Growth Performance, Body Composition and Protein and Energy Utilization of Pigs Fed *Ad Libitum* Diets Formulated According to Digestible Amino Acid Content[a]

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ABSTRACT : Four groups of six growing gilts each were fed *ad libitum* diets composed of cereals and soyabean (SBM) or rapeseed (RSM) meal and containing two levels of crude protein: high - 18.0% (RSM-H) and 16.9% (SBM-H) or low - 15.6% (RSM-L) and 15.1% (SBM-L). The diets were balanced by supplementation with crystalline amino acids and contained apparent ileal digestible lysine, methionine, threonine and tryptophan in proportions (1.00:0.32:0.57:0.18) according to CVB (1995). Voluntary feed intake, weight gain and slaughter and chemical body composition of animals were assessed. Protein and energy balances from 25 to 70 kg body weight were calculated by the comparative slaughter method. Protein source had a significant effect on voluntary feed intake; it was 0.12 kg/d lower in pigs fed the SBM than RSM-diets. Pigs fed on the SBM-L diet consumed the least amount of feed (2.17 kg). Daily gain (average, 900±12.59 g) and feed conversion ratio (2.54±0.04 kg/kg) were not statistically affected by source (SMB and RSM) and protein level (high and low). In empty body similar amounts (g/kg) of protein (163 g), water (635 g) and ash (28 g) were found. However, pigs fed the RSM-L diet were fatter than those fed the SBM-L diet (188 vs. 161 g/kg). No statistical differences were observed in daily protein deposition, which on average amounted to 142±11 g, or carcass characteristics. An improvement of crude protein utilization by 6.3 percentage units was found by decreasing the protein concentration in the diets. Heat production in the body was not significantly affected by the treatments. (***Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 6 : 817-823***)

Key Words : Pigs, Ileal Apparent Digestibility, Body Composition

INTRODUCTION

A modern pig feeding system should consider diet formulation on the ileal amino acid digestibility basis (CVB, 1995; NRC, 1998). It is documented that true ileal digestibility is a better indicator for protein/amino acid availability in pigs than the apparent one (Sauer and Ozimek, 1986; Yin et al., 1993; Boisen and Moughan, 1996). Since apparent measurements are easier to perform, they are still in use.

From economical and environmental points of view, the level of protein in diets for pigs should be low. This usually involves high amino acid supplementation of diets and causes changes in the dietary proportion of free and protein bound amino acids. The extent of crystalline amino acid enrichment may influence on appetite of pigs (Haydon et al., 1989), their performance and body nitrogen retention (Fuller et al., 1995), nutrients distribution between parts of the body (Bikker, 1994; Millward, 1995), as well as protein and energy utilization (Fuller et al., 1995; Rao and McCracken, 1990).

Most data concerning ileal digestibility of amino acids and their utilization by animals originate from studies on pigs fed on low or moderate feeding levels and kept in somewhat different environmental conditions than in practice. The usefulness of such data in the nutrition of modern pigs fed *ad libitum* may be limited. There are only a few studies where *ad libitum* feeding is used but their results are diverse (e.g. Friesen et al., 1994; Quiniou et al., 1995) .

The aim of this study was to asses the effects of feeding diets differing in main protein source (soyabeen vs. rapeseed oil meal) and protein content (high or low crude protein level) but formulated to contain similar levels of apparent ileal digestible lysine, methionine, threonine and tryptophan on growth performance, body composition and protein and energy utilization of pigs under *ad libitum* feeding system.

The general objective was to validate the usefulness ileal digestible amino acids in formulating diets for pigs of high genetic potential maintained in *ad libitum* feeding conditions, which recently become commonly used in practice.

