Journal of Animal and Veterinary Advances 6 (10): 1146-1151, 2007
ISSN: 1680-5593

Optimal Biological Level of Total Lysine for Finishing Pigs Fed Sorghum-Soybean Meal Diets

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Abstract: Dietary lysine concentration determines growth performance of pigs when all other nutrients fulfill the requirements. The optimal biological level sets the maximum pig response. An experiment was conducted with 60 crossbred (Yorkshire×Landrace sows, Yorkshire×Duroc boars; 30 barrows and 30 gilts) finishing (47.47 kg of initial weight) pigs to estimate the Optimal Biological Level (OBL) of total dietary lysine in sorghum-soybean meal diets. Total dietary lysine levels were: 0.56, 0.66, 0.76, 0.85 and 0.96%. The analyzed variables were: Average Daily Gain (ADG), Average Daily Feed Intake (ADFI), Feed Gain Ratio (FGR), Backfat Thickness (BFT), Longissimus Muscle Area (LMA), Fat Free Lean Gain (FFLG) and Plasma Urea Nitrogen concentration (PUN). The global data showed that just FFLG was affected by dietary lysine level. There was no effect of the lysine concentration on any other variable in barrows; but there PUN was affected by the dietary lysine level in gilts. The OBL to maximize FFLG (in all pigs), calculated by regression analysis, was 0.89% total lysine and the OBL to minimize PUN was 0.72% total lysine for gilts. These results confirmed that the OBL for finishing pigs to use more efficiently the dietary protein concentration will be different, upon the pig sex and the optimization criterion used.

Key words: Finishing pigs, lysine, optimal biological level, sorghum-soybean meal diets

INTRODUCTION

The Amino Acids (AA) requirements for finishing pigs are influenced by factors such as the genetic potential for protein synthesis, sex, diet composition, diet digestibility and environmental factors. In order to optimize the growth performance of pigs, it is important to estimate the optimal lysine level in finishing diets (Wei and Zimmernan, 1998), because lysine is the first limiting AA in almost all feedstuffs used in pig diets.

The lysine concentration recommended for NRC (1998) is not adequate for pigs with higher growth and fat free lean gain potential. The requirements for this kind of pigs have to be established accordingly with their genetic potential and sex, to obtain the maximum response (Stahly *et al*., 1998). It has been reported that pigs fed different amounts of dietary lysine had lower Plasma Urea Nitrogen (PUN), indicating the maximum utilization of AA; so, this metabolite has been used to estimate the lysine requirement for pigs (Coma *et al*., 1995a, b). The optimal level of dietary lysine is obtained with regression analysis and with econometric methodology based on theories and applications of the Operations Research Science (Gonzalez and Orozco, 1996).

The objectives of this research were:

- To evaluate the effect of several dietary lysine levels on growth performance, carcass characteristics and plasma urea nitrogen concentration in finishing pigs.
- To estimate the Optimal Biological Level (OBL) of lysine for growth performance variables (NRC, 1998).
- Tto estimate the OBL for barrows and gilts.
- To evaluate the plasma urea nitrogen as an indicator of the optimal requirement of lysine for finishing pigs.

MATERIALS AND METHODS

Sixty (30 barrows and 30 gilts) crossbred (Yorkshire×Landrace sows, Yorkshire×Duroc boars) finishing (47.4 kg initial body weight) pigs were used in a completely randomized design, with 4 replicates of

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Table 1: Composition of experimental diets

