19.7, 20.0 and 20.8% using a linear broken-line model, and 22.6, 23.2 and 23.6% using a curvilinear-plateau model, respectively. On average, the optimal SID Trp:Lys was estimated at 22% for 25 to 50 kg pigs fed low CP, AA-supplemented diets under commercial conditions.

Key Words: growing pigs, lysine, tryptophan

661 Changes in amino acid accretion during immune activation of the chicken immune system by *E. coli*. V. J. Iseri* and K. C. Klasing, *University of California, Davis*.

The immune system requires appropriate levels of nutrients to support changes in leukocyte numbers and effector proteins during immune activation. However, a quantitative estimate of the amount of nutrients needed for maintenance and the additional amounts needed for a robust response has yet to be attempted. Thus, we quantified the total amino acid content of leukocytes in blood and tissues, protective plasma proteins, liver and pectoralis muscle in adult chickens before and after injected intravenously with dead *E. coli*. The amount of amino acids accreted during the early (first 2 d) and late (first 21 d) response were calculated. When comparing amino acids used for leukocytes and protective proteins relative to that in skeletal muscle, lysine was limiting during the early response and leucine, threonine, and valine were limiting for the late response. For liver, phenylalanine, asparagine, lysine, and valine were limiting relative to muscle during the early response and phenylalanine during the late response. Summing accretion for expansion of leukocytes, protective proteins and liver showed that lysine and asparagine were limiting during the early response and leucine, threonine, and valine were limiting during the late response. Supported by USDA Regional Research project 1013.

Key Words: chicken, *E. coli*, amino acids

662 Restricting sulfur amino acid intake in immune system stimulated pigs decreases plasma protein and albumin synthesis. N. Litvak* and C. F. M. de Lange, *University of Guelph, Guelph, ON, Canada*.

Chronic sub-clinical levels of disease occur frequently in intensive pork production and compromise nutrient utilization efficiency. Sulfur amino acids (Met+Cys; SAA) are involved in the pig's response to immune system stimulation (ISS) as substrates for generating compounds involved in the immune response, such as glutathione and acute phase proteins (APP; haptoglobin, fibrinogen, albumin). This study was conducted to determine the impact of ISS and SAA intake (high vs. low; 4.0 vs. 2.2 g/d) on the fractional synthesis rate (FSR) of albumin and protein in blood plasma, liver, and small intestine (SI) of pigs. Fifteen pigs (9.8 ± 1.4 kg BW) were allotted to one of 3 treatments: 1) Control (ISS-; high SAA), 2) ISS+ and high SAA, or 3) ISS+ and low SAA. For inducing ISS, pigs were injected intramuscularly twice, with a 48 h interval, with increasing doses of *E. coli* lipopolysaccharide (LPS); an ISS protocol that has been proven effective in previous studies. One day after the second LPS injection, FSR was determined using an intravenous infusion of a flooding dose of L-[ring-2H5]-Phe. Plasma levels of APP were not affected by ISS ($P > 0.10$; Control vs. ISS+ and high SAA). Only plasma albumin levels decreased with reduced SAA intake (29.0 vs. 24.2 g/L; ISS+ and high SAA vs. ISS+ and low SAA; SEM = 1.26; $P = 0.02$). Molar enrichment of free Phe in the liver and SI ranged from 86 to 91% of that in plasma, indicating adequate flooding. In plasma, total protein FSR was increased during ISS (50.3 vs. 56.9%/d, SEM = 1.64; $P = 0.01$) and plasma FSR tended to decrease with reduced SAA intake (56.9 vs. 52.5; SEM = 1.64; $P = 0.08$); albumin FSR was not affected by ISS ($P > 0.10$), but decreased with reduced SAA intake (49.5 vs. 41.9%/d, SEM = 1.57; $P = 0.01$). There were no treatment effects on FSR in liver and SI. The FSR of plasma proteins appears a more sensitive indicator of liver protein synthesis. Overall, these results suggest that restricting SAA intake during ISS decreases total plasma

protein and albumin synthesis, implicating SAA as important nutrients involved in the immune response.

