A procedure for ileostomisation of adult roosters to determine apparent ileal digestibility of protein and amino acids of diets: Comparison of six diets in roosters and growing pigs

P. van Leeuwen, L. Babinszky, M.W.A. Verstegen, J. Tossenberger

A procedure for the ileostomisation of adult roosters has been described with the use of flexible silicon cannulas. Apparent ileal digestibility coefficients for dry matter (aDC DM), crude protein (aDC CP) and amino acids (aDC AA) in six diets, formulated with maize, wheat gluten, faba beans, lupins, soybean meal and casein as the main protein sources were determined in the ileostomised roosters fitted with silicon cannulas. In addition, aDC data determined using roosters (present study) were correlated with previously published aDC data of the same diets determined with pigs [van Leeuwen et al. (1996a). Apparent dry matter and crude protein digestibility of rations fed to pigs and determined with the use of chromic oxide (Cr2O3) and linsoluble ash as digestive markers. Br. J. Nutr. 76, 551-562; van Leeuwen et al. (1996b). Validation of a mathematical model to explain variation in apparent ileal amino acid digestibility of diets fed to pigs. J. Anim. Feed Sci. 5, 303-315]. The ileal aDC CP in roosters ranged from 0.81 to 0.92. Significant (P < 0.05) differences in aDC CP and aDC AA were observed between diets. Between aDC in roosters and pigs linear relations were found. The linear models explained 85% of the variation in ileal aDC CP between the six diets determined in roosters and pigs. For ileal aDC AA, the explained part of the variation between roosters and pigs, ranged from 62 to 96%, depending on the particular amino acids, with the exception of aDC of Arg. The standard errors (S.E.) of the models for the prediction of the aDC AA in roosters from aDC AA of the pigs was < 0.04 units. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Poultry; Pigs; Ileal digestibility; Amino acids

1. Introduction

Karasawa and Maeda (1994) investigated the nitrogen (N) metabolism of chickens with regard to the role of the caeca and the effects of the retroperistaltic movement of digesta from the cloaca to the caeca. The amino acids (AA) synthesized in the caeca by microbial activity can not be used in birds (Mortensen and Tindall, 1981). The undigested AA which reach the caeca can be deaminated by the microflora but the endproducts have no nutritional
value (McNab, 1989). Moreover, Parsons (1986) observed a higher agreement between amino acid availability, measured in chick growth assays, and digestibility determined in caecectomised rather than in intact birds. This means that, in poultry, digestion in the distal part of the intestines, more specifically the caeca, is mainly fermentative and that the AA synthesized or disappearing in the caeca are not available for protein synthesis in the animal.

As in poultry, it has been shown that in pigs the amino acids from proteins digested in the large intestine do not contribute to protein synthesis in the animal (Zebrowska et al., 1978). The ratio of the proteins digested in the small and large intestine of pigs differs between ingredients (Dierick et al., 1987). So, ileal digestibility estimates amino acid availability better than faecal digestibility. Several studies have been reported on the apparent ileal digestibility of amino acids of feedstuffs in pigs. Tables for pig diet formulation are commonly used (Degussa, 1993; van Leeuwen et al., 1993; Rhône Poulenc, 1993; Eurolysin, 1995; CVB, 1998).

Also in birds, the relative contribution of the distal part of the gastro-intestinal (GI) tract to protein and AA digestion of different feedstuffs is not constant (Raharjo and Farrell, 1984; Green and Kiener, 1989; Angkanaporn et al., 1997) and technological treatments on feedstuffs may have effects on the proportion of protein digested in the different sections of the GI tract (Johns et al., 1986). This implies that for poultry, as in pigs, ileal digestibility values of protein and amino acids in feedstuffs may give a more accurate estimate of the amino acids potentially available for protein synthesis than faecal digestibility data (Raharjo and Farrell, 1984).