	Total lysine concentration (%)				
	0.56	0.66	0.76	0.85	0.96
Ingredients (%)					
Soybean meal (44%)	13.25	13.00	12.65	12.30	11.90
Sorghum grain	79.71	79.70	79.82	79.93	80.07
Corn oil	3.00	3.10	3.19	3.28	3.38
Minerals and vitaminsa	4.00	4.00	4.00	4.00	4.00
L-Lysine HCl	0.00	0.14	0.28	0.41	0.56
L-Threonine	0.04	0.05	0.05	0.06	0.07
DL-Methionine	0.00	0.01	0.01	0.02	0.02
Calculated content (%)					
Metabolizable Energy (Mcal kg^{-1})	3.336	3.336	3.336	3.336	3.337
Crude protein	13.2	13.2	13.2	13.2	13.2
Lysineb	0.56	0.66	0.76	0.85	0.96
Arginine	0.73	0.72	0.71	0.7	0.69
Histidine	0.34	0.34	0.33	0.33	0.32
Isoleucine	0.56	0.55	0.55	0.54	0.53
Leucine	1.42	1.41	1.4	1.39	1.38
Methionine+cistine	0.44	0.45	0.45	0.45	0.45
Phenilalanine+tyrosine	1.18	1.17	1.16	1.15	1.13
Threonine	0.52	0.52	0.52	0.52	0.52
Tryptophan	0.16	0.16	0.16	0.15	0.15
Valine	0.64	0.63	0.63	0.62	0.61
EAA:NEAAc (%)	49.6:50.4	50.1:49.4	50.5:49.5	50.8:49.2	51.1:48.9
Calcium	0.59	0.59	0.58	0.58	0.58
Total phosphorus	0.51	0.51	0.51	0.51	0.51
Available phosphorus	0.28	0.28	0.28	0.28	0.28
Determined analysis (%)					
Crude protein	13.24	11.67	13.02	11.62	12.77
Total phosphorus	0.52	0.52	0.50	0.49	0.53
Calcium	0.57	0.60	0.57	0.59	0.55
Dry matter	90.00	90.45	90.14	90.54	90.44

[a]Supplied per kg of diet: vitamin A, 6250 IU; vitamin D_3, 1093.75 IU; vitamin E, 10 IU; nicotinic acid, 140 mg; P, 50 g; Ca, 130 g; Fe, 24 ppm; Zn, 36 ppm, [b]NRC (1998) requirement (%) for finishing pigs (50-80 kg): lysine, 0.75; arginine, 0.27; histidine, 0.24; isoleucine, 0.42; leucine, 0.71; methionine+cystine, 0.44; phenylalanine + tyrosine, 0.70; threonine, 0.51; tryptophan, 0.14; valine, 0.52, [c]EAA:NEAA =Essential amino acids:non-essential amino acids (%)

3 pigs (1 barrow and 2 gilts, or 2 barrows and 1 gilt) each replicate, randomly assigned to 1 of 5 experimental diets based on sorghum grain-soybean meal, formulated to 5 total lysine concentrations (Table 1): 2 lysine levels under the NRC requirements (NRC, 1998) (0.56 and 0.66%), 2 lysine levels over (0.85 and 0.95%) and the NRC (1998) requirement (0.75%). The analyzed variables were: Growth performance (average daily feed intake, average daily gain, feed: gain ratio and fat free lean gain), carcass characteristics (backfat thickness, longissimus muscle area, body lean percentage) and plasma urea nitrogen concentration. Initial body weight was used as a covariate. Pigs were randomly distributed in pens, but an individual record of variables was maintained in order to analyze the sex effect, except for feed intake and feed:gain ratio. Feed and water were allowed *ad libitum*.

The change in body weight and feed intake were measured weekly. With these data, the average daily gain, average daily feed intake and Feed Gain Ratio (FGR) were calculated. The Backfat Thickness (BFT) and the Longissimus Muscle Area (LMA) were measured at the 10th rib, the first and the final day of the experiment using real time ultrasound (SonoVet 600, Medison America, Inc. Cypress, CA, USA) and these data were used to estimate Fat Free Lean Gain (FFLG) and Body Lean Percentage (BLP) using the NPPC equation (NPPC, 1991). Blood samples were obtained the first and the final day of the experimental period, via the vena cava with heparinized vacutainer tubes (BD Vacutainer Systems, NJ, USA). After the bleeding, blood was maintained in ice and carried out to the laboratory, where plasma was separated by centrifugation (1283 g) and was stored at-20°C until it was analyzed. Plasma Urea Nitrogen (PUN) concentrations were determined by colorimetrically measuring the product formed in the direct reaction of urea and diacetyl monoxime (Fawcett and Scott, 1960).

Feed samples were obtained and ground through a 1 mm screen for chemical analysis: Crude protein was determined by macrokjheldahl method (AOAC, 1990); total energy was determined by calorimetric bomb (Parr 1261, Parr Instrument Company, Inc., Moline, IL, USA) and calcium and phosphorus concentrations were determined by atomic absorption spectrophotometry (Karl *et al*., 1979) (Perkin-Elmer 4000, serie Lambda 2, Perkin Elmer Inc., Norwalk, CT, USA).

