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Temporary reduction of digestible lysine in nursery pig diets: performance and economic analysis

Redução temporária de lisina digestível em dietas de leitões em fase de creche: desempenho e viabilidade econômica

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ABSTRACT

To evaluate the effects of temporary dietary lysine restriction on nursery pigs' growth performance and its economic viability compared to control diets, 144 piglets (21-d-old) were assigned to randomized blocks, with two treatments and twelve replicates. The treatments were control-lys: lysine level as recommended from 21-32 and 32-42 days and low-lys: 90% of the lysine level of the control-lys diets. From 42 to 62 days, all animals received a control diet. From 21 to 32 days, pigs fed low-lys had worse average daily gain (ADG), feed conversion, and 32-d body weight (BW; $P \leq 0.05$). From 32 to 42 days, pigs fed low-lys had lower average daily feed intake, ADG, and 42-d BW ($P \leq 0.05$). From 42 to 62 days, pigs had similar performance ($P > 0.05$). Overall (21 to 62 days), pigs fed the low-lys had lower ($P <0.05$) ADG and final BW. At 27 and 29 days, pigs fed the low-lys diet had a higher ($P \leq 0.05$) incidence of diarrhea. The lowest feed cost and the highest economic efficiency index were recorded for the low-lys treatment. However, pigs fed the control-lys presented a 3.9% higher profitability. In conclusion, a temporary reduction of lysine in the diets of nursery pigs followed by an unrestricted diet in the subsequent period led to worse growth performance and lower economic viability.
Keywords: amino acids, compensatory growth, nutrition, phase-feeding, pig

RESUMO

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Objetivou-se com este estudo avaliar os efeitos da restrição temporária de lisina na dieta sobre o desempenho e viabilidade econômica de leitões em fase de creche. Foram utilizados 144 leitões, distribuídos em blocos ao acaso, com dois tratamentos e 12 repetições. Os tratamentos foram controle-lis, nível de lisina recomendado dos 21 aos 32 e 32 aos 42 dias de idade e baixa-lis, 90% do nível de lisina das dietas controle-lis. Dos 42 aos 62 dias, todos os animais receberam dieta controle. De 21 a 32 dias, leitões alimentados com baixa-lis tiveram pior ganho médio diário (GMD), conversão alimentar e peso corporal aos 32 dias (P≤0,05). Dos 32 aos 42 dias, leitões alimentados com baixa-lis apresentaram menor consumo médio de ração diário, GMD e peso aos 42 dias (P≤0,05). Dos 21 aos 62 dias, leitões alimentados com baixa-lis apresentaram GMD e peso corporal final menores (P≤0,05) quando comparados aos alimentados com controle-lis. At 27 and 29 days of age, pigs fed the low-lys diet had a higher (P≤0.05) incidence of diarrhea Aos 27 e 29 dias, leitões alimentados com baixa-lis apresentaram maior (P≤0.05) indicência de diarreia. O menor custo de alimentação e o maior índice de eficiência econômica foram registrados para baixa-lis. No entanto, os suínos alimentados com controle-lis apresentaram rentabilidade 3,9% maior. Como conclusão, a restrição temporária de lisina nas dietas de leitões piora o desempenho e diminui a viabilidade econômica.
Palavras-Chave: aminoácidos, alimentação por fase, crescimento compensatório, nutrição, suíno

INTRODUCTION

Highly digestible feed ingredients and feed additives are used to help young pigs transition from sow's milk to solid diets (Skinner et al., 2014; Valini et al., 2021). Thus, the cost of swine diets is greatest during the nursery phase of production due to the complexity of ingredients, e.g., whey, blood plasma and industrial amino acids. As compensatory growth has been associated with increased feed efficiency, it is a mechanism that may help to increase profitability (Taylor et al., 2013).

With the increasing availability of industrial amino acids, low-protein diets can be formulated based on the concept of ideal protein (NRC, 2012; Rostagno et al., 2017). Formulating based on ideal protein is an effective way to use fewer protein sources in the diet and thus reduce feed costs. According to the concept of ideal protein, the requirements for amino acids are expressed relative to the requirement for lysine (Edmonds & Baker, 1987).

