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Effect of Dietary Lysine Fed to Pigs at Late Finishing Stage on the Market-Value Associated Carcass Characteristics

Taiji Wang, Mark A. Crenshaw, Naresh Regmi, Timothy Armstrong,
John R. Blanton and Shengfa F. Liao
Department of Animal and Dairy Sciences, Mississippi State University,
MS 39762-9815, Starkville, Mississippi State, USA

Abstract: Although, dietary lysine requirement of pigs at late finishing stage is lower than that of younger pigs, it is the last but not least stage when producers can use nutritional measures to maximize pigs' growth performance and carcass quantity and quality. This study was conducted to evaluate the effect of dietary lysine on growth performance and carcass characteristics of late-stage finishing pigs (large white x landrace; body weight 94.4±6.7 kg). Nine barrows were randomly allotted to 3 treatments (3 pigs/treatment). Three corn and soybean-meal based diets were formulated according to the NRC nutrient requirements except for lysine whose concentrations (as-fed basis) were 4.30, 7.10 and 9.80 g kg^{-1} for diets 1 (lysine-deficient), 2 (lysine-adequate) and 3 (lysine-excess), respectively. The feeding trial lasted 5 weeks. Pigs fed diet 2 or 3 had higher average daily gain than pigs fed diet 1. Both hot and chilled carcass weights tended to increase linearly with increasing dietary lysine concentration. Loin eye areas of pigs fed diets 2 and 3 were increased by 18% and 9%, respectively when compared with pigs fed diet 1. Both trimmed and untrimmed ham weights of pigs fed diets 2 and 3 were increased by 21% compared to the pigs fed diet 1. Both dressing percentage and total lean cut weight increased linearly with increasing dietary lysine concentration. The back-fat thickness, belly weight and visual scores of loin color and loin marbling, however were not affected by dietary lysine concentration. The data indicated that there is still an opportunity for further improving the overall carcass merit via increasing dietary lysine supply for the pigs at late finishing stage which suggested that more dietary lysine supply over the NRC recommended level might benefit swine and meat industries by improving the market value of the pork.

Key words: Carcass characteristics, lysine, growth performance, finishing stage, pig

INTRODUCTION

The carcass characteristics of pigs are the determinants of pork quantity and quality and are directly associated with the market value of the pig (Marcoux *et al*., 2007) while pork quality and quantity largely depend on the quantity and quality of the tissue of skeletal muscle which is pertinent to the accretion of muscle proteins, the major chemical component of pork. The protein deposition or accretion requires dietary supply of Amino Acids (AAs) which function as building blocks for protein biosynthesis. While lysine, an essential dietary AA is the most abundant AA in body protein gain of growing-finishing pigs (7.1 g lysine per 100 g protein) (NRC, 2012), it is usually the first limiting AA in grain based swine diets because cereal grains are low in lysine content relative to the swine requirement for lysine. For example, sorghum, corn, wheat and barley contain approximately, 0.20, 0.25, 0.35 and 0.40% lysine, respectively (NRC, 2012) which cannot meet pigs' requirement at any given stage if fed cereal grains alone. What's more, among all plasma AAs, lysine is located at the top control level which affects the concentrations of most other AAs (Shikata *et al*., 2007). Therefore, dietary lysine at different concentrations would affect plasma concentrations of not only lysine but also other AAs as well (Liao *et al*., 2015), causing difference in pig muscle growth and carcass characteristics.

Dietary lysine requirement of pigs at late finishing stage is lower than that of younger stage, yet it is the last but not least stage when producers can use nutritional measures to maximize pigs' growth performance and carcass quantity and quality (Friesen *et al*., 1994; Hahn *et al*., 1995; Apple *et al*., 2004). Some studies that focused on the effect of dietary lysine on the growth performance and carcass characteristics of finishing pigs have been conducted previously (Castell *et al*., 1994; Friesen *et al*., 1994; Unruh *et al*., 1996; Loughmiller *et al*.,

Corresponding Author: Shengfa F. Liao, Department of Animal and Dairy Sciences, Mississippi State University, MS 39762-9815, Starkville, Mississippi State, USA

1998; De la Llata *et al*., 2002); in these studies, however, the dietary concentrations of other AAs were adjusted in different ratios to lysine based on an ideal protein model (Baker *et al*., 1993; NRC, 2012). This ratio adjustment is necessary for applying the ideal protein concept (Baker *et al*., 1993; Baker, 1997) in swine feeding practice but the adjustment makes it difficult to attribute the observed effects on growth performance and carcass characteristics to the dietary lysine alone. Thus, the objective of this study was to evaluate the effect of lysine which is the only variable in the diet on the growth performance and carcass characteristics of late-stage finishing pigs.