MATERIALS AND METHODS

The experiment was carried out on 30 growing gilts, originating from 6 litters of the synthetic line 990 of high lean growth genotype. After reaching a weight of ca. 15 kg, the animals were placed in individual pens (1.2×2.6 m^2) with a non-slatted floor

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in an insulated building. During the preliminary period (from 15 to 25 kg) all animals were fed a uniform diet until the beginning of the experiment. At the body weight of 25 kg, six pigs (one from each litter) were slaughtered and their body chemical composition was determined. The remaining pigs were divided into 4 groups (6 pigs per group) and allocated to experimental treatments. The pigs were fed individually *ad libitum* with mash feed and the daily feed intake was controlled. Water was freely available from drinking nipples. All animals were housed in a thermo-neutral environment. They were slaughtered at 70 kg body weight and their bodies were analyzed for protein, fat and ash content.

Two diets with higher -H (169 and 180 g/kg) and two with lower protein level -L (151 and 156 g/kg) containing either soyabean meal (SBM) or rapeseed meal (RSM) were used (tables 1 and 2).

Table 1. Composition of the diets (g/kg)

Protein source[1]	SBM		RSM	
Protein level[2]	H	L	H	L
Barley	367	400	-	-
Wheat	-	-	704	800
Maize	353	358	-	-
Soyabean (SBM)	230	180	-	-
Rapeseed meal (RSM)	-	-	250	160
Mineral-vitamin mix.[3]	5	5	5	5
$CaHPO_4 \cdot 2H_2O$	13	13	6	7
$CaCO_3$	7	7	10	9
NaCl	3	3	3	3
Maize starch	20	30	20	10
L-Lysine · HCl	1.54	2.83	3.93	4.96
DL-Methionine	0.39	0.60	-	0.22
L-Threonine	-	0.32	-	0.56
L-Tryptophan	-	0.15	-	0.10

[1] SBM and RSM - soyabean and rapeseed meal diets.
[2] L and H - low and high protein level.
[3] Amounts of vitamins and microelements supplied per kg of diet: vitamin A, 15000 IU; vitamin D_3, 2000 IU, vitamin E, 15 mg, vitamin K_3, 1.5 mg, vitamin B_1, 1.0 mg, vitamin B_2, 5 mg, vitamin B_6, 1.5 mg, vitamin B_{12}, 0.015 mg, biotin, 0.03 mg, folic acid, 0.5 mg, nicotinic acid, 15 mg, calcium pantothenate, 8 mg, choline chloride, 150 mg, Mn, 30 mg, Zn, 40 mg, Cu, 15 mg, Fe, 60 mg, J, 0.5 mg, Se, 0.15 mg, Co, 0.6 mg, virginiamycin (StafacR), 5 mg.

SBM diets contained barley and maize meal and those with RSM were based on wheat meal. In L diets, the low protein concentration was obtained by reducing the proportion of SBM (from 23 to 18%) or RSM (from 25 to 16%). All diets were formulated to contain similar levels of apparent ileal digestible lysine, methionine, threonine and tryptophan, with respective proportions 1.00:0.32:0.57:0.18, according to the Dutch recommendations (CVB, 1995). The content of digestible lysine was 7.65 g/kg. The diets were supplemented with crystalline amino acids: the RSM-H and SBM-H diets were supplemented with lysine or lysine and methionine respectively, whereas diets SBM-L and RSM-L were also supplemented with threonine and tryptophan. The levels of other essential amino acids, as well as cystine, were sufficient to cover the pigs' requirements. It was assumed that the digestibility of crystalline amino acids was 100%. The proportion of vitamin-mineral mixture in all diets remained constant, and they were isocaloric (14.7 MJ ME /kg DM).

Table 2. Chemical composition of the diets (g/kg)

Protein source[1]	SBM		RSM	
Protein level[2]	H	L	H	L
Chemical composition:				
Dry matter	863	860	876	876
Crude protein	169	151	180	156
Ether extract	23.9	25.0	43.2	29.4
Ash	45.3	44.3	40.7	37.5
Crude fibre	41.0	37.5	45.4	36.2
NDF	14.30	14.95	18.48	16.48
ADF	7.71	6.93	9.70	7.47
Energy, MJ/kg: GE	16.50	16.38	16.54	16.50
ME (calculated)	12.7	12.7	12.7	12.7
Amino acids, g/kg diet				
Crude:				
lysine	9.67	9.51	10.22	9.66
Methionine	2.72	2.96	3.22	3.00
Threonine	6.52	6.15	6.86	6.30
Tryptophan	1.98	1.91	2.10	1.93
Apparent ileal digestible:				
Lysine	7.65	7.65	7.65	7.65
Methionine	2.45	2.45	2.54	2.45
Threonine	4.60	4.36	4.37	4.36
Tryptophan	1.43	1.38	1.47	1.38

[1] SBM and RSM - soyabean and rapeseed meal diets.
[2] L and H - low and high protein level.