Apparent ileal digestibility values for poultry have been determined using caecectomised roosters (Green and Kiener, 1989). In caecectomised birds, digesta flows from the ileum into the rectum and cloaca where it is stored and diluted with the urine until excretion. It is usually assumed that the AA in the excreta originate only from the digesta. The amount of AA in urine has been generally assumed to be low and can be ignored (McNab, 1989). However, digesta in the cloaca is not sterile and urine N can be converted to amino acids in biomass. Moreover, post-ileum changes in amino acid composition of the digesta may occur because of the microbes in the cloaca of caecectomised birds.

An alternative method for the collection of ileal digesta uses animals surgically cannulated at the terminal ileum (Fussel, 1969; Okumura, 1976; Raharjo and Farrell, 1984). In these ileostomised birds, the digesta can be directly collected from the cannulas without contamination with feathers or urine. Surgical procedures for intestinal cannulation of fowl have been described by Fussel (1969), Okumura (1976) and Raharjo and Farrell (1984) using glass cannulas. More recently, flexible medical silicon tubing was demonstrated to be very effective for cannulations in pigs (van Leeuwen et al., 1988, 1991).

Slaughter method is frequently used to determine ileal digestibility of diets (Radivan et al., 1999). With this method the small amounts of digesta are derived from the small intestine over the 40-mm proximal ileal–caecal junction, on a certain moment of the day. This method needs many animals (40–60) to collect enough digesta for analysis and to have a representative sample of the digesta over a longer period. Also the way of sampling is critical because from the dead intestine easily mucosa can be scraped off.

Green and Kiener (1989) have studied the relation between ileal digestibility values determined in precise-fed (force-fed) caecectomised roosters and the same diets determined in ileo–rectal anastomised pigs. Even though many differences exist in the GI tract and in the digestive processes between poultry and pigs (Moran Jr., 1982), they found similarities in ileal digestibility of CP and AA of diets between both species.

The objectives of the present study were (a) to describe a surgical procedure for ileostomy in roosters with the use of cannulas made of flexible medical silicon tubing, (b) to determine the ileal digestibility of diets with different protein sources in roosters and (c) to relate the ileal digestibility data of six diets determined in ileal cannulated roosters with values previously determined for the same diets in cannulated pigs (van Leeuwen et al., 1996b).

The experiment was approved by the TNO Committee for Animal Welfare.
2. Materials and methods

2.1. Experimental protocol

2.1.1. Birds and housing

Ten adult roosters (Lohmann brown) with an average body weight (BW) of 2.8 kg were individually housed in metabolic galvanized wire mesh cages (40 x 75 x 60 cm, width x height x depth) with a feed and water bowl. No bedding was provided. The cages were placed in an environmentally controlled room with an air temperature of 19–21°C. Birds were maintained under a 16 h light with 8-h twilight cycle throughout.

2.1.2. Surgical procedure for ileostomy

The principle of the surgical procedure used in the present experiment was previously described by Schutte et al. (1991). From 3 weeks prior to the surgeries and for 3 weeks post-surgery the roosters were fed a highly digestible diet with soy flour meal (410 g/kg), maize starch (180 g/kg), glucose (200 g/kg), cellulose (Arbocel, 100 g/kg) and a premix of vitamins and minerals mixed with maize (110 g/kg). The cannulas consisted of a barrel with a flange (Fig. 1), both segments of the same medical grade silicon tubing, Type SR 16 (Maxxim B.V., s’Hertogenbosch, The Netherlands), with an 8 mm inner diameter (ID) and an 11 mm outside diameter (OD). The barrel and the flange were glued together with a silicon adhesive, Elastosil E41 (Wacker-Chemie GmbH, München, Germany).

