LEVELS OF DIGESTIBLE ISOLEUCINE ON PERFORMANCE, CARCASS TRAITS AND ORGANS WEIGHT OF GILTS (15 - 30 KG)

Níveis de isoleucina digestível sobre o desempenho, características de carcaça e peso de órgãos de fêmeas suínas (15 - 30 kg)

Leandro Dalcin Castilha[1], Paulo Cesar Pozza[2], Ricardo Vianna Nunes[3], Doglas Batista Lazzeri[4], Marcelo Luiz Somensi[5], Magali Soares dos Santos Pozza[3]

ABSTRACT

The ideal protein concept for pigs has allowed reducing levels of crude protein in the diet, since synthetic amino acids are included because the branched chain amino acids may be limiting. In order to determine the digestible isoleucine requirement for gilts from 15 to 30 kg, a performance assay was accomplished, using 40 crossbreed gilts of high genetic potential, averaging 15.00 ± 0.52 kg of body weight, alloted in a randomized blocks design, consisting of five treatments (0.45, 0.52, 0.59, 0.66, 0.73% of digestible isoleucine), four replicates and two animals per experimental unit. Performance traits were determined and at the end of the experiment one animal per experimental unit was slaughtered to determine carcass composition and organs weight. Levels from 0.45 to 0.73% of digestible isoleucine did not affect the carcass traits and organs weight of gilts from 15 to 30 kg. A quadratic effect (P<0.05) of digestible isoleucine levels on isoleucine efficiency for weight gain was observed, that increased up to 0.506% digestible isoleucine, which ratio of digestible isoleucine: lysine was 0.51.

Index terms: Swine nutrition, branched chain amino acids, nutritional requirements, carcass composition.

RESUMO

O conceito de proteína ideal, para suínos, tem permitido reduzir os níveis de proteína bruta da dieta, desde que haja a inclusão de aminoácidos sintéticos, pois os aminoácidos de cadeia ramificada podem ser limitantes. Com o objetivo de determinar a exigência de isoleucina digestível para fêmeas suínas dos 15 aos 30 kg, foi realizado um ensaio de desempenho, utilizando-se 40 fêmeas suínas, mestiças de alto potencial genético, com peso vivo inicial de 15,00 ± 0,52kg, distribuídas em um delineamento experimental de blocos ao acaso, constituído de cinco tratamentos (0,45; 0,52; 0,59; 0,66; 0,73% de isoleucina digestível), quatro repetições e dois animais por unidade experimental. Foram determinadas características de desempenho e, ao final do experimento, um animal de cada unidade experimental foi abatido, para a determinação da composição de carcaça e peso de órgãos. Níveis de 0,45 a 0,73% de isoleucina digestível não influenciaram as características de carcaça e peso de órgãos dos animais. Houve efeito quadrático (P<0,05) dos níveis de isoleucina digestível sobre a eficiência de utilização de isoleucina para ganho de peso, com aumento até o nível 0,506%; cuja relação isoleucina:lisina digestível foi de 0,51.

Termos para indexação: Nutrição de suínos, aminoácidos de cadeia ramificada, exigências nutricionais, composição de carcaça.

(Received in may 24, 2012 and approved in june 27, 2012)

INTRODUCTION

For many years the swine diets were formulated to achieve the crude protein requirements, which in most cases meant that the diets were unbalanced on amino acid levels, resulting in excess of these nutrients and causing its deamination, leaving the resulting nitrogen available for the synthesis of other compounds or simply excreted, causing environmental pollution.

With the availability of synthetic amino acids, the diets have been formulated with levels of these nutrients closer to animal requirements, respecting the ideal protein concept. Thus, the total protein requirement was reduced due to a better efficiency of amino acids utilization, reducing nitrogen excretion and negative impact of manure on the environment (HINSON; ALLEE; CRENSHAW, 2007; D'MELLO, 2003).