The apparent digestibility of protein and energy was determined after three-day faeces collection in all pigs weighing about 45 kg. Chromic oxide was used as an indigestible marker (0.2%).

After slaughter, the carcass and non-carcass parts (viscera, blood, hair), as well as thyroid gland, were weighed separately. The carcasses were chilled overnight, depth of backfat at 5 positions was measured on the right half of the carcass. Afterwards, the right half carcass was partially dissected into lean and fat. Left half of carcass and the viscera with collected blood were autoclaved separately for 8 hrs, homogenized and the samples were analyzed for protein, ether extract, water and ash content. Retention of nutrients in the body during growth period from 25 to 70 kg was estimated by comparative slaughter method described by Kotarbińska (1971). Date on the chemical composition of ouiwels slaughtered at the beginning of the experiment were used to estimate the total protein, ester extract, ash and water content in the other in pigs at the start of the experiment. The gains of these components over the experimental period were calculated as the difference between the determined final values and the estimated initial values in the body.

Dry matter, protein (N×6.25), ether extract (EE), crude fibre, starch, sugar and ash were analyzed using standard methods (AOAC, 1990). The contents of neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using Fibertec System M by the method described by Van Soest (1973). Chromic oxide was determined according to Fenton and Fenton (1979). Amino acids analyses were performed with a Beckman 6300 high pressure amino acid analyzer using the modified procedure described by Buraczewska and Buraczewski (1984). The content of apparent ileal digestible amino acids in the feeds was determined by Buraczewska et al. (1999). All components used in the present and Buraczewska's studies originated from the same batches.

The content of rapeseed meal glucosinolates was analyzed by HPLC according to the ISO-9167-1 (1991) method. The gross energy content in the diets and the faeces was determined by combustion of samples in a bomb calorimeter.

Metabolizable energy of diets was calculated from the digestible energy content after correction for the protein content (Noblet et al., 1989). The energy content in the body was estimated from the protein and fat contents using the coefficients: 23.9 kJ/g for protein and 39.8 kJ/g for fat (Brouwer, 1965). Heat production in pigs was calculated as the difference between metabolizable energy intake and the amount of energy deposited in the body. Individual data from the digestibility trial were taken to estimate the efficiency of digestible protein and metabolizable energy for protein and energy retention in the body.

Protein level and protein source were used as the main factors in the variance analysis. The significance of differences between means was tested with the least significance LSD-test at $p<0.05$. All calculations were performed using Statgraphics Plus version 7.0 (1993).

RESULTS

No problems with animal health were recorded throughout the entire experiment and no abnormalities were found at the post-slaughter examination.

Treatments had no significant effect on the faecal apparent digestibility of nutrients (table 3). The apparent digestibility of dry mater and energy were on average 79.8 and 80.3%, respectively, while digestibility of protein was lower (73.3±4.5%). Metabolizable energy estimated from digestible energy content was close to presumed values (table 2), except for the RSM-L diet that was about 0.2 MJ/kg higher than calculated.

Average daily feed intake for all groups was 2.28 (±0.13) kg (table 4). Pigs fed diets containing RSM, consumed 0.12 kg more ($p<0.05$) feed than pigs fed

Table 3. Apparent digestibility (%) of dry matter, energy and crude protein in the diets

Item	SBM		RSM		SE[a]	Treatment effects[b] p<0.05
	H	L	H	L		
Dry matter	78.6	80.3	79.4	80.9	0.705	-
Energy	80.1	80.7	79.3	80.9	0.353	-
Crude protein (faecal)	73.0	73.3	73.5	73.3	0.580	-

[a] Standard error; [b] S=protein source, P=protein level.