Key Words: immune system stimulation, protein synthesis, sulfur amino acids

663 Response to dietary L-glutamine supplementation in weaned piglets: A serum metabolomic comparison and hepatic metabolic regulation analysis. Y. Xiao,* A. Chen, T. Wu, L. Yang, and Q. Hong, *College of Animal Sciences, Zhejiang University, Hangzhou, Zhejiang, China*.

A novel metabolomic method based on gas chromatography/mass spectrometry was applied to investigate the serum metabolite in response to dietary L-glutamine (Gln) supplementation in piglets. Sixteen 21-d-old piglets were weaned and randomly assigned into 2 groups, one with the Gln group and the other with the control group, representing 1% Gln (wt:wt) and isonitrogenous L-alanine, respectively. Serum samples were collected to characterize metabolites after a 30-d treatment. Additionally, 4 liver samples per group were collected to examine the enzyme activity and genes expression involved in metabolic regulation. Results showed 12 metabolites were significantly altered by Gln treatment, including carbohydrates, amino acids, and fatty acid. A leave-one-out cross-validation of random forest analysis indicated that proline and glycerol were the most important metabolites among the 12 different metabolites. These data demonstrated that the control and Gln-supplemented pigs showed a wide range of metabolic difference across carbohydrate metabolism, arginine and proline metabolism, tyrosine metabolism, and glycerophospholipid metabolism. Principal component analysis yielded separate clustering of profiles between the 2 treatment groups. Metabolic enzyme activity of alanine aminotransferase and hexokinase increased by 26.77% ($P = 0.026$) and 26.18% ($P = 0.004$), respectively, in the liver of Gln-supplemented pigs over the control, whereas pyruvate kinase (PK) activity decreased by 29.08% ($P = 0.001$). The mRNA level of PK decreased by 66.10% ($P = 0.034$) in the liver. No significant difference was observed for the mRNA level of mammalian target of rapamycin and peroxisome proliferator-activated receptor gamma. Based on the data, correlation networks for the Gln-supplemented and control pigs revealed that Gln treatment changed carbohydrate, lipid and amino acid metabolism in the whole body of the early weaned piglets. These findings provide fresh insight into specific metabolic pathways and lays the groundwork for the complex metabolic alteration in response to dietary Gln supplementation in pigs.

Key Words: glutamine, metabolomics, piglets

664 Effects of dietary glutamine supplementation on nutrient absorption and activity of enzymes involved in glutamine metabolism and energy production in the jejunum of weaned piglets. A. Chen,* Y. Xiao, T. W. Wu, Q. Hong, and C. Yang, *College of Animal Sciences, Zhejiang University, Hangzhou, Zhejiang, China*.

The influence of L-glutamine (Gln) on the coefficient of total tract apparent digestibility (CTTAD) and apparent ileal digestibility (AID), the jejunal enzyme activity associated with nutrient absorption, and the energy production in weaned piglets has not been sufficiently studied. The aim of the present paper is to provide a profile of the effects of Gln on CTTAD, AID, the activities of jejunal enzymes in connection with nutrient digestion and absorption and energy production. The piglets were weaned at 21 d of age. There were 2 groups in Exp. 1 and Exp. 2, representing supplementation with 0 or 1% Gln to the basal diet. In Exp. 1, the CTTAD of the dietary components and energy was assessed