There are reports that the level of dietary protein in growing and finishing phases can be reduced in 4% without affecting the growth rate and feed efficiency when adequate amounts of essential amino acids are provided in the diet (JONGBLOED; LENIS, 1998; PARR; KERR; BAKER, 2004). Among the essential amino acids lysine, threonine, methionine and tryptophan are considered key

[1]Universidade Estadual de Maringá/UEM – Avenida Colombo – 5790 – Centro – 87020-900 – Maringá – PR – Brasil – leandrocastilha@hotmail.com
[2]Universidade Estadual de Maringá/UEM – Maringá – PR – Brasil
[3]Universidade Estadual do Oeste do Paraná/UNIOESTE – Marechal Candido Rondon – PR – Brasil
[4]Diplomata S/A Industrial e Comercial – Cascavel – PR – Brasil
[5]Universidade Federal do Rio Grande do Sul/UFRGS – Porto Alegre – RS – Brasil

amino acids (HAHN; BAKER, 1995). However, the marked reduction of protein concentration demands the inclusion of other synthetic amino acids, such as valine and isoleucine (LE BELLEGO; NOBLET, 2002).

Liu et al. (2000a, b) suggested that isoleucine must be a limiting amino acid in diets with low crude protein, based on corn and soybean meal for growing-finishing pigs with high genetic potential for protein deposition. Pigs fed with a deficient isoleucine diet showed a depression in performance compared to animals fed with a positive control diet, and also showed a reestablishment of performance as the isoleucine was supplemented in the diet (PARR; KERR; BAKER, 2003).

Thus, the purpose of this study was to determine the digestible isoleucine requirement of gilts from 15 to 30 kg, based on performance and carcass traits.

MATERIAL AND METHODS

An experiment was carried out to determine the growth performance, carcass traits and organs weight of gilts (15 to 30 kg), at the Experimental Farm of Universidade Estadual do Oeste do Paraná - UNIOESTE, Brazil. The experiment was established in 2010 and in agreement with the Animal Welfare Committee of this Institution.

Forty crossbreed gilts (Pietráin X Landrace X Large White) of high genetic potential and average performance were used, with 15.00 ± 0.52 kg initial weight, allotted in a randomized block design, consisting of five digestible isoleucine levels (0.450; 0.520; 0.590; 0.660 and 0.730%), four replicates and two animals per experimental unit.

The animals were housed in a nursery building provided with metal pens (1.00 x 1.20 m), suspended, with polypropylene floor, equipped with semi-automatic feeders and nipple drinkers, located in masonry building with concrete floor and tilting windows. The animals had free access to feed and drinking water. During the experiment, the temperature inside the laboratory was daily registered.

Diets were based on corn and soybean meal (Table 1) with low crude protein (14.15%) level. All diets were supplemented with Lys, Met, Thr, Trp and Val to provide the recommended levels, according to Rostagno et al. (2005). The Ile-deficient basal diet was previously submitted to a digestibility assay, resulting in 0.45% of digestible isoleucine. Then, was accomplished the adjustment of essential amino acids, using synthetic amino acids (L-lysine, L-threonine, DL-methionine, L-tryptophan and L-valine), to ensure to a minimum the recommendations of Rostagno et al. (2005). To assure the levels of 0.520, 0.590, 0.660 and 0.730% of digestible isoleucine, L-isoleucine was added to the basal diet replacing the inert. Glutamic acid was used in experimental diets to provide the same nitrogen level for all the treatments.

The initial (IBW) and final (FBW) body weight of the animals were individually recorded to determine the average daily gain (ADG), and the corresponding feed intake was recorded during whole experiment. Diets were weighed and given to the animals to calculate the average daily feed intake (ADFI), feed:gain ratio (F:G), average daily nitrogen intake (ADNI), nitrogen efficiency for weight gain (NEWG), average daily intake of lisine (ADLisI), lisine efficiency for weight gain (LisEWG), average daily intake of isoleucine (ADIleI) and isoleucine efficiency for weight gain (IleEWG).