Table 4. Feed intake, daily gain and feed conversion ratio

Item	SBM		RSM		SE[a]	Treatment effects[b] p<0.05
	H	L	H	L		
Initial live weight, kg	25.0	25.1	25.1	25.0	0.102	-
Final live weight, kg	69.0	69.2	69.2	69.2	0.221	-
Feed intake, kg/d	2.28	2.17	2.30	2.37	0.020	RSM>SBM,
Average daily gain, g/d	884	904	887	925	12.591	-
Feed conversion ratio, kg/kg	2.58	2.41	2.60	2.58	0.030	-

[a] Standard error; [b] S=protein source, P=protein level.

the SBM-diets. The largest differences in feed intake were observed between the SBM-L (2.17 kg) and RSM-L (2.37 kg/d) groups. No effects of protein level on feed intake were found.

Generally, pigs grew well with maximum growth rates above 900 g/day (table 4). Neither of treatments affected significantly body weight gain nor the feed conversion ratio (average 2.54±0.20 kg/kg).

The mean empty body composition (g/kg) of six pigs slaughtered at 25 kg was: water 703±10.2, protein 160±8.4, fat 96±8.5 and ash 31±2.5.

Neither the protein source nor protein level affected the final empty body weight which amounted to 65.3±1.2 kg (table 5). In comparison with the body composition of pigs slaughtered at 25 kg, the empty body of pigs at the final weight contained per kg less water (635±18 g), more fat (175±21 g) and a similar amount of protein (162±5.5 g) and ash (28 ±1.9 g).

The protein content in the carcass tissues accounted for 83.7 (±1.3)% of the empty body protein, but significant interaction between the source and protein level was found in protein distribution in the body. Pigs fed the SBM-L diet contained proportionally more protein in the carcass and less in the viscera than fed on other diets.

Daily protein deposition in the body of pigs from 25 to 70 kg was high (142±11g) (table 5). Pigs fed the SBM-L diet deposited somewhat more protein (147 g/d) than those fed the RSM-L diet (141 g/d), but neither protein source nor protein level affected protein deposition significantly. Pigs fed the SBM-diets utilized protein by 4.1 percentage units better than those fed the RSM-diets (40.3 vs. 36.2%). A greater difference (6.3 percentage units) was found in pigs fed with diets of low vs. high protein levels (41.4 vs. 35.1%).

Daily protein deposition related to digested lysine intake (g/g) ranged from 7.77 to 8.83. Pigs fed the SBM-H diet deposited 7.94 g protein from 1 g of digestible lysine, while after feeding the SBM-L diet, the protein/lysine ratio increased to 8.83 g/g showing a parallel improvement in protein efficiency from 35.9 to 44.7%. In contrast to the SBM-diets, lowering the protein concentration in the RSM-diets (from 18.0 to 15.6%) resulted in diminished protein deposition, related to digestible lysine, to a level of 7.77g/g, and improved protein utilization, but only by 3.8 percentage units (from 34.3 to 38.1%).

The rate of fat deposition during growth from 25 to 70 kg was the highest (213 g/day) in the RSM-L pigs and the lowest in the SBM-L pigs (173 g/d). For the fat content and protein/fat ratio, significant ($p<0.05$) interactions between the source and protein level in the diets were found; the empty body of pigs fed the RSM-L diet contained 27 g/kg more fat than pigs fed the SBM-L diet.

Differences between groups in carcass characteristics (table 6) were not significant and showed a similar tendency as for chemical components in the empty body of animals. Weights of lean or fat cuts were highly correlated with protein or ether extract content in the carcass (r=0.81 and r=0.91, respectively). In the primal cuts of pig carcass, lean accounted on average for 67.5 (±3.02)%.