at 3, 5, 10, 15, and 30 d after weaning. In Exp. 2, productive performance, AID, jejunal enzyme activities, and expression of peroxisome proliferator-activated receptor gamma (PPAR γ) were measured at 10 and 30 d post-weaning. Results showed that dietary Gln supplementation significantly improved the CTTAD of DM, OM, GE, and AA, and the CTTAD increased significantly with the extension of days after weaning. For the entire experiment, the average daily gain increased by 12.40% ($P = 0.049$) in the Gln group. Dietary Gln supplementation increased the AID of GE, Leu, Lys, Cys, and Pro by 12.50 ($P = 0.047$), 7.03% ($P = 0.041$), 5.95% ($P = 0.036$), 9.30 ($P = 0.025$), 11.17% ($P = 0.009$), respectively, at 10 d post-weaning; Pro by 6.11% ($P = 0.044$) at 30 d post-weaning. Jejunal brush border membrane-bound alkaline phosphatase activity increased in the Gln-supplemented pigs by 30.36% ($P = 0.048$) and 6.21% ($P = 0.30$) at 10 and 30 d post-weaning, respectively. Compared with the control pigs, the mRNA level of PPAR γ decreased by 10.85% ($P = 0.14$) and 41.88% ($P = 0.023$) after the administration of 1% Gln for 10 and 30 d, respectively. The activity of glutamine synthetase decreased by 48.89% ($P = 0.044$) at 10 d post-weaning, and pyruvate kinase by 13.13% ($P = 0.036$) at 30 d post-weaning in the Gln-supplemented pigs. In conclusion, 1% Gln supplementation to the post-weaned piglet diet enhanced the CTTAD and AID of diet, improved intestinal absorption, and modified jejunal enzyme activities related to Gln metabolism and energy production.

Key Words: L-glutamine, nutrient absorption, weaned piglets

665 Effects of oral supplementation with glutamate or combination of glutamate and N-carbamylglutamate on intestinal mucosa morphology in weanling piglets. W. Xin^{1,2}, P. Zhang^{1,2}, L. Zhiqiang¹, L. Tiejun¹, and Y. Yulong^{*1,2}, ¹Key Laboratory for Agro-ecological Processes in Subtropical Region, Institute of Subtropical Agriculture, Chinese Academy of Sciences, China, ²State Key Laboratory of Food Science and Technology and College of Life Science and Food Engineering, Nanchang University, China.

To evaluate the effects of glutamate (Glu) or combination of glutamate and N-carbamylglutamate (NCG) on intestinal mucosa in weanling piglets, 18 Duroc \times Landrace \times Yorkshire piglets weaned at 28 d (BW 5.56 ± 0.51 kg) were grouped into 3 treatments, and fed one of the following diets for 30 d: a standard diet (SD), SD+Glu (1%), SD+Glu (1%)+NCG (0.05%). All the piglets were killed for blood and tissue collection. The results showed that compared with the control group, Glu increased concentration of blood glucose and glucagon ($P < 0.05$) and reduced plasma insulin ($P < 0.05$) in weaned piglets. Both of Glu or combination of Glu and NCG decreased serum urea nitrogen and ammonia concentration ($P < 0.05$), and Glu+NCG increased average intestine weight significantly ($P < 0.05$). Compared with the control group, adding Glu to the diet resulted in a higher villus height ($P < 0.05$) in both of duodenum and jejunum. However, there was no difference in crypt depth at the 2 different locations, and the villus height/crypt depth ratio was unaltered ($P > 0.05$). The RT-PCR results showed that combination of Glu and NCG significantly increased PCNA mRNA abundance in both jejunum and ileum ($P < 0.05$), while they also significantly increased β -catenin and decreased VEGF in ileum ($P < 0.05$). There were no differences in expression of these genes between the Glu and Glu+NCG groups ($P > 0.05$). Only Glu increased ($P < 0.05$) PCNA mRNA abundance in jejunum, and Glu+NCG significantly decreased VEGF mRNA in jejunum ($P < 0.05$). These results indicated that oral supply of Glu improved intestinal mucosa morphology, and combined Glu and NCG had more favorable effects on self-renewing of intestinal mucosa than supply of glutamate alone.

Key Words: glutamate, N-carbamylglutamate, mucosal morphology