Global and sex data were analyzed using GLM

procedure (SAS, 1999) of SAS, with the statistical model mentioned above and means were compared using least square means. The models utilized to estimate the Optimal Biological Level (OBL) of lysine were as follows:

- Simple lineal regression model.
- Lineal model with cuadratic transformation.
- Llineal model with cubic transformation.
- Noll *et al.* (1984) non-lineal, exponential-model.
- Morales *et al.* (1999) non-lineal, exponential model.

These models were analyzed using GLM procedure of SAS (1999) for lineal regression and using NLIN procedure for non-lineal regression. The lower Mean Square of Error (MSE) was used to select the best model of prediction to construct the econometric model, because this value can be calculated both with lineal and non-lineal regression models.

The construction of the econometric model to estimate OBL of lysine for FFLG and PUN (the only 2 variables with statistical differences) had the next format: Objective function: Maximization or minimization Y = f (lysine) and under the next restrictions: AX >= B; axlysine-lysine = 0; X, xlysine >= 0, non-negative condition. Where, Y is the FFLG or PUN, A is the nutrient (lysine) concentration in the ingredients, X are the ingredients used to formulate the diets, a is the amount of nutrients calculated to maximize the response variable related to lysine function and B are the requirements (NRC, 1998) suggested for finishing pigs.

The OBL of lysine were calculated with the Solver command of Excel (2001) for variables showing significant differences between treatments ($p<0.05$).

RESULTS

The global analysis of data showed that the level of total lysine had no effect ($p>0.05$) on ADG, ADFI, FGR, BFT, LMA and PUN (Table 2). There was a significant effect on FFLG ($p<0.05$), with the highest FFLG in pigs fed 0.56% of dietary lysine and the lowest in pigs fed 0.76% of lysine, the NRC recommended level (NRC, 1998). In the regression analysis of data, a significant difference for FFLG ($p<0.05$) was observed and the best adjusted model to predict OBL of total lysine was the cubic regression model: $Y_{ij} = 3.0554 - 11.7295(Lys) + 15.3224(Lys*Lys) - 6.5407(Lys*Lys*Lys) + 0.00393$ (Pi = 47.47), with a Mean Square Error (MSE) of 0.00042 and an R^2 of 0.69. The optimization analysis estimated an OBL of total lysine to maximize FFLG of 0.89%, with an average of 0.328 kg d^{-1} of FFLG, under the restrictions settled for the other ingredients.

Table 2: Effect of dietary lysine level (average and standard error of the mean) on growth performance, carcass characteristics and plasma urea nitrogen of finishing pigs

	0.56		0.66		0.76		0.85		0.96	
Lysine level, (%)	Average	±SE	Average	±SE	Average	±SE	Average	±SE	Average	±SE
Global										
Growth performance	2.619	0.14	2.731	0.137	2.527	0.136	2.775	0.141	2.72	0.138
Feed intake, kg d^{-1}	0.849	0.036	0.865	0.035	0.82	0.035	0.9	0.036	0.87	0.036
Weight gain, kg d^{-1}	3.084	0.102	3.167	0.1	3.101	0.099	3.085	0.103	3.121	0.101
Feed:Gain ratio, kg kg^{-1}										
Carcass characteristics	1.638	0.137	1.774	0.134	1.538	0.133	1.637	0.138	1.838	0.135
Backfat thickness, cm	27.74	1.311	28.35	1.28	28.78	1.272	28.79	1.316	29.62	1.286
Longissimus muscle area, cm^2	0.335a	0.012	0.300ab	0.011	0.295b	0.011	0.331ab	0.012	0.318ab	0.011
Fat free lean gain, kg d^{-1}										
Plasma urea nitrogen, mg 100 mL^{-1}	20.46	1.581	18.11	1.544	19.57	1.534	21.55	1.587	19.98	1.551
Barrows										
Growth performance										
Weight gain, kg d^{-1}	0.926	0.052	0.957	0.059	0.941	0.064	0.988	0.048	0.873	0.048
Carcass characteristics										
Backfat thickness, cm	2.087	0.159	2.132	0.182	1.793	0.197	1.736	0.149	2.14	0.149
Longissimus muscle area, cm^2	29.94	1.633	30.45	1.87	30.34	2.021	30.32	1.532	30.95	1.527
Fat gree lean gain, kg d^{-1}	0.347	0.024	0.314	0.027	0.337	0.029	0.36	0.022	0.333	0.022
Plasma urea nitrogen, mg 100 mL^{-1}	21.67	1.971	20.05	2.257	22.95	2.439	22.26	1.849	21.66	1.843
Gilts										
Growth performance										
Weight gain, kg d^{-1}	0.776	0.05	0.785	0.059	0.745	0.049	0.809	0.05	0.829	0.048
Carcass characteristics										
Backfat thickness, cm	1.351	0.113	1.545	0.133	1.282	0.112	1.599	0.112	1.457	0.108
Longissimus muscle area, cm^2	26.03	1.964	27.38	2.309	27.41	1.938	27.02	1.949	27.09	1.875
Fat free lean gain, kg d^{-1}	0.317	0.03	0.289	0.035	0.269	0.03	0.293	0.03	0.281	0.29
Plasma urea nitrogen, mg 100 mL^{-1}	19.38ab	1.711	15.86b	1.376	18.55ab	1.155	20.46a	1.162	17.12ab	1.118