Feed was removed 24 h prior to surgery, but water was always freely available. Each rooster was pre-medicated with an intramuscular injection of 1 mg of Ketamin (Nimatec®, Eurovet, Bladel, The Netherlands; given as a sedative), 10 mg of flunixin-meglumine (Finadyne®, Schering Plough Animal Health, USA; as an analgesic), 0.3 ml of Depomycine® 20/20 (Mycofarm, De Bilt, The Netherlands; as a wide spectrum antibiotic) and 0.05 mg of atropinsulphate (Eurovet, Bladel, The Netherlands; as a cholinergic blocker). Oxygen (O₂) with isoflurane as anaesthesia was then given with a mask. After sedation, each rooster was intubated (OD of the silicon rubber trachea tube was 3 mm). When the anaesthesia relaxed the muscles, the rooster was placed on its back on the surgery table and the area ventral of the pubis was cleaned with a general disinfectant. Laparotomy was performed by a 4-cm straight incision at the ventral side of the right pubis. The ileo-cecal junction was positioned at the incision. The intestine was closed with two absorbable sutures (Polysorb GL-181/CV-25) around the terminal ileum, with a distance of 3 mm between the sutures. The ileum was transected between the sutures. A purse string suture (Polysorb GL-181/CV-25) was placed at the antimesenteric side of the proximal part of the transected intestine. An incision was made in the intestine between the purse string suture, the flange of the cannula was inserted and fixed immediately with the ligature. A second ligature was placed around the cannula. The cannula was then exteriorized through a stab incision in the body wall about 2 cm ventral of the first incision (Fig. 2). After a routine closure of the laparotomy, the cannula was fixed externally with tape, so that the intestine and the abdominal wall just came in light contact with each other. Too much pressure would increase local necrosis. After a period of 3 weeks, the digestibility trial started. Time needed for surgery was, included the introduction of the anaesthesia, about 1 h. The number of animals alive after 2 months was over 90%.

2.2. Experimental diets

After a pre-test period of 3 weeks, the roosters were fed maize starch based diets with maize (diet 1); wheat gluten (diet 2); faba beans with a low tannin content (LT) (diet 3); lupins, angustifolius, white (diet 4); soybean meal (diet 5) and casein (diet 6) as main protein sources (Tables 1 and 2). The incorporation rates of the feedstuffs were calculated in order to obtain diets containing 160 g/kg CP. In diet 1, 94 g/kg wheat gluten meal was added to elevate the CP content of the diet to 160 g/kg. The same batch of the diets were used in previously conducted digestibility experiments with pigs (van Leeuwen et al., 1996a,b). Diets were stored at −20°C for 2 years until the use in the present rooster experiment. For the present experiment with the ileostomised roosters, the meal was more finely ground over a 1-mm screen (and not pelleted). The
feed intake was restricted to 80 g/day, equivalent to a semi ad libitum level. Water was freely available.

2.3. Determination of ileal digestibility in ileostomised roosters

The ileal digestibility experiment consisted of four periods (P1, P2, P3 and P4) of 14 days each. Diets 1–6 were assigned randomly with no rooster receiving the same diet twice. The digestibility coefficients of each diet were determined in at least five different roosters.

After 11 days of adaptation to the rations, without fasting periods, digesta were collected over 3 successive days (72 h) via a plastic bottle of about 10 g connected to the cannula (Fig. 1). Digesta were removed hourly over the day (8.00–20.00) and each 6 h during the night and immediately frozen (−20°C). Digesta was more frequently collected during the day rather than in the night. This was done (1) to have the possibility to compare digesta composition for the two different procedures separate and (2) to keep the roosters quiet during the night, maintaining the normal bio rhythm of the roosters as
much as possible. Unpublished results showed no systematically differences. After each experimental period, digesta of the 3 day collections were thawed and pooled per bird.

2.4. Analytical procedures

Feedstuffs, diets and freeze-dried digesta were ground through a 1-mm screen using a Retsch AM 1 grinder prior to chemical analysis. Nitrogen (N) was analyzed by the Kjeldahl method and crude protein (CP) was calculated as N × 6.25. Dry matter (DM) contents were determined after drying at 80°C overnight. Amino acids were determined according to Bech-Anderson et al. (1990).