All animals of each block were allocated for slaughter on the same day. The pigs were fasted for feed (24h), slaughtered, shaved and eviscerated. The liver, heart, kidney, pancreas and spleen were weighed. The eviscerated carcasses were weighed and split longitudinally through the vertebrae midline. The right half was chilled for 24 hours at -18º C and crushed. After homogenization, samples were pre-dried, pre-degreased and crushed again, for analysis of moisture, protein and fat, according to Association Of Official Analytical Chemists-AOAC techniques (2005).

Four animals with average weight of 15.00 kg were slaughtered to determine carcass composition at the beginning of experiment. Protein and fat deposition were calculated by comparing the carcass composition of the animals at the beginning and end of the experiment. The dry matter, crude protein, ether extract, efficiency of protein deposition and energy retained in the carcass were determined, as well as the relative weight of liver, kidney, pancreas, heart and spleen.

The performance data, carcass traits and relative weight of organs were analysed by analysis of variance (ANOVA) using the general linear models (GLM) procedure of SAS (SAS INSTITUTE, 1999). A polinomial regression was used to estimate the best level of digestible isoleucine. Linear and quadratic models were used to show effects of increasing levels of digestible isoleucine on growth performance, carcass traits and relative weight of organs, according to the adjustment obtained for each parameter by SAS.

Table 1 – Ingredients, chemical and energetic compositions of the experimental diets with different levels of digestible isoleucine for gilts from 15 to 30 kg.

Ingredients (%)	Levels of digestible isoleucine (%)				
	0.450	0.520	0.590	0.660	0.730
Corn	78.50	78.50	78.50	78.50	78.50
Soybean meal	14.50	14.50	14.50	14.50	14.50
Soybean oil	0.81	0.81	0.81	0.81	0.81
Dicalcium phosphate	1.68	1.68	1.68	1.68	1.68
Limestone	0.65	0.65	0.65	0.65	0.65
Sodium bicarbonate	0.62	0.62	0.62	0.62	0.62
Antioxidant[a]	0.01	0.01	0.01	0.01	0.01
Salt	0.04	0.04	0.04	0.04	0.04
Mineral supplement[b]	0.05	0.05	0.05	0.05	0.05
Vitamin supplement[c]	0.10	0.10	0.10	0.10	0.10
L-Lysine HCl	0.61	0.61	0.61	0.61	0.61
DL-Methionine	0.17	0.17	0.17	0.17	0.17
L-Threonine	0.21	0.21	0.21	0.21	0.21
L-Tryptophan	0.04	0.04	0.04	0.04	0.04
L-Valine	0.15	0.15	0.15	0.15	0.15
L-Isoleucine	0.01	0.08	0.15	0.22	0.30
Glutamic acid	0.87	0.78	0.70	0.61	0.52
Inert[d]	0.96	0.98	0.99	1.01	1.02
Tilosin phosphate[e]	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00
Calculated composition					
Metabolizable energy (Mcal/kg)	3.232	3.232	3.232	3.232	3.232
Crude protein (%)	14.15	14.15	14.15	14.15	14.15
Calcium	0.720	0.720	0.720	0.720	0.720
Available phosphorus (%)	0.400	0.400	0.400	0.400	0.400
Sodium (%)	0.204	0.204	0.204	0.204	0.204
Potassium (%)	0.487	0.487	0.487	0.487	0.487
Chlorine (%)	0.191	0.191	0.191	0.191	0.191
Digestible lysine (%)	0.991	0.991	0.991	0.991	0.991
Digestible threonine (%)	0.624	0.624	0.624	0.624	0.624
Digestible met + cis (%)	0.583	0.583	0.583	0.583	0.583
Digestible methionine (%)	0.363	0.363	0.363	0.363	0.363
Digestible tryptophan (%)	0.168	0.168	0.168	0.168	0.168
Digestible arginine (%)	0.718	0.718	0.718	0.718	0.718
Digestible valine (%)	0.684	0.684	0.684	0.684	0.684
Digestible leucine (%)	1.173	1.173	1.173	1.173	1.173
Digestible isoleucine (%)	0.450	0.520	0.590	0.660	0.730
DEB (Meq/kg)[f]	159.48	159.47	159.47	159.47	159.46

