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Energy and amino acid content in phase 1 nursery diet: piglet performance and body chemical composition[1]

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ABSTRACT - It was evaluated the effects of metabolizable energy (ME) and digestible lysine (dLYS) densities on performance and body composition of weaned piglets. The study used 114 piglets weaned at 7.4 ± 0.80 kg, out of which 108 were allotted in the nursery and 6 were slaughtered on the weaning day to determine comparative data of body chemical composition. Six nutrients densities were stipulated from a previous study based on the highest nitrogen retention, maintaining the following ME:LYS relationship in the experimental diets: 3,390:1.291; 3,450:1.409; 3,650:1.411; 3,780:1.461; 3,940:1.507; and 4,109 kcal/kg ME:1.564% dLYS. The experimental diets were offered for 13 days when the piglets reached 12.986 ± 1.449 kg of body weight. The probable residual effects of nutritional density on the subsequent performance of the piglets were evaluated. At the end of initial phase 1, six piglets from each density were slaughtered to determine their chemical composition in body fractions and empty body. There was no significant influence of nutritional levels on the performance of the piglets at the end of the evaluation. The results of food conversion and body composition confirm the level indicated in the previous study, 4 g dLYS/Mcal of ME. The increase of energy and lysine densities confirms the need for a correct relationship among both of them to assure better performance of the piglets at the beginning of the growing phase.

Key Words: digestible amino acid, performance, swine, weaned

Densidade de energia e aminoácidos em dietas de leitões na fase pré-inicial de creche: desempenho e composição química corporal

RESUMO - Avaliaram-se os efeitos da densidade de energia metabolizável (EM) e lisina digestível (LIS) sobre o desempenho e a composição corporal de leitões após o desmame. Utilizaram-se 114 animais desmamados aos 7,4 ± 0,80 kg; desses animais, 108 foram alojados na unidade de creche e 6 foram abatidos no dia do desmame para determinação dos dados comparativos da composição química corporal. Seis densidades de nutrientes foram estipuladas a partir de estudo anterior, com base na maior retenção de nitrogênio, mantendo-se as seguintes relações EM:LIS nas dietas experimentais: 3.390:1,291; 3.450:1,409; 3.650:1,411; 3.780:1,461; 3.940:1,507; e 4.109 kcal/kg EM:1,564% LIS. As dietas experimentais foram oferecidas durante 13 dias, quando os leitões atingiram o peso de 12,986 ± 1,449 kg. Avaliaram-se os prováveis efeitos residuais da densidade nutricional no desempenho subseqüente dos leitões. Ao término da fase inicial-1, seis leitões de cada densidade foram abatidos para determinação da composição química nas frações corporais e no corpo vazio. Não houve influência significativa dos níveis nutricionais no desempenho dos leitões ao término da avaliação. Os resultados de conversão alimentar e composição corporal ratificam o nível indicado em estudo anterior, de 4 g LIS/Mcal. O aumento da densidade de energia e lisina confirma a necessidade da correta relação entre ambos para assegurar o melhor desempenho dos leitões na fase inicial de crescimento.

Palavras-chave: aminoácido digestível, desempenho, desmamados, suíno

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Introduction

Improvement in swine nutrition requires periodic reviews of nutritional levels recommended for each animal category. These requirements depend on environmental conditions and on the management that the pigs are submitted to as much as on health conditions and genotypes existing in the world market, where Brazil is strongly insertet. As a result, the importance of lysine as a first limiting amino acid in most diets, which have been formulated to attend the maximum requirements for protein deposition during the growth of swines has greater evidence.

The supplied energy needs to meet the requirements for maintenance and accretion of body mass. However, the non-intrinsic conditions of the animals may determine the efficiency with which dietary energy is utilized. Considering the importance of energy, new studies need to focus on the same specificities as for amino acid requirements at different stages of pig development. For this, the knowledge of amino acid and energy interaction, as well as a better relationship between them is essential, mainly when using the concept of ideal ratios among essential and limiting amino acids on the development of pigs maintained under good production conditions.

If feed intake after weaning is low, an increase in dietary nutrient content is fundamental for optimal growth piglet. In this case, dietary metabolizable energy (ME) content has an important role.

Based upon previous studies whose objective was to establish a better relationship between digestible lysine (dLYS) and metabolizable energy, this study determined the dietary effects of metabolizable energy and digestible lysine contents on performance and body composition of piglets during the pre-starter nursery phase.

Material and Methods

This experiment was conducted in the swine facilities of the Instituto de Zootecnia in Nova Odessa, São Paulo, Brasil. Room temperatures during the study was maintained from 27.5 ± 2.1^{o}C (maximum) to 21.3 ± 1.3^{o}C (minimum).