Therefore, one strategy to minimize costs might be the temporary reduction of lysine in weaned piglets' diets (Gomes et al., 2021), followed by a diet meeting the amino acid requirements for the phase (Skinner et al., 2014). Reducing the dietary amino acid content may reduce growth temporarily, which may lead to compensatory growth during a subsequent realimentation period (Skiba, 2005). During realimentation, pigs that have previously experienced reduced growth may have better performance ratios and reach a similar final body weight (BW) of pigs fed unrestricted diets (Skinner et al., 2014; Totafurno et al., 2020). However, little available research examines compensatory growth during the nursery phase and this, along with an economic analysis, is lacking in the literature.

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The temporary reduction of lysine in weaned piglets' diets followed by an unrestricted diet in the subsequent period is hypothesized to lead to similar growth performance as nonrestricted pigs and would be economically feasible at the end of the nursery phase. Thus, the objective of this study was to evaluate the effects of temporary dietary lysine restriction on nursery pigs' growth performance and its economic viability compared to control diets.

MATERIALS AND METHODS

The experimental protocol followed ethical animal research principles (CONCEA, 2016) and was approved by the Ethical Committee on Animal Use of Universidade Federal de Viçosa (protocol n° 041/2020). The experiment was conducted on 2020, in a commercial–experimental barn, located in the municipality of Oratórios, in the state of Minas Gerais, Brazil (20° 25' 5"S, 42° 47' 28"W).

A total of 144 pigs (AGPIC 415 × Camborough), castrated males and females, weaned at 21 days old and with an initial BW of 5.58 ± 0.66 kg, were used in a 41-day trial. The pigs were housed in suspended pens (1.70 × 1.20 m). Each pen housed six pigs (0.34 m²/pig) with free access to feed and water. The minimum and maximum temperatures in the nursery room were 20.8 ± 2.49 ºC and 30.3 ± 1.79 ºC, respectively.

The pigs were assigned to a randomized block design according to their initial BW, with twelve replicates. Pigs were fed in three phases from 21 to 32, 32 to 42, and 42 to 62 days of age. In the first two phases, treatments consisted of (1) control-lys: 1.45% and 1.34% of standardized ileal digestible (SID) lysine from day 21 to 32 and 32 to 42, as Rostagno et al. (2017) recommend and (2) low-lys: 1.30% and 1.21% of SID lysine from day 21 to 32 and 32 to 42, equivalent to 90% of the SID lysine level of the control-lys diets. In the last phase, from day 42 to 62, all animals received a common diet recommended for the phase (Table 1).

Table 1. Ingredients and calculated nutritional composition of diets fed from 21 to 32, 32 to 42 and 42 to 62 days of age.

	21-32 d		32-42 d		42-62 d
Ingredients g/kg	Control-lys[1]	Low-lys[2]	Control-lys	Low-lys	Control
Corn	373.3	377.0	399.5	402.5	584.7
Soybean meal	174.0	174.0	225.6	225.6	322.1
Dried whey	150.0	150.0	110.0	110.0	-
Soybean Micronized	100.0	100.0	80.0	80.0	-
Extrude corn	80.0	80.0	80.0	80.0	-
Plasma protein	40.0	40.0	25.0	25.0	-
Sugar	30.0	30.0	30.0	30.0	30.0
Dicalcium phosphate	12.5	12.5	13.1	13.1	15.7
Limestone	8.7	8.7	8.3	8.3	7.4