[a] BHT. [b] Content/kg: Fe, 100 g; Cu, 10 g; Co, 1 g; Mn, 40 g; Zn, 100 g; I, 1.5 g; and QSAD vehicle (1.000 g). [c] Content/kg: vit. A, 10,000,000 U.I.; vit D_3, 1,500,000 U.I.; vit. E, 30,000 U.I.; vit B_1, 2.0 g; vit B_2, 5.0 g; vit. B_6, 3.0 g; vit B_{12}, 30,000 mcg; nicotinic acid, 30,000 mcg; pantothenic acid, 12,000 mcg; vit. K_3, 2,000 mg; folic acid, 800 mg; biotin, 100 mg; selenium, 300 mg; and QSAD vehicle (1,000 g). [d] Fine clean sand. [e] Growth promoter. [f] Dietary electrolyte balance.

RESULTS AND DISCUSSION

The low and maximum temperature averaged from 21.01 (± 3.09) and 29.87º C (± 3.75), respectively. The relative humidity was 47.51 (± 16.98) to 84.50% (± 12.79). The digestible isoleucine levels provided a quadratic effect (*P*<0.05) on ADFI (Table 2). However, no effect (*P*>0.05) of the digestible isoleucine levels where observed for ADG, F:G, IBW, FBW, ADNI, NEWG, ADLisI and LisEWG. Otherwise, Parr, Kerr and Baker (2003) found a significant difference on ADFI (1.288g) of pigs from 25 to 45 kg, fed with 0.46% digestible isoleucine. Barea et al. (2009), observed that 0.50% digestible isoleucine, for pigs from 11 to 23 kg, showed a better effect on ADFI (736g). The variation observed for ADFI, as a response for the levels of digestible isoleucine in the experimental diets, could be associated with the levels of the others branched chain amino acids. According to D'Mello (2003), a consequence of antagonism among amino acids of the same structural group, when one amino acid is in excess over the other, is the decline in food intake.

Several results of researches and practical evaluations showed that the excess of amino acids in the diet does not improve animal performance because it is not used efficiently (SAKOMURA; ROSTAGNO, 2007). The amino acids absorbed in excess, compared to the first limiting, are oxidized and excreted as nitrogen compounds, and the degradation of excess amino acids in the diet has a high energy cost (McLEOD, 1997).

When the quality or quantity of dietary protein is inadequate there could be a reduction of growth and weight loss due to degradation of protein tissue, in order to maintain vital functions (HINSON; ALLEE; CRENSHAW et al., 2007). The consumption of diets containing disproportionate amino acid content to the actual metabolic needs of non ruminant animals leads to physiological alterations with metabolic effects that influence the feeding behavior of these animals. The intake of imbalanced diet alters the amino acids concentration in plasma and tissues, with substantial reduction of the limiting amino acid. This is followed by a decrease in feed intake and slow growth (BERTECHINI, 2006).

As found by Barea et al. (2009), in the present study there was no effect of digestible isoleucine levels on ADG. This may be due to the large amount of synthetic amino acids used in experimental diets, which may have generated a competition at intestinal absorption and at protein synthesis sites, since they are absorbed more quickly (WEBB JUNIOR, 1990; WU, 1998). This may generate effects on feed intake, decreasing the ADG of animals fed high amounts of synthetic amino acids.

Table 2 – Growth performance of gilts (15 to 30 kg) fed diets containing different levels of digestible isoleucine.