It was used 114 weaned piglets with an initial body weight of 7.4 ± 0.80 kg. Out of these, 108 piglets were housed in randomized block design with six treatments and six replications and three animals per experimental unit. Initial weight was used to compose the blocks. The remaining piglets were slaughtered on the weaning day to provide basal body composition data.

Six concentrations of digestible lysine and metabolizable energy were used. Amino acids were established as two levels below and three levels above the optimum level determined in a preliminary study (Trindade Neto et al., 2009). The diets had 2.11 ± 0.28% of crude fiber and were considered highly digestible due to the characteristics of the ingredients used (AMIPIG, 2000).

The diets (Table 1) were used for 13 days, during which the piglets achieved 13.0 ± 1.45 kg of weight. After this experimental period, piglets were offered a highly nutritional standard phase 2 diet to evaluate probable residual treatment effects in a subsequent performance. In the diet formulation for phase 2 the requirement suggestions from NRC (1998) and Rostagno et al. (2005) were used to supply the nutritional levels: 3390 kcal ME; 7% lactose; 18% CP; 0.70% Ca; 0.32% Pd; 1.06% dLYS; 0.61% digestible methionine + cistine; 0.19% digestible tryptophan; 0.66% digestible threonine; 0.59% digestible isoleucine; 0.73% digestible valine. Other essential amino acids were supplied without including crystalline amino acids (Table 2).

Six piglets, selected from a group of 114 piglets were slaughtered at weaning to collect baseline data. The selection was such that 2 piglets represented the average weight of the whole group (7.4 ± 0.80 kg) while 2 piglets represented the heaviest group and the remaining 2 piglets represented the lightest group. The average data obtained in this stage were used to compare the values of body chemical composition for determination of the protein and lipid deposition at the end phase 1 of the experiment.

At the end of phase 1, after 16 hours of fast, 36 piglets (6/treatment) were slaughtered to determine the chemical composition in body fractions (blood, offal and carcass) and empty body, as well as the daily deposition rates. The slaughter was carried out by bleeding after electric concussion.

The pigs chosen for slaughter were those with an average weight from each pen, according to density, to evidence the difference between body composition and deposition daily rates. Empty body was defined by differences among fasting weight and the contents of the stomach, intestines and bladder.

After bleeding, the offal (empty digestive and urinary tracts, glands, reproductive organs, heart, liver, spleen, lungs, kidneys and perineal fat) were removed.

Three blood samples (approximately 80 mL) were collected for chemical analysis. Offal was removed, emptied and weighted. Offal and carcass were packed and maintained at minus 10^{o}C until processing. Blood, offal and carcass samples were dried and grounded for subsequent chemical analysis. Freezer dryer worked by vacuum system at 5 mm/Hg, at -52^{o}C and dried by sublimation. Samples were ground with dry ice in a blender.

Table 1- Ingredients and nutrient composition of experimental diets fed during phase 1 (13 days after weaning)