The efficiency of utilization of ME for the energy retained in the body was not affected by the

Table 5. Chemical body composition of the pigs

Item	SBM		RSM		SE[a]	Treatment effects[b] p<0.05
	H	L	H	L		
Empty body weight, kg	64.81	65.90	64.83	65.51	0.247	-
In empty body, g/kg:						
Protein	162	164	165	159	1.059	-
Fat	179	161	173	188	3.961	-
Ash	28.4	28.2	27.2	26.8	0.373	-
Water	631	647	635	626	3.428	-
Protein/fat	0.92	1.03	0.97	0.85	0.026	S×P
Carcass protein/ body protein ratio	0.832	0.848	0.837	0.832	0.026	S×P
Daily gain (25~70 kg), g						
Empty body weight	844	880	843	893	12.140	-
Protein	138	147	142	141	2.279	-
Fat	190	173	182	213	5.800	S×P
Ash	22.9	23.6	21.4	21.8	0.685	-
Water	493	536	497	517	8.878	-

[a] Standard error; [b] S=protein source, P=protein level.

Initial content in the body (at 25 kg): 3.65 kg protein, 2.19 kg fat, 0.71 kg ash and 16.17 kg water.

treatments (table 8) and amounted to 37.6±2.48%. Heat production expressed as the proportion of ME intake also did not differ between the groups.

DISCUSSION

The pigs in the experiment had a high potential for lean production as their daily gain from 25 to 70 kg was about 900 g and daily protein deposition over 140 g. The genetic capacity for protein deposition (7.8 g per kg body weight$^{0.75}$), of the animals in our study was comparable to that of pigs used in the recent studies by Fuller et al. (1995). However, in contrast to the most of the experiments, concerning protein metabolism, the pigs in our experiment were fed intensively.

In general, the daily intake of feed (2.28 kg) was high, and expressed in terms of metabolizable energy was 1.61 MJ/kg$^{0.75}$, which is over 3.5 times energy requirement for maintenance (ARC, 1981).

Slightly greater feed intake in pigs fed on RSM than on SBM diet, particularly at lower protein level, is difficult to explain since in other studies reduced intake was observed rather for RSM than for SBM diets (Bell et al., 1991; McIntosh et al., 1986). The possible explanation may be a lower net energy value of RSM resulting from greater NSP content and lower rate of precaecal energy digestibility. However, the lack of differences in the metabolizable energy utilization for growth between the diets does not confirm this hypothesis.

Average daily gain was not affected by

Table 6. Carcass characteristics of pigs at 70 kg live weight

Item	SBM		RSM		SE[a]	Treatment effects[b] p<0.05
	H	L	H	L		
Carcass weight, kg	53.3	54.5	53.3	54.2	0.297	-
Backfat thickness[c], mm	19.7	18.5	19.8	22.9	0.532	-
Area of eye of muscle longissimus dorsi, cm^2	32.1	33.8	31.1	32.6	0.855	-
Percent of meat in the primal cuts	67.6	69.7	67.4	65.1	0.552	-

[a] Standard error; [b] S=protein source, P=protein level; [c] Mean from 5 measurments.

Table 7. Protein and lysine balance (g/d) of growing pigs from 25 to 70 kg live weight

Item	SBM		RSM		SE[a]	Treatment effects[b] p<0.05
	H	L	H	L		
Intake: protein	385	327	414	370	4.003	RSM>SBM, H>L
Lysine	22.0	20.6	23.5	23.0	0.233	RSM>SBM
digested lysine	17.4	16.6	17.6	18.2	0.182	RSM>SBM
- syntetic	2.7	4.7	6.9	9.0	0.055	RSM>SBM, L>H
- protein bound	14.7	11.9	10.7	9.2	0.134	SBM>RSM, H>L, S×P
Protein deposited	138	147	142	141	2.279	-
Protein utilization: % of intake	35.9	44.7	34.3	38.1	0.715	SBM>RSM, L>H
% of digested	49.1	61.3	46.7	52.1	0.975	SBM>RSM, L>H
Protein deposited/lysine intake	6.29	7.10	6.05	6.15	0.121	SBM>RSM
Protein deposited/ digested lysine intake	7.94	8.83	8.08	7.77	0.156	-

[a] Standard error; [b] S=protein source, P=protein level.