2.5. Calculations

The apparent digestibility for DM, CP and AA of the diets were calculated from nutrient intake and the total collected amounts of digesta over periods of 3 days (72 h). The crystalline amino acids included were assumed to be completely absorbed.

The data set for the calculation of the correlations between ileal aDC CP and AA were derived from the cannulated roosters in the present experiment and from cannulated pigs from the previous experiment (van Leeuwen et al., 1996b).

2.6. Statistical analysis

Data were subjected to analysis of variance using the SPSS/PC + V5.0 software (Norusis, 1992). The diet type was treated using the following model:

\[ y_{i,j} = T + a \times D_i + e_{i,j} \]

where \( y_{i,j} \) = response measurements, \( D_i \) = diet type \((i = 1-6)\), \( T \) = mean value and \( e_{i,j} \) = residual error.

The number of periods per diet was similar and a first statistical analysis showed no significant effect of periods. Therefore the period was not included in the final model.

Treatment means were tested for difference by use of the Least Significant Difference test (Snedecor and Cochran, 1980). All statements of significance are based on a probability of \( P < 0.05 \).

Correlations were calculated between ileal aDC
Table 2  
Composition of the maize starch based diets with maize, wheat gluten, faba beans, lupins soybean meal and casein as substituting feedstuffs (% as fed)  

<table>
<thead>
<tr>
<th>Diet</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substituted feedstuff</td>
<td>Maize</td>
<td>Wheat gluten meal</td>
<td>Faba beans</td>
<td>Lupins</td>
<td>Soy-bean meal</td>
<td>Casein</td>
</tr>
<tr>
<td>Content substituted feedstuff</td>
<td>82.82</td>
<td>17.90</td>
<td>51.00</td>
<td>54.00</td>
<td>33.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Wheat gluten meal</td>
<td>9.40</td>
<td>51.90</td>
<td>26.78</td>
<td>24.98</td>
<td>43.30</td>
<td>53.35</td>
</tr>
<tr>
<td>Maize starch</td>
<td>2.00</td>
<td>2.25</td>
<td>1.85</td>
<td>1.60</td>
<td>1.75</td>
<td>1.60</td>
</tr>
<tr>
<td>Glucose</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>1.50</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Cellulose</td>
<td>5.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>CaCO$_3$</td>
<td>0.90</td>
<td>0.80</td>
<td>0.90</td>
<td>0.80</td>
<td>0.85</td>
<td>1.20</td>
</tr>
<tr>
<td>CaHPO$_4$·2H$_2$O</td>
<td>2.00</td>
<td>2.25</td>
<td>1.85</td>
<td>1.60</td>
<td>1.75</td>
<td>1.60</td>
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<td>NaCl</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>MgO</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>KHCO$_3$</td>
<td>1.30</td>
<td>1.80</td>
<td>0.20</td>
<td>0.40</td>
<td>0.35</td>
<td>0.40</td>
</tr>
<tr>
<td>NaHCO$_3$</td>
<td>0.30</td>
<td>0.40</td>
<td>0.30</td>
<td>0.30</td>
<td>0.35</td>
<td>0.40</td>
</tr>
<tr>
<td>L-lysine·HCl</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>L-threonine</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>DL-methionine</td>
<td>0.03</td>
<td>0.02</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Vitamin-trace element mixture</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
</tbody>
</table>

*Contributed the following vitamin sources, additional minerals and trace elements per kg of ration: vitamin E, 37.5 mg; riboavin, 6 mg; niacin, 30 mg; p-pantothenic acid, 15 mg; choline chloride, 120 mg; vitamin B$_6$, 0.45 mg; vitamin K$_3$, 3 mg; vitamin A, 9000 IU; vitamin D$_2$, 1800 IU; KI, 0.81 mg and CoSO$_4$·7H$_2$O, 7 mg; FeSO$_4$·7H$_2$O, 0.4 g; CuSO$_4$·5H$_2$O, 0.1 g; MnO$_2$, 0.07 g; ZnSO$_4$·H$_2$O, 0.3 g. This mixture was supplied with 20 ppm Tylosine as an antibiotic.

determined in the present experiment using roosters and from previously determined aDC data using pigs (van Leeuwen et al., 1996b). The model used to correlate the aDC CP and aDC AA determined in roosters and pigs was $y = ax + c$ where $y =$ aDC CP determined in roosters and $x =$ aDC CP determined in pigs.

