

# **A multicatheter surgical model to examine amino acid metabolism in weaned pigs**

Anna K. Shoveller, Suzan Cvitkovic, Janet A. Brunton, Robert F.P. Bertolo, Garson Law, and Ronald O. Ball

Alberta Pork Research Centre, 4-10 Agriculture/Forestry Centre, University of Alberta, Edmonton, AB T6G 2P5

We have developed a multi-catheter surgical model to determine the requirements and examine amino acid metabolism in piglets during the postnatal and weaning period. Surgical procedures have been developed which allow placement of catheters into the stomach and the femoral, portal and jugular veins. This is combined with the infusion of radioactive isotopes of amino acids to measure amino acid flux as well as both protein synthesis and oxidation.

Pigs are fed a complete diet either into the stomach (intragastrically) or entirely intravenously. This model simulates the gut of a pig which has suffered from gut dysfunction due to stresses such as imbalanced diet, low feed intake, diarrhea or other intestinal disease. This model has the advantage of being less variable and more reproducible than these syndromes.

The objective is to determine the oral amino acid requirements of young weaned pigs and the requirements of the gastrointestinal tract for amino acids, as separated from the needs of the whole body. Our ultimate objective is to develop diets which will enhance gut development post-weaning and increase recovery from gastrointestinal insult (such as diarrhea, low feed intake, changing feed composition or source, etc.).

## **Implications**

This research will lead to formulation of diets for weaned piglets that result in better performance, fewer feed intake problems, more consistent growth between piglets, fewer gastrointestinal problems, less mortality and morbidity, reduced costs for weaning diets and better subsequent performance to market weight. These results will have application to piglets weaned at very early ages (birth to 1 week), early weaning (10 to 14 days) and more traditional weaning ages (3-4 weeks). These approaches should also be useful in treating and increasing performance of growing/finishing pigs that suffer from similar intestinal and feed intake problems.

# Dietary arginine and proline requirements are influenced by gut function in neonatal piglets

Janet A Brunton<sup>1</sup>, Robert FP Bertolo<sup>2</sup>, Paul B Pencharz<sup>1</sup> and Ronald O Ball<sup>1,2</sup>

<sup>1</sup>Alberta Pork Research Centre, 4-10 Agriculture/Forestry Centre, University of Alberta, Edmonton, AB T6G 2P5;

<sup>2</sup>Dept of Human Biology and Nutritional Science, University of Guelph, Guelph, ON N1G 2W1;

In the neonatal piglet, the small intestine appears to be the primary site of arginine synthesis; the major precursor for arginine is likely proline. The small gut may also have a regulatory role in maintaining whole body proline supply. When gut function is compromised (ie. during weaning or gastrointestinal infection) dietary requirements for arginine and proline are probably increased due to a loss in gut metabolic function.

## Study Design

Gut atrophy was induced in a group of 2 d old piglets (N=6) by providing a nutritionally complete diet via continuous intravenous feeding (IV). A second group of piglets (N=6) was given the same diet via a surgically implanted gastric feeding catheters (IG). After a 4 d adaptation period, each pig was fed isonitrogenous diets free of arginine (-ARG), proline (-PRO) or arginine and proline (-ARG/PRO) on 3 consecutive days in a randomized crossover design. Serial blood sampling was used to monitor the rise in plasma ammonia levels (a consequence of arginine deficiency), and deficient diets were stopped when hyperammonemia reached a critical value of 270 mM (CrV) or at 8 h.

## Results

Time to CrV was shorter in IV pigs fed -ARG ( $5.8 \pm 1.6$  h) (mean  $\pm$  SD) and -ARG/PRO ( $6.0 \pm 1.3$ ) compared to IG pigs which all reached 8 h. The rate of rise in ammonia was greater for -ARG/PRO compared to -ARG in the IG pigs only (IG: -ARG vs -ARG/PRO,  $11 \pm 7$  vs  $31 \pm 15$ ,  $P=0.006$ ), indicating that only IG fed piglets could use dietary proline to ameliorate the arginine deficiency. Plasma arginine was greater in IG versus IV piglets at baseline ( $P=0.01$ ) and at cessation ( $P=0.005$ ) of the -ARG diet. The -PRO diets also resulted in plasma proline concentrations indicative of deficiency (compared to sow fed piglets) which was more profound in IV pigs (IV vs IG,  $67 \pm 20$  vs  $130 \pm 16$  mM,  $P<0.001$ ; sow fed =  $669 \pm 144$ ).