Table 8. Energy balance (kJ/kg$^{0.75}$) of growing pigs from 25 to 70 kg live weight

Item	SBM		RSM		SE[a]	Treatment effects[b] p<0.05
	H	L	H	L		
ME intake	1598	1526	1615	1704	16.821	RSM>SBM
Energy deposited as protein	183	194	188	187	2.934	-
Energy deposited as fat	422	382	401	470	12.576	P×S
Heat production, % of ME intake	62.3	62.2	63.5	61.5	0.423	-

[a] Standard error; [b] S=protein source, P=protein level.

experimental factors but a tendency to greater daily gains on lower than on higher protein level was observed. Empty body and carcass weight followed the same trend but differences did not reach statistical significance.

Generally, source of protein did not affect protein deposition but influenced significantly protein utilization (both as % of intake and of digested) which was greater on SBM than on RSM diets; the differences being more pronounced at the lower level of dietary protein.

In accordance with the assumptions of the present study, the diets were supplemented with crystalline lysine included in all the diets, at different levels (0.15-0.49%). Such supplementation widely changed the proportion of crystalline to protein-bound digestible lysine and this created the possibility to estimate the lysine effect on protein deposition, separately for crystalline (LYSc) and for protein-bound (LYSb) lysine. A following regression equation was obtained:

$$\text{Protein deposition}=7.45\ (\pm 0.92)\text{LYSc}+8.42(\pm 0.49)\text{LYSb},\quad se=10.1,\ n=24$$

The estimated partial coefficients (7.45 and 8.42g protein deposited from 1 gram of digestible lysine) may suggest a greater effect of protein-bound lysine, as compared to its crystalline form, on the rate of protein deposition in the body of pigs. The lower efficiency of crystalline lysine in pigs fed once or twice per day was usually attributed to different rates of absorption of added lysine than protein bound amino acids. It seems however unlikely that this factor may be important in *ad libitum* fed pigs. Assuming a lysine concentration in body protein gain as 7.2% (Susenbeth, 1995), the estimated efficiency of utilization of digestible lysine was 0.54 ($\pm$0.06) for crystalline lysine and 0.61 ($\pm$0.04) for protein-bound lysine. A similar difference in the coefficients of lysine utilization between the free and protein-bound form of this amino acid was reported by Lenis et al. (1994). Overall utilization of digestible lysine for protein deposition depended on both type of diet and amount of crystalline lysine inclusion.

Pigs fed both the SBM and RSM high-protein diets deposited similar amounts of protein in the body. However, at the lower protein concentration, protein deposition/ digested lysine intake (g/g) was affected by the type of diet: it was improved in the pigs fed the SBM-diet but deteriorated in the pigs fed the RSM-diet.

There is no simple explanation for such a reaction of the animals. In the case of the SBM-L diet, such a possibility could possibly arise if lysine digestibility were to be overestimated. Thus, greater lysine supplementation in the SBM-L diet could increase protein deposition in pigs. Nevertheless, the coefficient of apparent ileal digestible lysine in the SBM diet is similar to the tabulated (average) value (80 vs. 79) (Buraczewska et al., 1999; Degussa, 1996). Moreover, increasing net energy should be taken into consideration when lowering protein in a diet. Non-protein energy is better utilized by a pig than energy of protein-origin (Noblet, 1996). Modern pigs, such as those used in this study, are very susceptible to energy concentration in a diet (Rao and McCracken, 1990).

The negative response of RSM pigs to lower protein concentration could, at least partly, be explained by underestimation of lysine digestibility in the oilmeal. Thus, in contrast to the SBM-L diet, high lysine supplementation would not increase digestible lysine utilization. A negative effect of large inclusion of crystalline lysine to the diets for growing pigs is reported in many studies (Batterham and Murison, 1981; Bach Knudsen and Jorgensen, 1993).

An effect of glucosinolates on the pigs fed diets containing a large proportion of RSM should be also taken into consideration (Mawson et al., 1994), even when the RSM contains a low level of glucosinolates (5.1 μM/g fat-free DM in this study). Glucosinolates affect the hormone secretion of the thyroid gland and may modify protein and energy metabolism (Buchman and Wenk, 1989). In this experiment hormones were not determined, but the weight of the thyroid gland was controlled, as it is a simple and basic indicator of thyroxine secretion. The weight of the thyroid gland was low and did not differ between the RSM and SBM fed pigs (5.9 and 5.8 g, respectively). The energy balance was also similar in the groups. It seems, therefore, that the goitrogenic effect of glucosinolates on pigs was negligible.