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Soybean oil	6.6	7.9	7.6	8.5	22.5
Fumaric acid	5.0	5.0	5.0	5.0	4.0
Anti-caking[3]	3.0	3.0	2.0	2.0	-
Zinc Oxide	2.5	2.5	2.2	2.2	-
Choline chloride	2.0	2.0	1.5	1.5	0.5
L-lysine	3.7	1.8	2.9	1.2	3.4
DL-methionine	2.2	1.4	1.7	0.9	1.4
L-threonine	2.4	1.3	1.8	0.9	1.4
L-valine	0.9	0.0	0.2	0.0	-
L-tryptophan	0.5	0.2	0.3	0.0	0.1
Salt	0.6	0.6	1.2	1.2	4.7
Copper Sulfate	0.6	0.6	0.6	0.6	0.6
Vit-mineral premix	1.4	1.4	1.4	1.4	1.4
BHT	0.1	0.1	0.1	0.1	0.1
Calculated nutritional composition					
ME, kcal/kg	3,400	3,400	3,375	3,375	3,350
Crude protein, %	21.00	20.64	21.00	20.71	20.10
SID[4] lysine, %	1.451	1.306	1.346	1.211	1.206
SID threonine, %	0.972	0.875	0.902	0.812	0.784
SID met + Cys	0.813	0.731	0.754	0.679	0.687
SID tryptophan	0.276	0.248	0.256	0.231	0.229
SID valine	1.001	0.920	0.929	0.911	0.832
Calcium, %	0.850	0.850	0.825	0.825	0.773
Available P, %	0.505	0.505	0.471	0.471	0.431
Sodium, %	0.280	0.280	0.230	0.230	0.205
Lactose, %	11.25	11.25	8.25	8.25	-

[1]Control-Lys, following the recommendation of Rostagno et al. (2017); [2]Low-Lys, Lysine level of 90% of the recommendation of Rostagno et al. (2017); [3]Tixosil® (Solvay, Brazil) prevent the formation of lumps (caking); [4]SID = standardized ileal digestible.

Throughout the trial, feed was weighed before feeding and feed wastage was collected and weighed daily to determine the average daily feed intake (ADFI). At 21, 32, 42, and 62 days, pigs were individually weighed to calculate BW, average daily gain (ADG), and feed conversion (FC). The incidence of diarrhea was visually assessed at 26, 28, 30, and 32 days and categorized as 0 = absent or 1 = present for each pen.

The economic analyses were performed considering the whole nursery phase (21 to 62 days). To verify the economic feasibility of this strategy, first, the feed cost per kilogram of BW gain (Y_i) was calculated following the methodology proposed by Bellaver et al. (1992):

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$$Y_i = (C_i * I_i)/G_i$$

where Y_i is the feed cost per kilogram of BW gain; C_i is the feed cost per kilogram of the i^{th} treatment; I_i = feed intake of the i^{th} treatment; and G_i is the BW gain of the i^{th} treatment.

Thereafter, the economic efficiency index (EEI) for each treatment was calculated following the equation, proposed by Barbosa et al. (1992):

$$EEI = (FCe/CTe) * 100$$

where FCe is the lowest feed cost per kilogram of weight gain observed among the treatments and CTe is the cost of the considered treatment.

Subsequently, the profitability was calculated as follows:

$$Profitability = ([FBW - IBW] * P) - (C * I)$$

where FBW is the final BW at the end of the nursery phase; IBW is the initial BW at the beginning of the experiment; P is the price per kilogram of pig BW; C is the cost per kilogram of feed; and I is the feed intake per pig.

The feed costs and prices of the ingredients used were those recorded in the municipality of Ponte Nova in the state of Minas Gerais, Brazil, during July 2021. The price of the nursery pig was equivalent to 1.8 times the price of the finished pig/kg, a common local practice for the sale of nursery pigs. All values were converted to USD using the monthly average currency exchange rate according to the Banco Central do Brasil.

The pen was considered the experimental unit for the performance data analysis. The data were analyzed using the GLM procedure of SAS 9.4 (SAS Inst., Inc., Cary, NC, USA). Treatments were compared using an ANOVA F-test and the effects were considered significant at P≤0.05. Treatments consisted of two levels of digestible lysine (100% vs 90%). Diarrhea score data were analyzed using the FREQ procedure of SAS, in which the pen was considered the experimental unit, the effects were assessed with a chi-squared (X^2) test, and they were considered significant at P≤0.05.