## Implications

The dietary requirements for arginine and proline are increased with gastrointestinal trauma. Proline can spare the arginine requirement only when the gut is healthy

and fully functional.

# Threonine requirement in weaned piglets is affected by gut function

Garson Law<sup>1</sup>, Cathy Z.L. Chen<sup>2</sup>, Robert F.P. Bertolo<sup>2</sup>, Paul B. Pencharz<sup>1</sup> and Ronald O Ball<sup>1,2</sup>

<sup>1</sup>Alberta Pork Research Centre, 4-10 Agriculture/Forestry Centre, University of Alberta, Edmonton, AB T6G 2P5;

<sup>2</sup>Dept of Human Biology and Nutritional Science, University of Guelph, Guelph, ON N1G 2W1

Dietary threonine (Thr) is essential to the structure and function of the mucous lining of the gastrointestinal tract. This lining is highly comprised of Thr-rich mucous proteins and covers the entire lumenal surface of the gut in order to act as a protective barrier, lubricant, and to promote digestion. During weaning, piglets undergo gut stresses, resulting in such symptoms as diarrhea, where the mucous layer is disturbed and the digestive process is disrupted.

In this study, Thr requirement was determined in 26 and 25 Yorkshire piglets receiving intragastric and intravenous TPN, respectively, by the indicator amino acid oxidation technique. Intravenous feeding simulated conditions of gut stress due to lack of food intake. The effects of varying dietary intake of Thr on phenylalanine (Phe) oxidation under dietary conditions of adequate energy and Phe and excess tyrosine were examined. Phe oxidation was determined from a primed, constant intravenous infusion of L-[1-<sup>14</sup>C] Phe (3.5  $\mu$ ci/kg/h) and measurement of the specific radioactivity of Phe in plasma. Neither Phe flux and its components, nor Phe conversion to tyrosine were significantly affected by graded Thr intake. Phe oxidation (estimated from the absolute rate <sup>14</sup>CO<sub>2</sub> released in expired breath during the infusion of L-[1-<sup>14</sup>C] Phe) decreased linearly as Thr intake increased from 0.05 to 0.2 g/kg/d in piglets fed intravenously. At Thr intakes >0.2 g/kg/d, Phe oxidation was low and constant. An estimation of a safe level of Thr intake was determined to be 0.212 g/kg/d by break point analysis. In piglets receiving intragastric nutrition, Phe oxidation estimated by expired <sup>14</sup>CO<sub>2</sub> decreased linearly as Thr intake increased from 0.1 to 0.6 g/kg/d, and then remained constant at intakes >0.6 g/kg/d. An estimation of a safe level of Thr intake was determined to be 0.55 g/kg/d. The lysine requirement under these conditions is 0.84 g/kg/d and 0.98 g/kg/d for intravenous and intragastric feeding, respectively.

## Implication

These data indicate that 1) Thr use by the gut may account for up to 60% of whole-body needs; and 2) Adequate dietary Thr is critical for proper structure and function of the mucous lining of the gut. Therefore, Thr requirement may be greater during periods of recovery from gut stress such as following weaning.

# Comparison of intestinal characteristics in early-weaned versus suckling piglets of the same age

Robert FP Bertolo<sup>2</sup>, Angela L Ewtushik<sup>2</sup> and Ronald O Ball<sup>1,2</sup>,

<sup>1</sup>Alberta Pork Research Centre, 4-10 Agriculture/Forestry Centre, University of Alberta, Edmonton, AB T6G 2P5; <sup>2</sup>Dept of Animal and Poultry Science, University of Guelph, Guelph, ON, Canada, N1G 2W1

The weaning process is often characterized with initial reductions in performance and slower growth. This problem is compounded by the trend to earlier weaning, often as young as 10 days of age. A high quality post-weaning diet is required to aid the transition from highly-digestible sow's milk to less-digestible grain-based solid feed. The digestive system of the early-weaned piglet is immature, and as a result cannot fully tolerate an adult diet that is composed mainly of grain and oilseed meal often resulting in a growth lag. A diet that would shorten the adaptation period from the pre- to post-weaning phase would be beneficial to both the animal and the producer. The objective of this research was to first distinguish between the changes in intestinal development caused by alterations in diet composition (sow's milk versus dry feed), from those that occur naturally with age.