a, b = Values with different letter in the same row differ ($p<0.05$)

There were no effects of lysine level on all analyzed variables for barrows ($p>0.05$), but an effect of the lowest concentration (0.66%) of dietary lysine was observed in gilts for PUN, compared to 0.85% (the highest PUN concentration). To estimate the OBL of total lysine for gilts, there was a significant difference in the regression analysis for PUN ($p<0.05$) using the cubic model, with a MSE = 3.254 and an $R^2 = 0.55$. The optimization analysis estimated 0.72% of total lysine to minimize PUN, with a concentration of 17.53 mg 100 mL^{-1} of PUN, with the next model: $Y_{ij} = 393.98 - 1554.97(Lys) + 2119.84(Lys*Lys) - 943.74(Lys*Lys*Lys) - 0.079342(Pi = 46.12)$.

DISCUSSION

Growth performance: The global analysis showed that the control treatment had the lowest ADG and ADFI, although there was no significant difference. These results disagree with previous findings (Friesen *et al*., 1994) where lysine concentration increased ADG of growing (34-72.5 kg) pigs. There was a lineal tendency ($p>0.09$) to improve ADG in gilts; the higher values were observed in gilts fed the higher lysine concentrations. This tendency was similar to the values found in other reports (Coma *et al*., 1995) with a lineal effect of dietary lysine on growth performance of gilts and barrows. Other researchers (NRC, 1998; Rao and Mccracken, 1990) suggested higher lysine level to maximize ADG and FGR.

When feed intake was analyzed using regression, this variable fitted the lineal model more adequately and a lowest feed intake was obtained in pigs fed control (NRC, 1998) diet, which also showed the lowest ADG. This lower fed intake in pigs fed the control diet was previously reported (Cline *et al*., 2000); if pigs were fed diets with AA in excess or deficient, feed intake increased.

The FGR was not affected by dietary lysine concentration; the variation showed a difference lower than 3%. This result is different to other reports (Friesen *et al*., 1994) where a quadratic response was observed in gilts and the inflection point indicated 22 g d^{-1} of lysine to maximize FGR. The daily lysine intake observed in this experiment was 14.7, 18.0, 19.2, 23.6 and 26.1 g d^{-1} for T1, T2, T3, T4 and T5, respectively. This indicates that the dietary lysine level closer to the value of 22 g d^{-1} previously mentioned, is between 0.76 and 0.85%. It also has been reported that the growth performance of barrows and gilts fed higher lysine levels is different (Coffey *et al*., 1995) and little improvement on FGR and ADG was observed in barrows when dietary lysine concentration increased from 0.58-0.66%, although it improved 5% FGR in gilts.

Carcass characteristics and plasma urea nitrogen: The global data analyzed for regression fitted a cubic model (Table 2), however, there was no effect of dietary lysine concentration on BFT ($p>0.05$). This result is different to previous reports (Loughmiller *et al*., 1998; Dela, 2002) where, BFT was reduced in a lineal way as dietary lysine concentration increased. In this experiment, there was no significant difference in BFT in the global analysis of data; however, the barrows had 37% more backfat than the gilts and their lysine requirement to reduce BFT was greater.