RESULTS AND DISCUSSION

One of the strategies to minimize costs in pig farms during times of high ingredient costs is the temporary reduction of lysine in the diet of weaned piglets, aiming for compensatory growth in the subsequent period (Taylor et al., 2013; Gomes et al., 2021). However, few studies explore the effects of this reduction as well as the economic viability of modified diets for nursery pigs. Thus, a temporary reduction of lysine in weaned piglets' diets followed by an unrestricted diet in the subsequent period was hypothesized to lead to similar growth performance as nonrestricted pigs and be economically feasible at the end of the nursery phase. From 21 to 32 days of age, pigs fed low-lys diets had worse ADG, FC, and 32-d BW (P≤0.05), while ADFI was not affected (P>0.05; Table 2). From 32 to 42 days of age, pigs fed low-lys diets had lower ADFI, ADG, and 42-d BW (P≤0.05), while FC was not affected (P>0.05).

Table 2. Effects of control lysine and low lysine diets on nursery pig growth performance.

Item	Treatments[1] Control-lys[2]	Low-lys[3]	CV(%)[4]	P-value*

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21 to 32 d of age				
Initial BW, kg	5.48	5.49	5.82	0.92
ADFI, kg/d	0.24	0.23	9.78	0.26
ADG, kg/d	0.22	0.18	13.55	<0.01
FC	1.11	1.27	10.67	<0.01
32 d BW, kg	7.87	7.50	5.75	0.05
32 to 42 d of age				
ADFI, kg/d	0.55	0.45	12.67	<0.01
ADG, kg/d	0.42	0.35	7.92	<0.01
FC	1.31	1.30	13.78	0.88
42 d BW, kg	12.12	10.97	3.63	<0.01
42 to 62 d of age[3]				
ADFI, kg/d	0.95	0.92	9.16	0.57
ADG, kg/d	0.63	0.64	5.57	0.56
FC	1.50	1.45	8.16	0.29
62 d BW, kg	24.73	23.76	3.25	<0.01
21 to 62 d of age				
ADFI, kg/d	0.66	0.62	7.70	0.08
ADG, kg/d	0.47	0.45	3.89	<0.01
FC	1.41	1.40	6.32	0.82

[1] Experimental treatment diets were fed from 21 to 42 days of age, and a common diet was fed to all pigs from 42 to 62 days of age. [2] Following the recommendation of Rostagno et al. (2017); [3] Lysine level of 90% of the recommendation of Rostagno et al. (2017); [4] CV, coefficient of variation; *P ≤ 0.05 significant.

The lower growth performance of pigs fed low-lys diets was expected when the amino acid level in the diet was below the amount recommended to maximize growth performance in the *Brazilian Tables for Poultry and Swine* (Rostagno et al., 2017). Our results are consistent with other studies that demonstrated that lower lysine diets might impair pigs' performance (Taylor et al., 2013; Totafurno et al., 2020; Gomes et al., 2021). Moreover, the low-lys diet lowered the pigs' ADFI, similar to Taylor et al. (2013) and Gomes et al.'s (2021) findings. Along with reduced lysine in the low-lys diet, the other essential amino acids were reduced proportionally. Therefore, our results may be explained by the lower level of dietary tryptophan; Liang et al. (2018) have demonstrated that lower levels of tryptophan in the diet may lead to lower feed intake. Moreover, an optimal ratio between digestible lysine and metabolizable energy (ME) must be prioritized when the amino acid or energy contents of the diet change (Ferreira et al., 2019). Researchers have demonstrated that pigs present lower feed intake when fed lower SID lys:ME diets (Sweer et al., 2018; Ferreira et al., 2019), as might have been the case in the low-lys treatment.

At 27 and 29 days of age, pigs fed the low-lys diet had a higher (P≤0.05) incidence of diarrhea (Table 3). The higher incidence of diarrhea in pigs fed

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a low-lys diet may partially explain the lower ADG and, consequently, the differences in BW at 32 and 42 days between treatment groups. Our results are consistent with Gomes et al. (2021), who found that weaned piglets fed a low lysine diet experienced more diarrhea than pigs consuming a control diet. , Animals fed low lysine diets had other amino acids proportionally reduced, such as a threonine responsible for mucin synthesis and maintenance of intestinal integrity (Bertolo et al., 1998) and tryptophan related to improvement in intestinal barrier function, decrease in the expression of inflammatory cytokines, in addition to a reduction in the population of intestinal pathogens (Liang et al., 2018).

Table 3. Effects of control lysine and low lysine diets on number of pens (total of 12) with diarrhea.