We compared changes in intestinal physiology of suckling piglets at 12 and 24 days of age and changes in suckling versus early-weaned piglets consuming a commercial dry, pelleted feed. Experimental design consisted of three groups of male, intact, Yorkshire piglets; 1) 12-day old suckled group (n=6, 4.06 ± 0.35 kg), 2) 24-day old suckled group (n=6, 6.59 ± 0.57 kg), and 3) 24-day old early-weaned piglets, weaned at 12 days of age (n=7, 6.56 ± 1.32 kg). In general, early -weaned piglets had larger organs and intestinal tissue weights compared to both suckled groups (p<0.05). In particular, total mucosal weight was 50% greater in the early-weaned pigs compared to suckled pigs of the same age. In several sections of the intestine, villus height and crypt depth were greater in the early-weaned piglets compared to 24-day old suckled piglets (p<0.05).

## Implications

These data indicate that early-weaning increases intestinal growth in the piglet. Sow's milk is an adequate nutrition source at 12 days of age, whereas by 24 days, intestinal development is limited by exclusive suckling. However, maximizing feed intake in the early-weaned piglet is critical to achieve this growth potential. Because early weaning diets are so expensive compared to suckling, the ultimate goal in raising early-weaned piglets is to enhance the rate of intestinal development, thereby reducing the time required to feed the piglet starter diet.

# Lysine and phenylalanine requirements of sows

S. Möhn, R.F.P. Bertolo, P.B. Pencharz and R.O. Ball

Alberta Pork Research Centre, 4-10 Agriculture/Forestry, University of Alberta, Edmonton, AB T6G 2P5

The amino acid requirements of sows show a large variability. Traditional methods need a large amount of time and animals to obtain requirement values while the indicator amino acid oxidation method allows repeated measurements in a short time period. We propose to use this method to determine the requirements of lysine and phenylalanine for maintenance and pregnancy in sows.

The indicator amino acid oxidation method relies on the partitioning of amino acids to protein synthesis and oxidation. The oxidation of the indicator amino acid declines as the intake of the first-limiting amino acid increases. Once the intake of the first-limiting amino acid exceeds the requirement, the oxidation rate of the indicator remains constant. The requirement of the test amino acid can then be determined by two-phase regression analysis.

Chronically catheterized sows adapted to semi-synthetic diets are offered one of six diets differing only in the level of the test amino acid. After sufficient adaptation time, the animals are placed in an open-circuit respiration system to quantify expired  $^{14}\text{CO}_2$  and measure energy exchange during a 4-h primed, constant infusion of L-[1- $^{14}\text{C}$ ]-phenylalanine. This procedure is repeated until each animal has been offered each dietary level of the test amino acid.

Preliminary trials are conducted to determine the phenylalanine kinetics in sows and to determine the minimum time of adaptation to a dietary regimen to obtain valid measurements. Based on these results, the phenylalanine and lysine requirements for maintenance and late pregnancy are determined using latin square designs, which allow the estimation of the requirements of individual animals, as well as the population mean  $\pm$ SD. The results allow us to develop a factorial model for the amino acid requirements, based on maintenance needs and requirements for maternal and fetal growth.

## Implication

An improved knowledge of amino acid requirements allows the formulation practical sow diets with greater accuracy which will reduce the cost per unit feed and minimize the environmental impact of pig production.

# Influence of lysine and energy intake on lysine utilization in growing pigs

S. Möhn<sup>1</sup>, A.M. Gillis<sup>1</sup>, P.J. Moughan<sup>2</sup>, R.O. Ball<sup>3</sup> and C.F.M. de Lange<sup>1</sup>

<sup>1</sup>Department of Animal and Poultry Science, University of Guelph, Guelph, ON N1G 2W1; <sup>2</sup>Massey University, Palmerston North, New Zealand; <sup>3</sup>Alberta Pork Research Centre, 4-10 Agriculture/Forestry Centre, University of Alberta, Edmonton, AB T6G 2P5

There is still considerable debate about the efficiency of retaining available lysine (kLys) for body protein deposition (PD) in growing pigs. Possible factors of influence are animal performance potential, body weight (BW), nutritional regimen or the methodologies used to estimate kLys. In this study we determined the effects of true ileal digestible lysine intake (IDL) and metabolizable energy intake (MEi) and BW on whole body PD and kLys in gilts between 45 and 75 kg BW using the serial slaughter and N-balance methods.