Traits[*]	Levels of digestible isoleucine (%)					SEM	P
	0.450	0.520	0.590	0.660	0.730		
IBW (kg)	15.375	15.438	15.350	15.400	15.500	0.14	-
FBW (kg)	30.188	30.575	29.663	30.750	30.175	1.70	NS[d]
ADFI (g/d)[a]	993.50	972.90	930.94	900.50	967.63	71.8	<0.05
ADG (g/d)	490.25	500.50	493.25	509.50	487.75	59.7	NS
F:G (g/g)	2.042	1.944	1.852	1.896	1.853	0.19	NS
ADNI (g/d)	22.874	20.008	20.522	22.617	21.018	2.02	NS
NEWG (g/mg)	21.426	25.061	23.034	22.435	23.178	2.21	NS
ADLisI (g/d)	9.846	8.582	8.773	9.635	8.924	0.87	NS
LisEWG (g/mg)	49.779	58.426	53.884	52.664	54.590	5.19	NS
ADIleI (g/d)[b]	4.590	4.598	5.329	6.534	6.682	1.03	<0.05
IleEWG (g/mg)[c]	106.778	109.041	88.702	77.664	72.909	16.89	<0.05

[*] IBW: initial body weight, FBW: final body weight, ADFI: average daily feed intake, ADG: average daily gain, FG: feed gain ratio, ADNI: average daily nitrogen intake, NEWG: nitrogen efficiency for weight gain, ADLisI: average daily lisine intake, LisEWG: lisine efficiency for weight gain, ADIleI: average daily isoleucine intake, IleEWG: isoleucine efficiency for weight gain.
[a]Quadratic effect ($\hat{Y} = 1046.39 - 36.6983X - 200.437X^2$).
[b]Linear effect ($\hat{Y} = 0.40563 + 8.7408X$).
[c]Quadratic effect ($\hat{Y} = 153.690 - 64.6591X - 63.8703X^2$).
[d]NS: P>0.05.

In our study, there was no effect on F:G, as found by Lordelo et al. (2008) evaluating diets with different levels of digestible isoleucine (0.595 to 0.825%) for starter pigs. However, Kerr et al. (2004a) assessed levels of digestible isoleucine (0.47 to 0.83%) for crossbred pigs (7 to 11 kg) and observed that the best F:G was obtained at 0.65%. Similarly, Dean et al. (2005) assessed levels of digestible isoleucine (0.24 to 0.32%) for pigs (BW=80 kg) and observed an effect in the F:G.

There was linear effect (*P*<0.05) of the digestible isoleucine levels on ADIleI, because the treatments consisted in crescent levels of digestible isoleucine. A quadratic effect (*P*<0.05) of digestible isoleucine levels on IleEWG was observed, increasing until 0.506% of digestible isoleucine (Figure 1).

No differences (*P*>0.05) were found for carcass traits and relative organs weight of gilts fed diets containing different levels of digestible isoleucine (Table 3). However, Szabo et al. (2001) assessed different levels of digestible isoleucine for pigs (30 - 105 kg) and found effect on protein deposition (at 0.95% of digestible isoleucine). Figueroa et al. (2003), evaluating CP levels in swine diets (20 to 50kg) observed satisfactory values of backfat thickness using low a CP diet associated with the addition of synthetic amino acids, rather than the treatments with normal levels of CP (16%) or with CP reduction without the addition of crystalline amino acids (11%).

According to D'Mello (2003) isoleucine may be a glucogenic or ketogenic amino acid, influencing positively the synthesis of fat in the body, if in excess. However, this effect was not observed (Table 3), since the ether extract of carcass and fat deposition were not influenced by the digestible isoleucine levels.

Levels of digestible isoleucine from 0.45 to 0.73% did not influence relative weight of organs (P>0.05), however Kerr et al (2004b) found a linear reduction in relative weight of liver of pigs fed diets containing 16% CP, 12% CP and 12% CP supplemented with synthetic amino acids. According to the authors, the reduction in relative weight of liver may have occurred because this organ is the most required for the synthesis and degradation of proteins, when the CP is unbalanced.