Crude energy (kcal/kg)[1]	3872	3996	4168	4319	4499	4693
Metabolizable energy (kcal/kg)[2]	3390	3450	3650	3780	3940	4109
Ingredient (kg)						
Corn grain	48.400	45.800	43.300	41.620	36.420	32.400
Soybean meal 48%	12.000	12.000	12.000	12.000	12.000	12.000
Soybean protein extrate[3]	4.060	5.200	5.620	6.000	6.230	6.000
Gluten meal 60 %	2.000	2.000	2.000	2.000	2.000	2.000
Spray dried plasma	5.000	5.000	5.000	5.000	5.000	5.000
Sugar	2.000	2.000	2.000	2.000	2.000	2.000
Milk product-65[4]	2.070	5.500	10.80	17.000	22.000	26.000
Milk product-21[5]	20.000	18.000	15.22	10.000	10.000	10.000
Salt	0.300	0.300	0.300	0.300	0.300	0.300
Dicalcium phosphate	1.178	1.178	0.960	1.000	0.951	0.880
L-lysine HCL	0.337	0.333	0.338	0.432	0.421	0.535
L-threonine	0.126	0.129	0.165	0.186	0.210	0.245
DL-methionine	0.165	0.175	0.130	0.230	0.261	0.295
L-tryptophan	0.063	0.066	0.060	0.084	0.093	0.105
L-isoleucine	0.016	0.005	0.023	0.039	0.055	0.084
L-valine	0.006	0.004	0.029	0.054	0.084	0.126
Zinc oxide	0.320	0.320	0.320	0.320	0.320	0.320
Choline chloride	0.030	0.030	0.030	0.030	0.030	0.030
Butilhidroxitolueno (BHT)	0.025	0.025	0.025	0.025	0.025	0.025
Organic acids-P[6]	1.200	1.200	1.200	1.200	1.200	1.200
Antibiotic	0.030	0.030	0.030	0.030	0.030	0.030
Vitamin mix[7]	0.400	0.400	0.400	0.400	0.400	0.400
Mineral mix[8]	0.050	0.050	0.050	0.050	0.050	0.050
Inert material	0.224	0.255	0.0	0.0	0.0	0.0
Cost per kg (US$)	0.48	0.50	0.55	0.59	0.65	0.71
Calculated nutrient composition						
Digestible lysine (%)	1.291	1.409	1.411	1.461	1.507	1.564
Dry matter (%)[1]	90.29	89.47	89.82	90.81	91.15	91.81
Lactose (%)	14.83	14.80	14.97	13.80	15.8	17.4
Crude protein (%)[1]	20.34	20.20	21.07	21.68	22.15	21.15
Crude fiber (%)[1]	2.49	2.71	2.50	2.23	2.23	1.87
Digestible lysine (Mcal of ME)	4.05	4.05	4.05	4.05	4.05	4.05
Calcium (%)[1]	0.80	0.87	0.80	0.80	0.79	0.79
Total phosphorus (%)[1]	0.71	0.70	0.71	0.71	0.71	0.71
Available phosphorus (%)	0.50	0.50	0.45	0.45	0.45	0.45
Ash content (%)	5.46	5.56	5.24	5.06	5.31	6.14
Ether extract (%)[1]	3.44	3.85	6.39	7.86	9.46	11.60
Digestible threonine (%)	0.896	0.935	0.97	1.015	1.054	1.093
Digestible meth + cis (%)	0.785	0.82	0.85	0.89	0.924	0.959
Digestible tryptophan (%)	0.276	0.288	0.30	0.32	0.324	0.336
Digestible arginine (%)	1.125	1.159	1.21	1.24	1.253	1.233
Digestible isoleucine (%)	0.758	0.791	0.83	0.858	0.892	0.925
Digestible valine (%)	0.937	0.978	0.99	1.061	1.103	1.144
Digestible leucine (%)	1.834	1.909	1.86	1.96	1.972	1.961
Digestible histidine (%)	0.580	0.606	0.62	0.62	0.621	0.615
Digestible phenylalanine (%)	0.942	0.99	1.03	1.02	1.024	1.013

[1] Analyzed value.
[2] Estimated rate metabolizabel energy (ME): gross energy (87.56%) according to a previous digestibility study (Trindade Neto et al., 2009).
[3] ME 3560 kcal/kg; Crude protein 92%; Dig. Lys 5.41%; Dig, Thr 3.00%; Dig. Met + Cys 2.24%; Dig. Trp 0.846%; Dig. Ile 3.57%; Dig. Val 3.76%; Dig. Leu 6.55%; Dig. Phen 4.358%; Dig. tryptophan 3.12%; Ca 0.40%; Available phosphorus 0.32%.
[4] Fat 40%; Lactose 40%; ME 6498 kcal/kg; CP 10.5%; Dig. Lys 0.60%; Dig. Thr 0.46%; Dig. Met + Cys 0.35%; Dig. Trp 0.09%; Ca 0.25%; Available phosphorus 0.30%; Na 0.45%; Potassium 1.20%.
[5] Fat 5%; Lactose 70%; ME 3800 kcal/kg; CP 11.0%; Dig. Lys 0.73%; Dig. Thr 0.53%; Dig. Met + Cys 0.36%; Dig. Trp 0.13%; Ca 0.58%; Available phosphorus 0.66%; Na 0.80%; Potassium 2.00%.
[6] Calcium - 25%.
[7] Per kg: Vit. A 10,000,000 UI, Vit. D_3 2,200,000 UI, Vit. E 18,000 UI, Vit. K 5,500 mg, Vit. B_1 1,800 mg, Vit. B_2 6,000 mg, Vit. B_6 2,200 mg, Vit. B_{12} 24,000 mg, Niacin 36,000 mg, Folic acid 650 mg, Pantotenic acid 18,000 mg, Biotin 120 mg, Se 300 mg, BHT 20 mg.
[8] Per kg: Mn - 30,000 mg; Zn - 140,000 mg; Cu - 16,000 mg; Fe - 90,000 mg; Co - 200 mg; I - 850 mg.