MATERIALS AND METHODS

Animal trial procedures: A total of 9 crossbred finishing barrows (large white x landrace) with an average initial Body Weight (BW) 94.4±6.7 kg were housed in an environment controlled swine barn at the Leveck Animal Research Center of Mississippi State University (MS, USA). The pigs were randomly assigned to 9 individual feeding pens and then randomly allotted to 3 treatment groups according to a completely randomized experimental design. Each treatment consisted of three pen replicates with one pig in each pen.

A corn and soybean meal based diet (diet 1; a lysine-deficient diet) was formulated to meet or exceed the NRC (2012) recommended requirements for various nutrients, except for lysine. Diet 2 (a lysine-adequate diet) and diet 3 (a lysine-excess diet) were formulated by adding L-Lysine Monohydrochloride (98.5%; Archer Daniels Midland Co., Quincy, IL, USA) to diet 1 at the expense of corn at the ratios of 0.35 and 0.70%, respectively. The composition of feed ingredients and the calculated nutrient composition of the three experimental diets are listed in Table 1. The calculated total lysine contents (as-fed basis) in diets 1, 2 and 3 were 4.30, 7.10 and 9.80 g kg^{-1}, respectively.

The feeding trial lasted 5 weeks, during which time the pigs were allowed *ad libitum* access to the experimental diets and fresh water. All the pigs, feeders and waterers were checked 2-3 times on a daily basis (6:00 a.m. to 7:00 p.m.). Pigs' BWs were measured at the beginning and at the end of the 5 weeks trial for calculation of Average Daily Gain (ADG). All the experimental protocols involving caring, handling and treatment of pigs were approved by Mississippi State University Institutional Animal Care and Use Committee.

Carcass measurements: At the end of the feeding trial, the pigs were harvested at the Mississippi State University Meat Science and Muscle Biology Laboratory to determine carcass characteristics. Briefly, the pigs were stunned by electrical shock, exsanguinated and de-haired. After the head and feet were removed, the hot carcasses were eviscerated and split longitudinally into two halves. Then, the whole hot carcass were weighed prior to storing it in a cooler below 4°C. The dressing percentage was calculated by dividing the hot carcass weight by the live weight of the pig and multiplying by 100.

After 24 h storing, the chilled carcass was weighed again and the carcass length was measured from the anterior edge of the first rib to the anterior edge of the aitch bone. The right half of each carcass were then separated into five primal cuts which were ham, Boston butt, picnic, loin and belly. The ham was separated from the carcass by a straight cut approximately, perpendicular to a line parallel to the shank bones. The cut passes through a point which is between 3.8 and 8.8 cm from the anterior edge of the aitch bone. The shoulder composed of Boston butt and picnic were

Table 1: Composition of experimental diets (as-fed basis)[1]

Composition	Diet 1	Diet 2	Diet 3
Ingredients (g kg^{-1})			
Corn	908.44	904.94	901.44
Soybean meal	64.00	64.00	64.00
Canola oil	8.00	8.00	8.00
L-Lysine-HCl (98.5%)	0.00	3.50	7.00
DL-Methionine (99%)	0.40	0.40	0.40
L-Threonine (98.5%)	0.90	0.90	0.90
L-Tryptophan (99%)	0.35	0.35	0.35
Limestone	6.50	6.50	6.50
Dicalcium phosphate	9.00	9.00	9.00
Salt	2.00	2.00	2.00
Mineral premix[2]	0.33	0.33	0.33
Vitamin premix[3]	0.08	0.08	0.08
Total	1000.00	1000.00	
Calculated nutrient composition (g kg^{-1})[4]			
Metabolizable energy	13.90	13.90	13.90
Crude protein	104.50	107.50	110.50
Total lysine	4.33	7.08	9.82
Total methionine	2.37	2.36	2.36
Total threonine	5.02	5.01	5.00
Total tryptophan	1.40	1.40	1.39
Total Ca	4.58	4.58	4.58
Total P	4.32	4.31	4.30
Analyzed nutrient composition[5]			
Dry matter (%)	87.10	87.12	87.12
Gross energy (kJ kg^{-1})	15.30	15.10	14.90
Crude protein (g kg^{-1})	103.50	109.70	112.10
Crude fat (g kg^{-1})	29.70	29.80	29.50
Ash (g kg^{-1})	29.50	31.20	32.30