It can be concluded that pigs fed *ad libitum* with diets containing a high level of soyabean or rapeseed meal, and balanced according to the content of ileal apparent digestible amino acids, are similar in respect to daily gain, chemical body composition and the rate of protein deposition. However, when protein level in diets is reduced with simultaneous increase of inclusion of crystalline amino acids, prediction of efficiency of pig production seems to be less accurate.

One additional remark arises from the present study. In intensively fed pigs with high capacity for body protein deposition, utilization of ileal digested lysine for protein accretion estimated with the comparative slaughter method was approximately 15-20% lower than data obtained in most nitrogen balance experiments (Batterham, 1992). This fact should be taken into consideration when data from short-nitrogen balances are transmitted into practice.

REFERENCES

AOAC. 1990. Official Methods of Analysis. 15th Ed. Association of Official Analytical Chemists, Chapter 32, Washington, DC, USA.

Agricultural Research Council. 1981. The Nutrient Requirements of Pigs. Commonwealth Agricultural Bureau.

Bach Knudsen, K. E. and H. Jorgensen. 1993. Use of synthetic amino acid in pig and poultry diets. In Recent Developments in Pig Nutrition 2 (Ed. D. J. A. Cole, W. Haresign and P. C. Garnsworthy). Nottingham University Press. pp. 106-116.

Batterham, E. S. 1992. Availability and utilization of amino acids for growing pigs. Nutr. Res. Rev. 5:1-18.

Batterham, E. S. and R. D. Murison. 1981. Utilization of free lysine by growing pigs. Br. J. Nutr. 46:87-92.

Bell, J. M., M. O. Keith and D. S. Hutcheson. 1991. Nutritional evaluation of very low glucosinolate canola meal. A review. Can. J. Anim. Sci. 71:497-506.

Bikker, P. 1994. Protein and lipid accretion in body components of growing pigs: effects of body weight and nutrient intake. Ph.D. Thesis, Wageningen Agricultural University, Wageningen.

Boisen, S. and P. J. Moughan. 1996. Different expressions of dietary protein and amino acid digestibility in pig feeds and their application in protein evaluation: a theoretical approach. Acta Agric. Scand. Sect, A, Anim. Sci. 46:165-172.

Brouwer, F. 1965. Report of sub-committee on constants and factors. In Proceedings of 3rd Symposium on Energy Metabolism, Troon, EAAP Publication No. 11:441-443.

Buchman, N. and C. Wenk. 1989. Effects of feeding low and high glucosinolate rapeseed meal on metabolism and thyroid function of growing pig. Proceedings of 11th Symposium on Energy Metabolism, Pudoc, Wageningen. (Ed. Y. Van der Honing and W. H., Close). EAAP Publication No. 43:32-36.

Buraczewska, L. and S. Buraczewski. 1984. A note on determination of methionine and tryptophan. Proceedings VI Inmational Symposium Amino Acids. Serock, Poland. June 1981. Polish Scientific Publishers, Warszawa. pp. 47-50.

Buraczewska, L., J. Wasilewko, H. Fandrejewski, T. Zebrowska and In K. Han. 1999. Formulation of pig diets according to ileal digestible amino acids content. Livest. Prod. Sci. 59:13-24.

CVB. 1995. Voedenormen Landbouwhuisdieren. Centraal Veevoeder Bureau. No. 18, Lelystad, The Netherlands.

Degussa, A. G. 1996. The amino acid composition of feedstuffs. Amino Dat 1.0. Frankfurt, Germany.

Fenton, T. W. and M. Fenton. 1979. An improved procedure for the determination of chromic oxide in feed and faeces. Can. J. Anim. Sci. 59:631-634.