The digestible isoleucine level obtained for IleEWG (0.506%) was lower than that proposed by Rostagno et al. (2011) for the same phase and sex (0.595%), but intermediate to the levels proposed by NRC (1998), for male and female swines, from 10 to 20 kg (0.55%) and from 20 to 50 kg (0.45%). However, Henry et al. (1976) assessed levels of total isoleucine (0.38 to 0.62%) for pigs (15 to 50 kg) and found no effect on the performance variables and blood parameters, concluding that the lower level has met the requirement of this amino acid. Fu et al. (2006) also observed no effect on the performance variables when assessed levels of digestible isoleucine (0.60 to 0.88%) for barrows (12 to 22 kg) and concluded that the level 0.60% met the requirements of the animals. Similarly, Barea et al. (2009) evaluated levels of digestible isoleucine (0.50 to 0.58%) for male and female swines (11 to 23 kg) but found no effect on performance variables and concluded that the optimal level of digestible isoleucine is 0.50%, but it may be even lower.

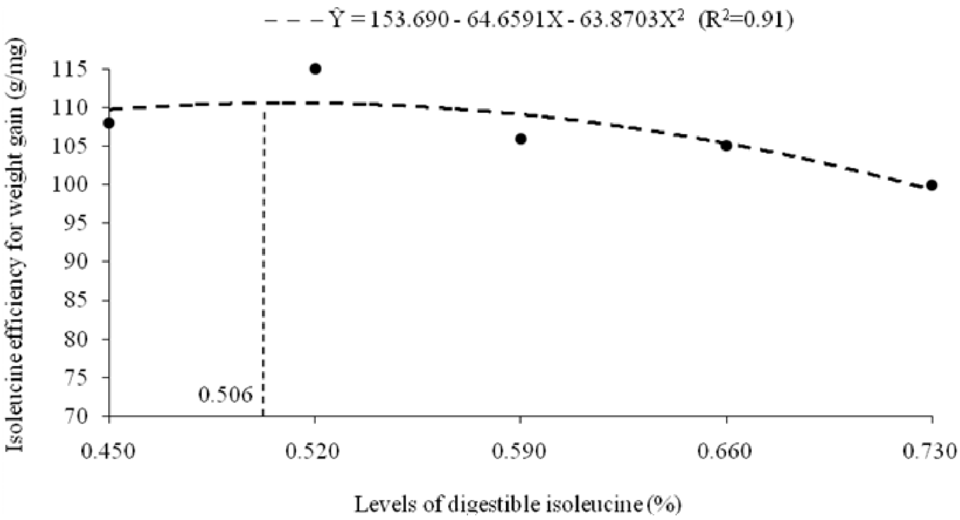

Figure 1 – Isoleucine efficiency for weight gain of gilts (15 to 30 kg) fed on the diets containing different levels of digestible isoleucine.

Table 3 – Carcass traits and relative weight of organs of gilts (15 to 30 kg) fed diets containing different levels of digestible isoleucine.

Carcass traits	Levels of digestible isoleucine (%)					SEM	P
	0.450	0.520	0.590	0.660	0.730		
Dry matter (%)	33.15	33.16	32.23	33.21	31.97	1.38	NS[a]
Crude protein (%)	36.33	39.01	33.92	38.01	33.78	3.40	NS
Ether extract (%)	43.30	46.94	42.27	43.91	42.08	3.06	NS
Protein deposition (g/d)	76.58	75.31	75.14	77.59	75.27	8.70	NS
Fat deposition (g/d)	78.44	74.23	75.02	73.55	71.41	4.58	NS
Protein deposition efficiency (g/d)	7.79	7.77	8.66	8.37	8.02	1.08	NS
Carcass energy retention (Mcal)	1.168	1.164	1.128	1.215	1.075	0.151	NS
Relative weight of liver (%)	3.27	3.70	3.15	3.20	3.76	0.52	NS
Relative weight of kidney (%)	0.56	0.56	0.53	0.51	0.52	0.07	NS
Relative weight of pancreas (%)	0.33	0.32	0.38	0.33	0.40	0.06	NS
Relative weight of heart (%)	0.59	0.59	0.64	0.59	0.62	0.07	NS
Relative weight of spleen (%)	0.24	0.19	0.21	0.18	0.22	0.05	NS

[a]NS: P>0.05.