[1]Diets 1-3 were formulated to contain total dietary lysine at 0.43, 0.71 and 0.98% (as-fed basis) of which diets 2 and 3 were formulated by adding 3.50 and 7.00 g kg^{-1} of L-lysine-HCl to diet 1 at the expense of corn. [2]The mineral premix contained Ca 132, Cu 10.0, Fe 80.0, Mn 50.0, Zn 100.0, I 500 and Se 300 mg kg^{-1}. [3]Each kilogram of vitamin premix contained the following: 22.05 million IU vitamin A, 3.31 million IU vitamin D_3, 66,138 IU vitamin E, 88 mg vitamin B_{12}, 220 mg biotin, 8,818 mg menadione, 15,432 mg riboflavin, 61,728 mg d-pantothenic acid and 88,183 mg niacin. [4]Values were calculated based on the nutrient composition of the ingredients reported by NRC (2012). The unit for metabolizable energy is kJ/kg. [5]Values were obtained from the proximate analysis of the three diets

separated from the carcass side by a straight cut that was approximately, perpendicular to the length of the side and posterior to the elbow. Boston butt and picnic were then separated by a straight cut, dorsal to the shoulder joint, at a right angle with the belly side. The belly was prepared by a straight cut that extends from a point that was ventral to the longissimus on the shoulder end to a point on the leg end ventral to the tenderloin. The loin was the top portion of the side remaining after removal of the ham, shoulder and belly.

The back-fat thickness was measured at the tenth rib and the average back-fat thickness was obtained by averaging three measurements at the first rib, the last rib and the last lumbar vertebra. Each of the primal cuts was weighed separately and the total weight of the Boston butt, picnic, loin and trimmed ham from a whole carcass made up a total lean cut weight. The total lean cut weight divided by the chilled carcass weight and multiplied by 100 gave a lean cut percentage of acarcass.

The loin eye was scored for color, firmness and marbling. The loin eye color was subjectively evaluated using a 5-point scale, ranking from1 (pale, soft and devoid of marbling) to 5 (dark, firm and moderately abundant or greater marbling). The area of loin eye was measured using a Plastic Grid (Product Number AS 0235E, Extension and Outreach, Iowa State University, Ames, IA, USA). Briefly, the grid was first placed over a tracing of a loin eye, the dots on the grid that fall into the boundaries of loin eye tracing were counted and then the dot numbers were converted to loin eye area (cm^2).

Statistical analysis: Experimental data were statistically analyzed using the General Linear Model (GLM) Procedure of SAS (Version 9.3; SAS Institute Inc., Cary, NC) with lysine level being the main effect. Orthogonal polynomial contrasts were used to analyze the linear and quadratic effects of the dietary treatment. Probability values less than or equal to 0.05 were considered as significant differences and 0.10 as tendencies.

RESULTS AND DISCUSSION

The effect of dietary lysine on the growth performance of the pigs is shown in Table 2. As expected, there were no differences in the initial BW ($p = 0.83$) among the three dietary treatment groups. Although, the final BWs of the three treatment groups were not significantly different ($p = 0.16$), the ADG showed both linear ($p = 0.01$) and quadratic ($p = 0.03$) relationships with the dietary lysine concentrations. The ADG of the pigs fed diets 2 and 3 were 41 and 35% higher, respectively than the pigs fed diet 1.

These growth performance data indicated that both the lysine-adequate and lysine-excess diets can increase the ADG of pigs comparing with the lysine-deficient

Table 2: Effect of dietary lysine at different levels on growth performance of finishing pigs[1]

Parameters measured	Diet[2] Diet 1	Diet 2	Diet 3	p-value[3] SE	Linear	Quadratic
Initial BW (kg)	94.00	93.90	95.40	4.41	0.834	0.883
Final BW (kg)	128.70	143.00	142.30	5.93	0.158	0.339
ADG (kg day^{-1})	0.99	1.40	1.34	0.07	0.012	0.030

[1]Each value representsa mean calculated from3 individually penned pigs for each dietary treatment. SE: Standard Error; BW: Body Weight, ADG: Average Daily Gain. [2]The levels of total dietary lysine were 4.30, 7.10 and 9.80 g kg^{-1} for diets 1, 2 and 3, respectively (as fed basis). [3]p-values were obtained from the orthogonal polynomial contrast analyses