Table 2 - Amino acid composition of experimental diets used in performance assays: data expressed in percentage as fed

Digestible lysine:	1.291	1.409	1.411	1.461	1.507	1.564
Total amino acid[1]						
Lysine	1.464	1.598	1.618	1.671	1.710	1.774
Threonine	1.035	1.122	1.144	1.181	1.193	1.211
Methionine	0.483	0.480	0.454	0.577	0.569	0.575
Cysteine	0.390	0.414	0.416	0.432	0.417	0.407
Methionine+ cysteine	0.874	0.894	0.869	1.008	0.986	0.982
Arginine	1.240	1.376	1.310	1.343	1.346	1.288
Isoleucine	0.821	0.892	0.894	0.938	0.953	0.961
Valine	1.052	1.118	1.129	1.173	1.193	1.203
Leucine	2.043	2.120	2.125	2.135	2.107	2.062
Histidine	0.541	0.577	0.570	0.579	0.578	0.560
Phenylalanine	1.082	1.166	1.141	1.158	1.161	1.140
Alanine	1.150	1.237	1.179	1.168	1.158	1.122
Glycine	0.845	0.852	0.843	0.854	0.868	0.835
Serine	1.177	1.200	1.191	1.217	1.204	1.179
Tyrosine	0.770	0.878	0.803	0.792	0.820	0.813
Aspartic acid	2.063	2.217	2.174	2.220	2.204	2.142
Glutamic acid	3.812	4.052	4.121	4.223	4.234	4.173

[1] Analyses conducted by Ajinomoto Biolatin-Brazil.
[2] Dry matter content of samples 90%.

Chemical analysis occurred in duplicate in the Instituto de Zootecnia, São Paulo. Water, protein, fat and ashes percentages on blood, offal and carcass (including head, feet, nails and hair) were determined according to AOAC (1984).

Weight gain, feed intake and feed conversion rates were measured after 13 days from the start and at the end of phase 2 after 19 days from the end of the preview phase. The characteristics considered were weight gain, feed intake, feed conversion rate, body chemical composition, water, protein, fat and mineral accretions in carcass and empty body, according to mathematic model:

$$\hat{Y}_{ijk} = \mu + C_i + B_k + e_{ijk},$$

in which $\hat{Y}_{ijk}$ = constant associated to all observations; μ = characteristic general average; C_i = i nutrient concentration effect, that i = 3400 and 1.378; 3550 and 1.439; 3700 and 1.500; 3850 and 1.561; 4000 and 1.622; 4150 and 1.683% of kcal de ME/kg and digestible lysine, respectively; B_k = k bloc effect, that k = 1; 2; ... 6; eij_k = random error associated each observation.

Results and Discussion

There were no significant differences on final body weight and on weight gain of piglets at the end of phase 1 (Table 3).

On feed intake (P=0.06) and on feed conversion rate (P=0.03) descendent linear effect was observed due to increase of energy, lysine and other dietetics amino acids concentration, according to respective equations: $\hat{Y} = 0.832065 - 0.0000705X$, R^2=0.42; and $\hat{Y} = 1.818859 - 0.0001285X$, $R^2 = 0.25$. The coefficients of determination are low for these characteristics; however, they suggested an increase in efficiency of dietary nutrient utilization even an absence of significant differences in weight gain and final weight at initial-1 phase according to increased energy and amino acid in diets.

The maintenance of relationship and the increase of nutrients density assured the nutrients supplied for growing needs, since the weight gain was satisfactory in all studied levels. Because of low statistic precision, the interpretation of these results requires reflection, as it will be discussed further.

The decrease of feed intake might be due to a supply of energetic demands according to increased metablizable energy, lysine and other amino acids. As the first limiting amino acid, the efficiency of lysine utilization changes as a consequence of relative absorption rate from maximum body protein synthesis demanded by the pig. Under adverse situation, the negative effect of amino acid occurs on growth rate when there is an excess, mainly because of a reduction in voluntary intake (Heger, 2003) and on net protein, due to amino acid deamination and consequent nitrogen elimination (D'Mello, 2003).

The correct energy supply is a fundamental factor on lysine and other amino acid use. The energy of the diet is usually a limiting factor of protein deposition in pigs until 40 kg of weight (Boisen, 2003). Therefore, the lysine requirement would be associated with optimum composition of available amino acids relative to energy of diet, and this combined needs decreases during the growing period as the pig grows. When there is an imbalance among dietary nutrients, utilization of the limiting amino acid is affected under *ad libitum* feeding conditions. In this case, the first symptom would a be reduced growth due to a decrease in feed intake (Van Lunen & Cole, 1998) and it occurs when the lysine: energy ratio is above the optimum (Moughan & Fuller, 2003).

By emphasizing the ideal protein application on piglet diet preparation for nursery periods, Gatel et al. (1992) concluded that the maximum weight gain for piglets from 8 to 25 kg would be obtained with the average ingestion of 4.73 g of lysine per Mcal of metabolizible energy. Similar suggestions were made by Williams et al. (1997) after comparing healthy pigs with immunologically challenged pigs, from 6 to 27 kg of body weight. In healthy pigs, average ingestion of lysine was 4.72 g per Mcal of metabolizible energy while in immunologically challenged pigs, lysine ingestion was 3.77 g per Mcal of metabolizible energy.