The calculations were conducted using SPSS/PC+V5.0 software (Norusis, 1992).

3. Results

Feed intake of the roosters 2 weeks post-surgery was similar to the feed intake prior to the surgeries. The weight of roosters decreased an average of approximately 100 g following surgery. The roosters were kept for more than 1 year and were used for additional experiments (not presented). During this period, the weights of the animals were slightly higher or unchanged compared to the weight prior to the surgery.

Results of the amino acid analysis of the diets have been previously reported (van Leeuwen et al., 1996b). The ileal aDC CP and aDC AA measured in roosters are presented in Table 3. The aDC CP of the maize–wheat gluten based diet (diet 1), the wheat-gluten diet (diet 2) and the casein diet (diet 6) were significantly ($P<0.05$) different from those of the faba bean diet (diet 3), lupin diet (diet 4) and soybean meal diet (diet 5). Differences between these diets were also found for the apparent digestibility of the indispensable amino acids, with the exception of lysine. The standard error of the mean (S.E.M.) was, in general, less than 0.02 of the mean digestibility values.
Table 3
Apparent digestibility of dry matter (DM), crude protein (CP=N×6.25) amino acids (AA) of the diets

<table>
<thead>
<tr>
<th>Diet</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substituted feedstuff</td>
<td>Maize</td>
<td>Wheat glutenmeal</td>
<td>Faba beans</td>
<td>Lupins</td>
<td>Soy-bean meal</td>
<td>Casein</td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>0.83&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.66&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.011</td>
</tr>
<tr>
<td>Crude protein</td>
<td>0.88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.012</td>
</tr>
</tbody>
</table>

**Indispensable amino acids**

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>0.85&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.91&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.89&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>0.010</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.87&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.78&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.015</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.77&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.78&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.014</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.91&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.94&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.012</td>
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<tr>
<td>Lysine</td>
<td>0.73&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.78&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.80&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.83&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.015</td>
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<tr>
<td>Methionine</td>
<td>0.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.72&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.016</td>
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<tr>
<td>Phenylalanine</td>
<td>0.88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.80&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.012</td>
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<tr>
<td>Threonine</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.73&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.74&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.74&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.021</td>
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<tr>
<td>Valine</td>
<td>0.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.77&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.79&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.012</td>
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</table>

**Dispensable amino acids**

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>0.85&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.89&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.73&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.017</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.83&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.80&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.015</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>0.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.97&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.86&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.010</td>
</tr>
<tr>
<td>Glycine</td>
<td>0.84&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.89&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.77&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.79&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.014</td>
</tr>
<tr>
<td>Proline</td>
<td>0.91&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.96&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.83&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.011</td>
</tr>
<tr>
<td>Serine</td>
<td>0.88&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.80&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.015</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.91&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.77&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.79&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.91&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.014</td>
</tr>
</tbody>
</table>

| Sum of analyzed AA | 0.88<sup>b</sup> | 0.92<sup>c</sup> | 0.80<sup>d</sup> | 0.84<sup>e</sup> | 0.81<sup>d</sup> | 0.89<sup>b</sup> | 0.012  |

<sup>a,b,c,d</sup> Different letters in the same row indicate a significant difference (P<0.05).

Correlations between the ileal aDC CP and AA determined in roosters and pigs are presented in Table 4. Fig. 3 shows the aDC CP, aDC Ile, Lys, Met, Thr and Ser determined in the pigs (x-axis) and roosters (y-axis). The correlation coefficients (R<sup>2</sup>) of reaction and did not seem to interfere with the animals health status.