Fuller, M. F., M. F. Franklin, R. McWilliam and K. Pennie. 1995. The responses of growing pigs, of different sex and genotype, to dietary energy and protein. Anim. Sci. 60:291-298.

Friesen, K. G., J. L. Nelssen, R. D. Goodband, M. D. Tokach, J. A. Unruch, D. H. Kropf and B. J. Keer. 1994. Influence of dietary lysine on growth and carcass composition of high-lean-growth gilts fed from 34 to 72 kilograms. J. Anim. Sci. 72:1761-1770.

Haydon, K. D., D. A. Knabe and T. D. Tankskey. 1984. Effects of level of feed intake on nitrogen, amino acid, and energy digestibilities measured at the end of the small intestine and over the total digestive tract of growing pigs. J. Anim. Sci. 59:717-724.

Haydon, K. D., M. D. Harrison and C. R. Dove. 1989. Effect of varying ileal protein level on the performance of growing-finishing swine. Nutr. Rep. Int. 40:939-947.

ISO-9167-1. 1991. Polish Standard, HPCL Method of Glucosinolates Determination (in Polish).

Kotarbińska, M. 1971. The chemical composition of the body in growing pigs. Rocz. Nauk rol. B-93:129-135.

Lenis, N. P., J. van der Meulen, J. Th. M. van Diepen and J. G. Bakker. 1994. The effect of essential to non-essential amino acid ratio on the utilization of dietary protein in growing pigs. Proceedings of 6th International Symposium on Digestive Physiology in Pigs, Bad Doberan, 4-6th October 1994, Dummerstorf, Germany (Ed. W. B. Souffrant and H. Hagemeister). EAAP Publication No. 80:39-41.

Mawson, R., R. K. Heaney, Z. Zdunczyk and H. Kozlowska. 1994. Rapeseed meal-glucosinolates and their antinutritional effects. Part 3. Animal growth and performanc. Die Nahrung. 38:167-177.

McIntosh, M. K., S. K. Baidoo, F. X. Aherne and J. P. Bowland. 1986. Canola meal as a protein supplement for 6 to 20 kilogram pigs. Can. J. Anim. Sci. 66:1051-1056.

Millward, D. J. 1995. A protein-stat mechanism for regulation of growth and maintenance of the lean body mass. Nutr. Res. Rev. 8:93-120.

Noblet, J., H. Fortune, S. Dubois and Y. Henry. 1989. Nouvelles based d'estimation des teneurs en energie digestible, metabolisable et nette des aliments pour le porc. INRA, Paris. pp. 106.

Noblet, J. 1996. Digestive and metabolic utilization of dietary energy in pig feeds: comparison of energy systems. Rec. Adv. Anim. Nutr. 1996:207-231.

National Research Council. 1998. Nutrient Requirements of Swine. 10th revised Ed. National Academy Press, Washington. DC, USA.

Rao, D. S. and K. J. McCracken. 1990. Effect of protein intake on energy and nitrogen balance and chemical composition of gain in growing boars of high genetic potential. Anim. Prod. 51:389-397.

Sauer, W. C. and L. Ozimek. 1986. Digestibility of amino acids in swine: results and their practical applications. A review. Livest. Prod. Sci. 15:367-388.

Statgraphics Plus vr 7.0 for DOS. 1993. Statistical Graphics System by Graphics Corporation.

Susenbeth, A. 1995. Factors affecting lysine utilization in growing pigs: an analysis of literature data. Livest. Prod. Sci. 43:193-204.

Quiniou N., J. Noblet, J. Van Milgen and J. Y. Dourmad. 1995. Effect of energy intake on performance, nutrient and tissue gain and protein and energy utilization in growing boars. Animal Sci. 61:133-143.

Van Soest, P. J. 1973. Collaborative study of acid detergent fibre and lignin. J. Assoc. Off. Chem. 56:513-530.

Yin, Y. L., R. L. Huang, H. Y. Zhang, C. M. Chen, T. J. Li and Y. F. Pan. 1993. Nutritive value of feedstuffs and diets for pigs: I. Chemical composition, apparent ileal and faecal digestibilities. Anim. Feed Sci. Technol. 44:1-27.