Because of discrepancies found in results from literature, it was confirmed that one of the greatest challenges of nutrition is determining the physiologic limit into which the animal can respond satisfactorily to dietary nutrient supply. Non intrinsic factors are determinants on characterization of genetic potential that is measured as performance.

Some considerations about the results and data precision in this study are important. The average temperatures were 27.4°C (maximum) and 21.9°C (minimum); therefore, there were different levels of thermal comfort (22 to 24°C) for piglets in this development phase. According to Patience et al. (1995), fluctuations above 2°C have harmful effects on the growth rate and feed conversion rate. However, this is the reality for Brazilian swine production conditions, as it occurred from December to January. The application of results probably would not be the same during the winter period when temperature variation are lower and stimulate feed intake.

When calculated, the relative values of weight gain, liver weight, kidney weight and offal total weight, indicate that estimated levels in 3650 kcal of ME and 1.411 of digestible lysine would be close to the requirements. Moreover, the better performance did not coincide with hypertrophy of these organs, which is normally caused by excessive nutrient supplies and high catabolic activity.

Regarded to the variation on the sizes of the organs, Chan & Hargrove (1993) explained that the exposure of the liver to high concentrations of amino acid and blood hormones from hepatic portal vein presented two important effects. First, the increase of the size of this organ and of the kidney when hepatic and kidney cells proliferate. This proliferation is due to increase of DNA and RNA and activation of enzymes needs for cell constituent synthesis and cellular division, resulting in growth and protein accretion. Second, the increase of enzymes concentration for catabolism of exceeding amino acids and the use of the resultant carbon chains. Amino acid concentration in general circulation does not increase the levels observed in portal circulation. High quantities of protein impose an adaptation and increase of enzyme concentration in the liver and kidneys that convert amino acid to precursors during glucose

Table 3 - Piglet performance and body deposition rates during nursery period, according to nutritional levels of energy and lysine

Digestible lysine (%)	1.378	1.439	1.500	1.561	1.622	1.683	CV (%)
Metabolizable energy (kcal/kg)	3390	3450	3650	3780	3940	4109	-
Lysine:metabolizable energy (g/Mcal)	0.40	0.42	0.40	0.41	0.41	0.41	-
Metabolizable energy (kcal/kg)[1]	3450	3560	3700	3850	4000	4180	-
Digestible lysine (%)[2]	1.291	1.409	1.411	1.461	1.507	1.564	-
Lysine[2]:Metabolizabe energy (g/Mcal)[1]	0.374	0.395	0.384	0.379	0.377	0.374	-
	Phase 1 – Dietary contents						
Initial weight, IW (kg)	7.52	7.40	7.39	7.41	7.45	7.42	1.2
Final weight, FW (kg)	13.52	12.42	13.25	13.09	12.85	12.79	5.1
Weight gain (g/day)	445.7	375.0	462.7	437.3	418.2	413.3	10.9
Feed intake (g/day)**	611.8	544.2	568.7	583.3	563.3	523.3	10.2
Relative weight gain (FW – IW)/IW × 100	79.84	67.84	79.17	76.68	72.48	72.38	10.9
Feed conversion rate**	1.37	1.45	1.23	1.33	1.35	1.28	6.6
Energy intake (kcal/day)[1]	2111	1937	2110	2246	2259	2187	-
Lysine intake (g/day)[2]	7.9	7.6	8.1	8.6	8.5	8.2	-
Lysine intake (g/Mcal)[2]	3.7	3.9	3.8	3.8	3.8	3.8	-
Piglet weight slaughtered – fast (kg)[3]	13.40	12.72	13.27	13.69	13.06	12.62	5.3
Liver weight (g)	323.2	311.4	293.8	317.8	321.1	318.0	4.6
Relative liver weight (%)	2.84	2.80	2.58	2.99	2.86	2.89	5.8
Kidney weight (g)	81.2	83.4	73.2	79.3	80.2	78.7	5.5
Relative kidney weight (%)	0.71	0.75	0.64	0.75	0.71	0.72	6.6
Relative offal weight (%)	12.83	13.37	11.22	13.56	12.68	13.12	7.5
Carcass protein deposition (g/day)**	46.4	43.0	51.0	43.7	47.9	43.8	13.9
Carcass fat deposition (g/day)	29.1	28.5	37.0	24.7	28.9	31.5	23.4
Carcass water deposition (g/day)	209.2	181.5	210.0	182.0	212.1	191.7	11.8
Carcass ash deposition (g/day)	5.0	4.4	4.9	4.4	4.8	4.5	17.3
Empty body protein deposition (g/day)	59.2	53.2	63.0	56.2	59.8	55.3	14.1
Empty body fat deposition (g/day)	32.1	30.6	39.2	27.2	31.3	34.0	25.9
Empty body water deposition (g/day)	280.5	231.4	266.0	238.1	269.2	252.4	15.9
Empty body ash deposition (g/day)	5.9	5.2	5.8	5.2	5.7	5.4	17.3