There was no significant difference between treatments for LMA in the global analysis, but there was a lineal tendency ($p<0.08$) to increase LMA as dietary lysine increased (Table 2). This result agrees with other reports (Friesen *et al*., 1994; Hahn *et al*., 1995). In the regression analysis of this variable, there was a lineal non-significant tendency to increase LMA; the barrows had 13% greater LMA (30.4 *vs* 26.99 cm^2) compared to gilts. This result disagrees with other research (Friesen *et al*., 1994; Hahn *et al*., 1995) where gilts had greater LMA than barrows.

There was significant difference for FFLG between 0.56% lysine (higher) and 0.76% (lower; control diet). This is a different result compared to other reports (Loughmiller *et al*., 1998) where a higher lysine concentration was needed to increase protein synthesis in pigs. The barrows may need higher lysine levels than gilts to maximize FFLG. However, there was no effect of lysine concentration on FFLG in barrows; the cubic model was the one which fitted the regression analysis (0.85% of dietary lysine is needed to increase FFLG) and this level coincided with the lowest BFT. In other report (Cline *et al*., 2000), a significant difference was not observed between lysine levels, but it was suggested that pigs can tolerate high levels of dietary lysine and this improves FFLG. Similar results are observed for gilts; however, the gilts fed the control diet had the lowest FFLG. This suggests that these gilts may need higher lysine level to improve FFLG. The previous result is different than the reports of other researchers (Cline *et al*., 2000). The barrows had higher FFLG than gilts, which disagrees with other results (Cline *et al*., 2000) where a higher protein synthesis was observed in gilts suggesting a higher lysine requirement.

The global analysis for PUN concentration showed no effect of dietary lysine level. However, the treatment with 0.85% of lysine had the highest PUN level, in coincidence with the highest ADG and ADFI and the lowest value was observed in pigs fed 0.66% of dietary lysine. The adequate utilization of AA is reflected in a

lower PUN and the poor utilization means higher PUN concentration; the last case may also be observed in pigs fed diets with amino acid imbalance. There was no significant difference for PUN in barrows. In gilts, there was a significant difference between 0.66 and 0.85% of dietary lysine, with the lowest and the highest PUN, respectively. The value of 0.66% lysine is lower than the NRC requirement (NRC, 1998), so, seems that the level needed to minimize PUN is lower than the one to maximize ADG.

Optimization analysis: The Optimal Biological Level (OBL) of lysine, calculated for barrows and gilts for FFLG, was 0.89%, higher than the NRC requirement (NRC, 1998) obtained with biological models to estimate lysine requirements for lean growth potential and backfat content. It has been observed that pigs with genetic potential for higher lean growth rate need higher dietary lysine levels (0.80-0.95%) to maximize FFLG and that pigs with medium genetic potential for lean growth rate had no higher needs of lysine than the recommended level (Coffey *et al*., 1995). That means that the lysine requirements of barrows and gilts increase as improves their genetic potential for higher lean growth rate. It had been suggested (Rao and McCracken, 1990; Yen *et al*., 1986 a,b) that both gilts, barrows and boars require 5-6 g of lysine d-1 above the NRC requirement (NRC, 1998), a level similar to the one (0.89%) obtained in this experiment.

The OBL of lysine to minimize PUN in gilts was 0.72%; this value is similar to the one previously reported (Coma *et al*., 1995a) for gilts and barrows. This levels is lower than the NRC requirement (NRC, 1998), maybe because of the genotype of pigs and the kind of ingredients (sorghum grain-soybean meal) used in this experiment. These results confirmed that the lysine level to minimize PUN is lower than the one needed to maximize ADG. Although several reports had indicated that the NRC requirements (NRC, 1998) are just a starting point to estimate lysine requirements for pigs of different stages, the determination for each sex and for shorter weight intervals may be better to maximize the growth performance of pigs (Hahn *et al*., 1995).

CONCLUSION

The PUN for gilts is an indicator of the efficient utilization of dietary lysine. The lysine levels analyzed did not affected growth performance or carcass characteristics, except FFLG for both barrows and gilts and the PUN in gilts. So, the 0.76% of dietary lysine (close to the 0.75%, NRC requirement) was different to the OBL to maximize FFLG (0.89%) for all pigs, or to minimize PUN in gilts (0.72%). Because of that, we concluded that the optimal biological level of dietary lysine will be different, depending on the optimization objective variable that is used to estimate this value.

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