Days of age	Treatments[1] Control-lys[2]	Low-lys[3]	P-value
25	3/12	7/12	0.09
27	1/12	5/12	0.05
29	0/12	4/12	0.02
31	1/12	1/12	1.00

[1] Experimental treatment diets were fed from 21 to 42 days of age, and a common diet was fed to all pigs from 42 to 62 days of age. [2] Following the recommendation of Rostagno et al. (2017); [3] Lysine level of 90% of the recommendation of Rostagno et al. (2017); *P ≤ 0.05 significant by X^2 test.

From 42 to 62 days of age, pigs previously fed the low-lys diet had similar (P>0.05) ADFI, ADG, and FC as those fed the control-lys diet. However, pigs fed the control-lys diet had a greater final BW (P≤0.05). Thus, although low-lys-fed pigs presented a similar ADG from 42 to 62 days, it was insufficient to reach a similar final BW as pigs fed the control diet.

Notably, pigs from the low-lys treatment might have shown partial compensatory growth from 42 to 62 days. According to Skiba (2005), there are two types of compensatory growth, complete and partial. Complete compensatory growth occurs when compensatory growth is so strong that the pig attains the same BW weight and body composition at the same age as nonrestricted animals. Partial compensatory growth occurs when animals' growth rate increases but the magnitude or duration is insufficient to attain similar performance as nonrestricted animals, which may explain this study's findings.

During the entire nursery phase (21 to 62 days of age), pigs fed the low-lys treatment had lower ADG compared to those fed the control-lys diet (P≤0.05), while ADFI and FC were unaffected (P>0.05). Thus, the higher ADG and final BW of the control-lys pigs reinforce the importance of following nutritional manuals' recommendations for maximum growth performance.

During the entire experimental period, the lowest feed cost and the highest EEI were recorded for the low-lys treatment (Table 4). The lower feed cost occurred due to the reduction of lysine and other industrial amino acids in the low-lys initial diets, lowering the total feed costs. Besides diet, the EEI also considers the ADFI and ADG. Thus, the highest EEI indicated that feeding low-lys diets was economically efficient and resulted in low production costs. However, the EEI does not consider the sale value of the pig; therefore, we decided to estimate the profitability.

Table 4. Economic analysis of feeding control lysine and low lysine diets for nursery pigs.

	Treatments[1]	
Item	Control-Lys[2]	Low-Lys[3]
Feed cost (US$/Kg)	0.55	0.54
EEI (%)[3]	96.9	100
Profitability (US$)	33.5	32.2

[1] Experimental treatment diets were fed from 21 to 42 days of age, and a common diet was fed to all pigs from 42 to 62 days of age. [2] Following the recommendation of Rostagno et al. (2017); [3] Lysine level of 90% of the recommendation of Rostagno et al. (2017). [3]EEI - economic efficiency index.

The pigs fed the control-lys diet presented a 3.9% higher profitability when compared to those fed the low-lys diet. Their improved profitability can be explained by the higher final BW of the control-lys group, associated with the piglets' market price. Thus, in this study, the temporary reduction of lysine in the nursery diets was found to be less practical than the diet in which the phase recommendations were obeyed. However, in other economic scenarios, lysine reduction may be feasible. After feeding a low-lys diet had improved the EEI, the cost to produce one kilogram of BW was lower compared to that of doing so in pigs fed a control diet. Therefore, when pork is devalued, lower dietary lysine levels might provide a higher profit margin.

In this study, a temporary reduction of lysine in the diets of weaned piglets followed by an unrestricted diet in the subsequent period led to partial compensation of growth performance. Thus, contrary to our initial hypothesis, the nursery pigs were not able to attain a similar final BW compared to nonrestricted animals. Moreover, the temporary reduction of lysine in diets was not economically feasible at the end of the nursery phase. However, due to the improved EEI, in other economic scenarios, such alternatives might be considered.

CONCLUSIONS

A temporary reduction of lysine in the diets of weaned piglets followed by an unrestricted diet in the subsequent period led to worse growth performance and lower economic viability in the examined economic scenarios. Moreover, piglets fed the low lysine diet had a higher incidence of diarrhea.

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