1. Estimated value based on laboratory analysis and an average value obtained in a metabolism essay in which ME:GE was 89.15%
2. Estimated value based on laboratory analysis and the weighted average relation of 88.15% digestibility, used as relation to total lysine from the main ingredients.
3. Slaughtered: 6 piglets per treatment with average weight from each treatment, at the final of experimental phase.
** Quadratic effect (P=0.06).

and fat acids synthesis. On the other hand, a diet high in carbohydrates reduces the activity of enzymes that participate in gluconeogenesis and amino acid catabolism. Therefore, there is a physiological relationship of opposition between protein and carbohydrates establishing the nutritional requirements, according to the age of the pig age and body weight changes.

On a daily rate of protein deposition of carcass, there was a quadratic effect (P=0.06) of nutritional density $\hat{Y} = 547.29089 - 0.2641232X + 0.00003515X^2 - R^2\ 0.60$). In this case, the optimal level of metabolizable energy would be close to 3700 kcal/kg or an intake of 2130 kcal/day, based on analyzed composition. For digestible lysine, the approximate values would be 1.44% or 4 g digestible lysine/Mcal, based on laboratory analysis values adjusted by digestibility indices as observed by Trindade Neto et al. (2009).

There were no significant differences on lipid deposition, carcass water and ash contents among dietary treatments. The average values obtained for these characteristics were 30.4, 197.4 and 4.7 g/day, respectively.

The changes in performance (Table 3) coincided with accretion of carcass protein and increase in weight, although there were no significant differences (P=0.07). During the growth period, protein synthesis is allocated preferentially to muscle composition in a direct relation with water content. This relation in lean tissue corresponds to ¾ of water and ¼ protein (Claus & Weiler, 1994).

On the empty body, there were no significant differences on daily rates of chemical composition. The results obtained from deposition changed from 53 to 63 g/day of protein, 27 to 39 g/day of fat, 230 to 269 g/day of water and 5 to 6 g/day of ash content. Le Bellego & Noblet (2002) observed that amino acid supply did not affect energy utilization and body composition of weaned piglets from twenty eight days of age to slaughtered at 15 kg. In this study, they used 4.23 g of lysine/Mcal NE in diets that changed from 3,380 to 3,413 kcal/kg of ME.

Average values obtained in empty body and carcass have some equivalencies mainly regarded to the protein and fat (Table 3). This information would confirm observations by Boisen (2003) about pig body composition, that for every kilo of deposited protein, there is a corresponding gain of 4.4 kg. In this study with weaned piglets in the initial phase of growth, the relationship between gain and daily deposition of protein was 7.3 and when the addition of protein and fat deposition was considered, the relation decreased to 4.7. Values found here are comparable to those suggested by Van Lunen & Cole (1998) for piglets at 15 kg.

A linear increase of lysine requirement was confirmed by Trindade Neto et al. (2001), and in another study, Trindade Neto et al. (2004) increased the levels and observed a quadratic response for the quantity of protein in the carcass. In the second study, the authors estimated 1.51% total lysine, about 1.30% digestible lysine, using diets with 3,250 kcal ME and estimated intake 4.06g/Mcal of ME. The estimated intake was similar in this experiment and confirmed the need to establish the correct relation between lysine and energy and when to use the ideal relation among amino acids for growth and muscle accretion.

There were no significant effects of dietary energy and lysine levels on the weights of body fractions and their chemical composition (Table 4). Offal, blood and carcass weight, as well as corresponding proportions on empty body, did not differ with energy and lysine variations in diets. Similarly, there were no significant effects of dietary treatment on water, protein, fat and ash composition. The lack of differences among dietary treatment on weights and respective chemical components may be explained by the fact that there were no statistical variation of animal weights at slaughter. The absences of effect on energy and lysine levels revealed uniformity in chemical component synthesis during the interval of the studied weight.

Percentages of water and fat components on the carcass were similar to those found by Auldist et al. (1997) in a study with piglets at 7 kg of body weight and diets changing from 1.37 to 1.74% of lysine. Trindade Neto et al. (2001) verified major efficiency of lysine utilization for muscle protein synthesis of piglets when total lysine level was elevated to 1.25%. These observations confirmed the results by Susenbeth (1995) and Auldist et al. (1997) showing that an increase in dietary lysine levels stimulates the development of protein fractions or compartments of the body. However these authors did not determine an optimum dietary limit. Results of the present study indicate an optimum dietary lysine level with energy demand, both of which are higher than reported in previous studies.