The digestible isoleucine level obtained in this study (0.506%) provided a 0.51 ratio of digestible isoleucine:lysine, being lower than that one proposed by Rostagno et al. (2011) for the same phase (0.55) and the ratio proposed by National Research Council-NRC (1998) for male and female swines from 10 to 20 kg and 20 to 50 kg (0.54%), similarly, Wiltafsky et al. (2009) obtained a 0.54 ratio. The diet composition may alter the requirement of amino acids, since digestible leucine may result in amino acid imbalance, increasing the isoleucine requirement and, according to Moser et al. (2000), the interrelationship between branched chain amino acids may alter its metabolism in the animal organism.

CONCLUSION

Levels from 0.45 to 0.73% of digestible isoleucine did not affect the carcass traits and weight of organs of gilts from 15 to 30 kg. The level of 0.506% digestible isoleucine for gilts from 15 to 30 kg provided the best efficiency of isoleucine for weight gain, providing a ratio of digestible isoleucine:lysine of 0.51.

ACKNOWLEDGEMENTS

This study was funded by the Conselho Nacional de Pesquisa e Desenvolvimento Tecnológico – CNPq (National Council for Scientific and Technological Development).

REFERENCES

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS – AOAC. **Official methods of analysis**. 18th edition. AOAC, Maryland, 2005, 1094p.

BAREA, R. et al. The standardized ileal digestible isoleucine-to-lysine requirement ratio may be less than fifty percent in eleven- to twenty-three-kilogram piglets. **Journal of Animal Science**, Champaign, v.87, n.8, p.4022-4031, Aug.2009.

BERTECHINI, A.G. **Nutrição de Monogástricos**. Lavras: UFLA, 2006. 303p.

D'MELLO, J.P.F. **Amino acids in animal nutrition**. 2nd edition, CABI Publishing, United Kingdom: Edinburgh, 2003, 515p.

DEAN, D.W. et al. Isoleucine requirement of 80- to 120-kilogram barrows fed corn-soybean meal or corn-blood cell diets. **Journal of Animal Science**, Champaign, v.83, n.11, p.2543-2553, Nov.2005.

FIGUEROA, J.L. et al. Growth carcass traits and plasma amino acid concentration of gilts fed low-protein diets supplemented with amino acids including histidine, isoleucine and valine. **Journal of Animal Science**, Champaign, v.81,n.6, p.1529-1537, Jun.2003.

FU, S.X. et al. True ileal digestible isoleucine requirement and ratio in 12 to 22 kg pigs. **Journal of Animal Science**, Champaign, v.84, p.283 (Suppl. 1, Abstr), Apr.2006.

HAHN, J.D.; BAKER, D.H. Optimum ratio of threonine, tryptophan, and sulfur amino acids for finishing swine. **Journal of Animal Science**, Champaign, v.73, n.2, p.482-489, Feb.1995.

HENRY, Y.; DUEE, P.H.; RERÁT, A. Isoleucine requirement of the growing pig and leucine-isoleucine interrelationship. **Journal of Animal Science**, Champaign, v.42, n.2, p.357-364, Feb.1976.

HINSON, R.B.; ALLEE, G.L.; CRENSHAW, J.D. Use of spraydried blood cells and isoleucine supplementation in pig starter diets. **Journal of Animal Science**, Champaign, v.85, p.93 (Suppl. 2, Abstr), Mar.2007.

JONGBLOED, A.W.; LENIS, N.P. Environmental concerns about animal manure. **Journal of Animal Science**, Champaign, v.76, n.10, p.2641-2648, Oct.1998.