A total of 52 female Yorkshire pigs were allocated to 13 dietary regimens and subjected to N-balances at 45 and 75 kg BW and to serial slaughter between these BW. In addition, 26 animals were sacrificed as the initial slaughter group. Semi-synthetic diets based on casein and cornstarch provided protein-bound lysine to allow a PD of 70% (L70, IDL 11.1 g/d) or 90% (L90, IDL 13.2 g/d) of the pigs' maximum PD. At L70, the pigs were fed 1 of 6 levels of MEi ranging from 14.0 to 23.5 MJ/d. At L90, pigs were fed 1 of 7 levels of MEi ranging from 15.6 to 26.4 MJ/d. Based on the results of the N-balances and serial slaughter, MEi and IDL had independent effects on PD and kLys. When MEi increased, PD and kLys increased until a plateau was reached. At the plateaus, PD was determined by IDL and there was no effect ( $P > 0.1$ ) of MEi on kLys. Based on the N-balances, there was no effect ( $P > 0.1$ ) of BW on kLys. The results indicate that the efficiency of retaining absorbed available lysine intake over maintenance for PD (marginal kLys) is about 75% and was not affected by BW, energy or lysine intake levels evaluated in this study.

## Implication

The marginal efficiency of retaining absorbed and available lysine is about 75 % and appears not affected by body weight, energy or lysine intake. This value can be used to predict the lysine requirements of different groups of pigs under a range of conditions.

# **Development of whole body protein and lipid deposition growth curves in pigs of a defined commercial genotype.**

Mark L. Lorsch, John F. Patience and Doug A. Gillis.

Prairie Swine Centre Inc., P.O. Box 21057, 2105 - 8th Street East, Saskatoon, SK. S7H 5N9.

Further improvements in pork quality and production efficiency can be achieved through greater precision in diet formulation. Providing the nutrients required to achieve production and carcass quality objectives, while avoiding costly over formulation, is the key to minimizing feed costs. Clearly, diets can be formulated more accurately by defining lean accretion curves and the partitioning of nutrients to carcass lean and lipid. The critical step is linking energy and amino acid requirements to lean and lipid gain, so that the precise need for energy and amino acids can be supplied in diets. Fifty-eight barrows and gilts were used in a carcass analysis experiment to characterize the changes in body composition (i.e. water, protein, lipid and ash content) from 24 to 120 kg. Protein deposition rate increased after 24-kg bodyweight, reached a peak, and proceeded to decline towards 120-kg bodyweight. Peak protein deposition was calculated as 150 g/d between 43 and 52-kg bodyweight and 133 g/d between 68 and 74-kg bodyweight, for barrows and gilts, respectively. Barrows deposited protein at a greater rate than gilts until 87-kg bodyweight. Protein deposition for barrows was less than gilts after 87-kg bodyweight because of a continual increase in their rate of lipid deposition towards 120-kg bodyweight. Differences in protein and lipid deposition between genders throughout growth imply differences in amino acid and energy requirements.

## **Implication**

These findings reinforce the need for split sex and multiple phase feeding programs to enhance production efficiency. This information allows pork producers to minimize feed costs, as well as maximize returns from the sale of market animals, since carcass indices are dependent on the proportion of lean and lipid on the carcass.

# Effect of enzyme supplementation of wheat-canola meal diets on growth performance and nutrient digestibility in weaned pigs

R.T. Zijlstra, S. Li, and J.F. Patience.

Prairie Swine Centre Inc., P.O. Box 21057, 2105 - 8th Street East, Saskatoon, SK. S7H 5N9.

The nutritional value of canola meal is limited by fibrous components. Thus, the objective was to evaluate the effect of increasing rates of enzyme supplementation ( $\beta$ -glucanase and xylanase mix) on growth performance and nutrient digestibility.

Pigs (PIC; N=96) were weaned at 21-days, housed in groups of 4 pigs and, after a 7-day acclimation period, allowed free access to 1 of 4 diets for 28-days. Diets were a basal diet (65% wheat, 25% canola meal) or the basal diet with enzyme mix at three inclusion rates (1, 2, 4 g/kg). Overall, average daily feed intake (ADFI;  $P < 0.05$ ) and average daily gain (ADG;  $P < 0.05$ ) increased quadratically with supplementation.

Specifically, supplementation at 2 g/kg increased ADFI 16% (729 versus 629 g/d;  $P < 0.05$ ) and ADG 13% (451 versus 398 g/d;  $P < 0.05$ ), compared to the basal diet.