Based on empty body, the average chemical composition in natural matter basis was the following: protein,16.85%; fat, 9.94%; ash, 1.22%; and water, 71.99%. These results are consistent with the ones reported by Whittemore (1993) in which body protein content is more stable than fat content, ranging from 14 and 18%, with an average of 16%. The author suggested that body lean content changes inversely to fat tissue partly because of the change in the water content in the lean tissue. This change could be associated with a decrease in protein anabolism and a simultaneous increase in fat deposition as the age of the pig and body weight changes. Therefore, growth efficiency is associated with muscle mass accretion. Normally, the muscle has 70 to 75% water, 5 to 15% fat and 20 to 25% protein. In young swines, when muscle protein synthesis rate is high, the water content may be as high as 80%, however, in adult swines it may be under 70% (Whittemore, 1993).

In the same way, body protein and fat deposition rate are indicative of protein synthesis efficiency in response to nutritional levels in diet. The absence of effect among experimental diets suggests that levels of digestible lysine, around 1.5%, and metabolizable energy around 3,700 kcal/kg are better indications in climatic conditions of this study (20 to 29°C). Trindade Neto et al. (2004) suggested the need for new studies with total lysine levels above 1.46% and emphasized that some characteristics may show some changes from better nutritional levels , even though the response has been small. It was also observed that when they are isolated, these variables may not be considered to better determine lysine levels due to contradictory results from literature in relation to lysine effects on swine body chemical composition, determined in samples with or without fat.

Increase of protein concentration (P<0.05) on de-fatted dry matter confirms a major efficiency in the synthesis and protein deposition (anabolism) in response to an increase in lysine. The responses obtained on de-fatted dry matter indicate that body chemical composition may change in small quantities. This small variation could be from a combined supply of limiting and other amino acids in protein metabolism of swines.

According to Friesen et al. (1996), protein synthesis would not be totally associated with muscle deposition during growth, but the preferential destination would be the skeletal muscle deposition. Using piglets up to the forth week of age, Davis et al. (1996) concluded that the intensity of muscle protein synthesis is a feed response. In the

Table 4 - Effects of dietary lysine levels on body chemical composition of piglets at 13.0 ± 1.2 kg of fast body weight[1]

	Digestible lysine (%)[2]								
	1.291	1.409	1.411	1.461	1.507	1.564	Probability-F		
	Metabolizable energy (kcal/kg)[1]								
	3390	3450	3650	3780	3940	4109	CV (%)	RL	RQ
Empty offal (g)	1900	1604	1672	1694	1694	1775	17.7	ns	ns
Empty offal (%)[5]	14.37	12.86	12.85	13.79	13.27	14.31	10.8	ns	ns
Water (%)[3]	81.01	80.81	80.60	81.15	80.94	81.13	0.8	ns	ns
Protein (%)[3]	14.57	14.77	15.06	14.40	14.64	14.45	3.4	ns	ns
Fat (%)[3]	3.66	3.64	3.60	3.76	3.69	3.67	9.4	ns	ns
Ash (%)[3]	0.76	0.79	0.74	0.70	0.73	0.75	8.0	ns	ns
Blood (g)	774	725	756	723	744	720	10.0	ns	ns
Blood (%)[5]	5.85	5.81	5.81	5.89	5.83	5.80	2.4	ns	ns
Water (%)[3]	83.62	83.35	83.43	83.65	83.69	83.26	0.5	ns	ns
Protein (%)[3]	14.41	14.60	14.61	14.44	14.39	14.81	2.8	ns	ns
Fat (%)[3]	1.38	1.49	1.34	1.33	1.35	1.31	9.3	ns	ns
Ash (%)[3]	0.59	0.56	0.62	0.58	0.57	0.62	5.8	ns	ns
Carcass (g)	9359	8935	9468	8902	9399	9114	10.8	ns	ns
Carcass (%)[5]	70.79	71.63	72.75	72.48	73.66	73.48	10.1	-	-
Water (%)[3]	70.11	69.50	69.55	69.78	70.17	69.46	1.2	ns	ns
Protein (%)[3]	16.88	17.15	16.69	17.37	17.00	17.00	13.4	ns	ns
Fat (%)[3]	11.55	11.94	12.46	11.44	11.52	12.19	6.5	ns	ns
Ash (%)[3]	1.46	1.41	1.30	1.41	1.31	1.35	8.3	ns	ns
Empty body (kg)[4]	13.221	12.474	13.014	12.282	12.760	12.404	10.3	ns	ns
Water (%)[3]	72.52	71.78	71.45	71.99	72.29	71.90	1.3	ns	ns
Protein (%)[3]	16.54	16.91	16.96	17.17	16.82	16.70	13.5	ns	ns
Fat (%)[3]	9.65	10.06	10.42	9.59	9.71	10.2	6.8	ns	ns
Ash (%)[3]	1.29	1.26	1.17	1.25	1.18	1.20	7.3	ns	ns
Protein (%)[6]	92.75	93.08	93.54	93.23	93.47	93.27	0.5	*	ns
Ash (%)[6]	7.25	6.92	6.60	6.77	6.53	6.73	7.3	*	ns
Protein:water rate[3]	0.23	0.24	0.24	0.24	0.23	0.23	4.6	ns	ns
Protein:fat rate	1.70	1.69	1.63	1.80	1.73	1.65	7.4	ns	ns