The measurements made in this experiment have a low variation (Table 3) and compare well with measurements in other reports (Green and Kiener, 1989; Fuller et al., 1994). In the present experiment, diets which were already prepared for an experiment with pigs (van Leeuwen et al., 1996b) were given to the roosters. However, material fed to the roosters was reground using a 1-mm screen to avoid blockages in the cannulas. Regrinding can affect the digestibility for coarse diets, as demonstrated in pigs by Fuller et al. (1994). Even though there were differences between the studies in the grinding procedures, feeding level, and methods of digesta collection, the values of aDC CP and aDC AA for roosters did not change indicates that the condition of the animals was unchanged which implies that the supply of minerals was adequate. Moreover, the flexible silicon cannulas did not give any tissue reaction and did not seem to interfere with the animals health status.

4. Discussion

Previous experiments (van Leeuwen, not published) and the present experiment have shown that ileal cannulated animals can be maintained for more than 1 year at a constant body weight. Due to the caecal–colonic bypass, sodium absorption as observed by van der Klis et al. (1993) in the distal part of the GI tract, was not possible. The observation that the body weight of the colostomised adult
Table 4
Correlations between apparent digestibility coefficients in roosters as dependent variable (y) with apparent digestibility coefficients in pigs as independent variable (x) in a linear model (y = ax + c; N=6)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>a</th>
<th>c</th>
<th>R²</th>
<th>S.E.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>0.8782</td>
<td>0.2857</td>
<td>0.83</td>
<td>0.035</td>
<td>0.01</td>
</tr>
<tr>
<td>Crude protein</td>
<td>0.5512</td>
<td>0.4008</td>
<td>0.85</td>
<td>0.022</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Indispensable amino acids
- Arginine: 0.6691, 0.2556, 0.47, 0.021, 0.13
- Histidine: 0.6237, 0.2801, 0.76, 0.027, 0.02
- Isoleucine: 0.5002, 0.4139, 0.66, 0.036, 0.05
- Leucine: 0.6111, 0.3446, 0.82, 0.028, 0.01
- Lysine: 0.6974, 0.2354, 0.76, 0.036, 0.02
- Methionine: 0.4168, 0.5139, 0.90, 0.027, 0.01
- Phenylalanine: 0.5034, 0.4419, 0.86, 0.022, 0.01
- Threonine: 0.6105, 0.3140, 0.78, 0.030, 0.02
- Valine: 0.5679, 0.3716, 0.77, 0.032, 0.02

Dispensable amino acids
- Alanine: 0.5884, 0.3382, 0.74, 0.038, 0.03
- Aspartic acid: 0.3732, 0.5201, 0.69, 0.017, 0.04
- Glutamic acid: 0.6332, 0.3351, 0.76, 0.025, 0.02
- Glycine: 0.5087, 0.4404, 0.85, 0.019, 0.01
- Proline: 0.5048, 0.4493, 0.85, 0.024, 0.01
- Serine: 0.4861, 0.4433, 0.62, 0.030, 0.06
- Tyrosine: 0.5794, 0.3448, 0.82, 0.028, 0.01

the soybean meal diets were similar. The mean apparent ileal digestibilities of CP (aDC CP) for the soybean meal diet with restricted-fed cannulated roosters in the present experiment was 0.81. Green and Kiener (1989) reported aDC CP of 0.83 for a similar diet in caecectomised forced-fed adult roosters. The apparent amino acid digestibility (aDC AA) of soybean meal determined in the present study and determined by Green and Kiener (1989) were Lys=0.83 and 0.84, Met=0.84 and 0.85 and Thr=0.74 and 72, respectively. It should be pointed out that the soybean meal may not have been identical in both studies. Angkanaporn et al. (1997), reported higher values (aDC Lys=88 and aDC Thr=85). However, they used a batch of soybean meal with a 0.8% higher CP content and 0.3% lower CFi content compared with the soybean meal used in the present study.