KERR, B.J. et al. Isoleucine requirements and ratios in starting (7 to 11 kg) pigs. **Journal of Animal Science**, Champaign, v.82, n.8, p.2333-2342, Aug.2004a.

__________. Utilization of spray-dried blood cells and crystalline isoleucine in nursery pig diets. **Journal of Animal Science**, Champaign, v.82, n.8, p.2397-2404, Aug.2004b.

LE BELLEGO, L.; NOBLET, J. Performance and utilization of dietary energy and amino acids in piglets fed low protein diets. **Livestock Production Science**, Amsterdam, v.76, n.2, p.45-48, Jan.2002.

LIU, H. et al. Amino acid fortified corn diets for late-finishing barrows. **Journal of Animal Science**, Champaign, v.78, p.45 (Suppl. 2, Abstr), Jan.2000a.

__________. Effect of reducing protein and adding amino acids on performance, carcass characteristics and nitrogen excretion, and the valine requirement of early-weaned finishing barrows. **Journal of Animal Science**, Champaign, v.78, p.66 (Suppl. 2, Abstr), Jan.2000b.

LORDELO, M.M. et al. Isoleucine and valine supplementation of low-protein corn-wheat-soybean meal based diet for piglets: growth performance and nitrogen balance. **Journal of Animal Science**, Champaign, v.86, n.11, p.2936-2941, Nov.2008.

MCLEOD, M.G. Effects of amino acid balance and energy: protein ratio on energy and nitrogen metabolism in male broiler chickens. **British Poultry Science**, Edinburgh, v.38, n.4, p.405-411, Sep.1997.

MOSER, S.A. et al. The effects of branched-chain amino acids on sow and litter performance. **Journal of Animal Science**, Champaign, v.78, n.3, p.658-667, Mar.2000.

NATIONAL RESEARCH COUNCIL – NRC. **Nutrient requirements of swine**. 10th edition, Washington, D.C.: National Academic of Science, 1998, 245p.

PARR, T.M.; KERR, B.J.; BAKER, D.H. Isoleucine requirement of growing (25 to 45 kg) pigs. **Journal of Animal Science**, Champaign, v.81, n.3, p.745-752, Mar.2003.

__________. Isoleucine requirement for late-finishing (87 to 100 kg) pigs. **Journal of Animal Science**, Champaign, v.82, n.5, p.1334-1338, May.2004.

ROSTAGNO, H.S. et al. **Tabelas brasileiras para aves e suínos:** composição de alimentos e exigências nutricionais. Viçosa: UFV, 2005, 186p.

__________. **Tabelas brasileiras para aves e suínos:** composição de alimentos e exigências nutricionais. Viçosa: UFV, 2011, 252p.

SAS INSTITUTE, SAS/STAT users guide. Version 6.12. Cary, NC. 1999.

SAKOMURA, N.K.; ROSTAGNO, H.S. **Métodos de pesquisa em nutrição de monogástricos**. Jaboticabal: Funep, 2007, 283p.

SZABO, C. et al. Effect of dietary protein source and lysine:DE ratio on growth performance, meat quality, and body composition of growing-finishing pigs. **Journal of Animal Science**, Champaign, v.79, n.11, p.2857-2865, Nov.2001.

WEBB JUNIOR, K.E. Intestinal absorption of protein hydrolysis products: a review. **Journal of Animal Science**, Champaign, v.68, n.9, p.3011-3022, Sep.1990.

WILTAFSKY, M.K. et al. Estimation of the optimum ratio of standardized ileal digestible isoleucine to lysine for eight- to twenty-five-kilogram pigs in diets containing spray-dried blood cells or corn gluten feed as a protein source. **Journal of Animal Science**, Champaign, v.87, n.8, p.2554-2564, Aug.2009.

WU, G. Intestinal mucosal amino acid catabolism. **The Journal of Nutrition**, Bethesda, v.128, n.8, p.1249-1252, Aug.1998.