[1] Estimated value on laboratory analysis and average value used from metabolism assay where ME:CE was 89.15%.
[2] Estimated value on laboratory analysis base and the weighted average relation of 88.15% digestibility used as relation to total lysine from main ingredients.
[3] Data from natural matter basis.
[4] Empty body = fast weight minus digestive tract and urinary contents.
[5] Values expressed as percentage of empty body.
[6] Data from de-fatted samples on dry matter basis.

Table 5 - Piglet performance during the nursery phase following dietary treatment in phase 1

Metabolizable energy (kcal/kg)[1]	3450	3560	3700	3850	4000	4180	CV (%)
Lysine[2]:metabolizable energy (g/Mcal)[1]	0.374	0.395	0.384	0.379	0.377	0.374	-
Digestible lysine (%)[2]	1.291	1.409	1.411	1.461	1.507	1.564	-
Initial phase 1 – 12.986 to 23.935 kg from subsequent dietetics densities applied							
Final weight (kg)[3]	25.07	22.85	23.94	24.72	23.30	23.73	6.9
Weight gain (g/day)	612	548	561	587	554	571	11.7
Feed intake (g/day)	1031	902	936	969	933	918	10.1
Feed conversion rate	1.67	1.65	1.67	1.65	1.70	1.60	7.0
Total period – 7.432 to 23. 935 kg							
Weight gain (g/day)	550	486	521	534	497	513	9.6
Feed intake (g/day)	862	757	792	811	783	757	8.6
Feed conversion rate	1.56	1.56	1.53	1.51	1.57	1.48	5.7

[1] Estimated value based on laboratory analysis and average value from metabolism assay were ME:CE was 89.15%
[2] Estimated value based in laboratory analysis and weighted average relation of 88.15% digestibility used as relation to total lysine from the main ingredients.
[3] Evaluation of probable residual effects from treatments applied in phase 1.

present study the nutrients concentration, on carcass and empty body, confirm a lysine level no lesser than 1.50%, according to Trindade Neto et al. (2004). The energy level, however, is higher to those previously reported.

Ash concentration in de-fatted matter linearly decreased ($P<0.05$) in response to increasing dietary lysine concentration. Similarly in the carcass, the reduction in ash concentration in the empty body was probably due to the gradual changes and deposition in different tissues. According to Trindade Neto et al. (2004) there was not an explanation for that observed variation, as a result of increasing body protein concentration as mentioned by Whittemore (1993), that ash and protein rate is relatively constant due to the use of bones as structure support for musculature.

Non significant statistical effect on protein and fat quantity or concentration in body fractions and empty body, indicate similar efficiency of energy and lysine use for protein synthesis in piglets in response to an increase in dietary nutrients density. Results of feed conversion rate, protein deposition in carcass and protein concentration on de-fatted dry matter confirm observations by Susenbeth (1995) and Trindade Neto et al. (2001) that an increase of lysine levels stimulates the development of protein fractions or compartments of body. This situation occurs when a pig has the genetic potential for high deposition of muscle mass, and the requirements to support this maximal use efficiency is supplied. When the animal has good health conditions, the optimal level can be attained, and the changes around this will be minimal (Williams et al., 1997).

Significant differences from residual effects of dietary treatments applied during phase 1 on subsequent phase and the total nursery period (Table 5) were not observed. The animals that had lower intake of the experimental diets in phase 1 were as efficient as the others were in their use of the diet that was offered in the subsequent phase. The recovery at initial phase 2 and the total period of nursery showed that the quality of the diets used permitted animals with worse performance from the phase 1 to become equal to others, under some physiological limits.

Conclusions

Increase in dietary energy and lysine density confirms the need for a correct balance among to ensure good performance of piglets during the initial growing phase. The results of feed efficiency and body composition confirm the indicated levels: 4 g dLYS/Mcal in previous study. New studies focusing on amino acid and energy concentration will be able to show favorable responses about limits of nutrients concentration on performance and body composition of piglets after weaning.

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