Amino acids, which are in low concentrations in the diet, will give a lower apparent digestibility than expected on the basis of the apparent digestible protein. From studies in pigs (Dammers, 1964; Fan et al., 1994) and birds (Angkanaporn et al., 1997), it is known that a low intake of CP or a particular AA results in a relatively low aDC, due to the higher amounts of endogenous protein or AA in the digesta relative to the intake. The aDC Lys from the diets with proteins from cereals (diet 1 and 2) were low compared with the CP digestibility of the corresponding diets and compared with the digestibility of the other diets. This finding is related with the relatively low Lys content in the protein of cereals compared with legume seeds and casein. The low content of Met in the faba beans diet also resulted in a relatively low aDC of Met.

For each of the diets, the aDC of the sum of the individual AA, determined in roosters, was similar to the aDC CP. Green and Kiener (1989) also found higher values in caecectomised roosters. They also found a similar aDC for CP and for the sum of the individual AA for diets with vegetable protein sources. However, possibly due to the technique, the aDC sum of the individual AA of meat and bone meal diets fed to roosters was 5 percentage units lower than compared with the aDC CP. In the present experiment, meat and bone meal was not included. In pigs the aDC of the sum of the individual AA diets, with different feedstuffs (including meat meal), was in general, similar or higher to the aDC CP (Green and Kiener, 1989; van Leeuwen et al., 1996b; Grala, 1997).

In spite of the large differences in anatomy and physiology between roosters and pigs (Moran Jr., 1982), the aDC CP showed a high correlation. The Explained part of the variation of aDC of CP between roosters and pigs using a linear model was 85%. For the individual amino acids, the R² value was 0.62–0.90, with the exception of aDC Arg (R²=0.47). The latter can be explained because of the small range of the values of aDC for Arg in roosters and pigs (in roosters the range was 0.84–0.91 and in pigs it was 0.87–0.96).

In the present experiment, the aDC of highly digestible diets (aDC>0.85) were in roosters similar or lower than in pigs. The aDC values in roosters tended to be higher than the values determined in pigs when the aDC in pigs was <0.8. Green and Kiener (1989) also found higher values in caecoc-
Fig. 3. The apparent ileal digestibility (aDC) values of crude protein (CP), Lys, Met, Thr, Ileu and Ser determined in pigs (x-axis) and roosters (y-axis).
tomised roosters than in anastomised pigs for diets with soy bean meal and sunflower meal (aDC CP in roosters ranged from 0.78 to 0.83). However, for diets with meat and bone meal or rape seed meal as the protein source (aDC CP in roosters ranged from 0.54 to 0.73), aDC determined in roosters was similar or lower than in pigs. The differences in aDC between pigs and roosters are related to many factors such as endogenous secretions, the anatomy and physiology of the digestive tract and differences in microbial activity. The fact that so many factors contribute to the differences in digestibility between roosters and pigs suggests that extending the range of data on aDC a non-linear correlation will improve the mathematical description of the correlations.

In summary,

- using the presented surgical procedure for ileostomisation, with the use of silicon cannulas, digestibility experiments can be conducted over a long period
- significant ($P<0.05$) differences in aDC CP and AA were observed in the diets
- aDC of CP and AA of soybean meal determined in the present experiment were comparable with data from the literature determined in adult caecectomised roosters
- the levels of aDC CP in roosters was correlated with aDC CP determined in pigs ($R^2=40.85$) when aDC CP in roosters was >0.8.

Although more work is needed to validate the presented correlations, it is likely that this approach can be used for the prediction of aDC values for roosters from values determined in pigs and the reverse.

Acknowledgements

Authors wish to thank K. Deuring and D.J. van Kleef for technical assistance and J. Wiebenga for statistical data analysis.

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References