Pigs (n=6 per treatment) were euthanised to collect small intestine digesta. Supplementation did not affect apparent digestibilities of DM, energy, and NDF. Supplementation at 4 g/d reduced viscosity of ileum digesta 30% (1.9 versus 2.7;  $P < 0.05$ ), compared to the basal diet.

## Implication

Enzyme supplementation increased feed intake and growth performance in weaned pigs with free access to a wheat-canola meal diet, but did not affect nutrient digestibility.

# Variation in the digestible energy content of field peas for grower pigs.

R. T. Zijlstra, J. F. Patience, S. L. Fairbairn, D. A. Gillis, and D. L. Whittington.

Prairie Swine Centre Inc., P.O. Box 21057, 2105 - 8th Street East, Saskatoon, SK. S7H 5N9.

Description and definition of the variation in nutritional value of feed ingredients are becoming increasingly important to the swine industry. We have previously shown that barley digestible energy (DE) for growing pigs varied by 15%. The specific objective of this study was to describe the variation in DE content in samples of 11 field pea varieties that were grown on a single plot of land in Saskatchewan.

Eleven field pea diets (field peas, 40%; wheat, 55.7%; vitamins and minerals, 3.9%; chromic oxide, 0.4%) and one control diet (95.7% wheat) were fed in mash form twice daily at intake levels estimated to provide 2.5 x maintenance DE. Barrows ( $38.7 \pm 5.0$  kg, SD) were housed individually in metabolism crates allowing separate collection of feces and urine during 4-day collections. Three replicates provided 50 observations in total, with 4 observations per field pea diet and 6 observations for the control diet. Dry matter, gross energy and chromic oxide were analyzed in diets and feces according to standard procedures. The DE content in the field pea samples (90% DM) ranged from  $3098 \pm 115$  kcal/kg in variety Emerald to  $3739 \pm 101$  kcal/kg in variety Mustang (overall variety effect,  $P < 0.0001$ ), with a mean DE content of  $3476 \pm 205$  kcal/kg.

The range in economic value of the 11 field pea samples in grower diets was calculated with a feed formulation program. Briefly, (1) a grower diet containing 25% field peas was formulated using the average DE content and price (220 CD\$/tonne) for field peas; (2) for each of the 11 field pea samples, the specific DE content was entered in the spreadsheet, diets were reformulated, and the price of field peas was adjusted to maintain the original diet price. Accordingly, the economic value of field peas ranged from 168 to 256 CD\$/tonne.

## **Implication**

The degree of variation in DE content observed in field peas, like that in other ingredients, hinders precise diet formulation. The economic implications of such variation are unacceptably large.

# **The energy content of barley fed to growing pigs: Characterizing the nature of its variability and developing prediction equations for its estimation**

S.L. Fairbairn<sup>1</sup>, J.F. Patience<sup>1</sup>, H.L. Classen<sup>2</sup> and R.T. Zijlstra<sup>1</sup>

<sup>1</sup>Prairie Swine Centre Inc., P.O. Box 21057, 2105-8th St East, Saskatoon, SK. S7H 5N9 and <sup>2</sup>Dept. Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK. S7N 0W0

Presently, the pork industry attempts to formulate energy levels in swine rations to within a tolerance of 1.5%. This is difficult to achieve in practice when the energy content of primary ingredients fluctuates by up to 15%. This experiment was carried out to define the sources of variation in the energy content of barley and to develop a practical method to accurately estimate the DE and ME content of individual barley samples. Four samples of each of five hulled barley varieties (AC Lacombe, B-1602, Bedford, Harrington and Manley) were collected to obtain a range of quality within each variety. Sixty crossbred barrows, average BW of 35.3-kg, were housed in individual metabolism crates to facilitate separate collection of urine and faeces. Five day collection periods followed a 5 day diet acclimation period. The mean DE and ME content of the 20 samples were 2934 and 2857-kcal/kg (90% DM), respectively, and varied among samples by 15.2% (447 kcal). The ADF fraction accounted for 85% of the total energy variation in the 20 samples. The economic value of the 20 barley samples was observed to vary by \$38/tonne (CD\$) or 35% due to fluctuations in the DE content.

## **Implication**

This experiment confirms the large variation in the energy content of barley. This work describes the factors which influence this variation and presents equations based on chemical and/or physical measurements which might be used to predict the DE and ME content of individual barley samples.