diet. Based on the conventional ideal protein concept (Baker *et al*., 1993; Baker, 1997), the lower concentration of dietary lysine can lead to unbalanced AA ratios of a diet, causing the lack of lysine for body protein synthesis while an adequate lysine supply in combination with its correct ratios with other AAs can lead to a balanced-AA diet, resulting in a higher ADG of pigs. In general, oral lysine intake is well tolerated by pigs and the toxicity of lysine seldom develops (Liao *et al*., 2015). Excess dietary lysine beyond the NRC (2012) recommendation can be absorbed to the blood circulation, causing increased level of free lysine in the plasma which may further stimulate body muscle protein biosynthesis. It is of interest to point out that the ADG of pigs fed a lysine-adequate diet in this study was higher than the NRC (2012) estimated ADG (1.40 vs. 0.87 kg day^{-1}) which might reflect that the modern genetic line of pigs used in this study had a higher growth potential at the late finishing stage. Therefore, it can be postulated that the contents of other AAs and the energy density in a lysine-excess diet may become limiting factors that restrict the growth potential of modern faster growing pigs.

The effects of dietary lysine at different levels on the carcass characteristics of finishing pigs is shown in Table 3. Both hot and chilled carcass weights tended to increase linearly ($p<0.10$) with increased dietary lysine concentrations which was in agreement with the improvement of ADG of these pigs. Furthermore, although there were no differences ($p = 0.79$) in carcass length among three dietary treatments, the dressing percentage of the pigs was increased linearly with increased dietary lysine concentrations ($p = 0.04$) which was consistent with the result of hot carcass weights. Cisneros *et al*. (1996) and Bidner *et al*. (2004) reported that feeding lysine deficient diets reduced the dressing percentages of finishing pigs. Intriguingly, the present study showed that dietary inclusion of lysine at a level that is in excess by NRC (2012) recommendation could further increase the dressing percentage of pigs at the late finishing stage.

The back-fat thickness (at the tenth rib or the average) was not affected ($p = 0.17$ to 0.70) by the dietary lysine at three different concentrations (Table 3). Goodband *et al*. (1990) reported similar results that the back-fat measurement was not affected by dietary

Table 3: Effect of dietary lysine at different levels on carcass characteristics of finishing pigs[1]

Parameters measured	Diet[2] Diet 1	Diet 2	Diet 3	p-value[3] SE	Linear	Quadratic
Hot carcass (kg)	95.30	109.60	111.30	5.51	0.085	0.382
Chilled carcass (kg)	91.20	104.00	105.80	5.27	0.097	0.425
Dressing (%)	73.90	76.60	78.20	1.13	0.036	0.738
Carcass length (cm)	88.30	88.50	88.90	1.43	0.788	0.949
Back-fat 10th Rib (cm)	3.05	3.39	3.89	0.38	0.168	0.862
Back-fat average[4] (cm)	2.94	2.82	3.08	0.24	0.703	0.555
Loin color	3.00	2.67	3.00	0.19	1.000	0.207
Loin marbling score	2.67	2.33	2.33	0.33	0.506	0.697
Loin weight (kg)	16.90	19.20	19.80	1.23	0.135	0.586
Loin eye area (cm^2)	34.30	40.50	37.50	1.47	0.173	0.044
Belly weight (kg)	8.98	9.23	10.10	0.82	0.366	0.758
Boston butt weight (kg)	6.96	8.32	8.54	0.58	0.101	0.458
Picnic weight (kg)	8.59	9.22	9.83	0.46	0.108	0.966
Untrimmed ham (kg)	19.40	23.40	23.50	0.68	0.006	0.067
Trimmed ham (kg)	18.40	22.20	22.40	0.63	0.004	0.057
Lean cut weight (kg)	50.80	58.90	60.60	2.69	0.042	0.366
Lean cut (%)	55.70	56.60	57.20	0.68	0.066	0.733

[1]Each value representsa mean calculated from 3 individually penned pigs for each dietary treatment. SE: Standard Error. [2]The levels of total dietary lysine were 4.30, 7.10 and 9.80 g kg^{-1} for diets 1, 2 and 3, respectively (as fed basis). [3]p-values were obtained from the orthogonal polynomial contrast analyses. [4]The average back-fat thickness was obtained by averaging three measurements at the first rib, the last rib and the last lumbar vertebra

lysine level among the porcine somatotropin treated finishing pigs. However, their results were not consistent with some other studies which showed that lower concentrations of dietary lysine increased back fat thickness (Witte *et al*., 2000; Bidner *et al*., 2004; Tous *et al*., 2014). Theoretically, a diet deficient in lysinemay allow more energy (saved from the expenditure of energy for body protein synthesis and the energy released from the catabolism of other extra AAs) for fat deposition, yet the main reason for the result discrepancy between this study and some previous studies might be because the late-stage finishing pigs used in this study still maintain a high lean growth (instead of fat deposition) potential as was discussed above.

Also as shown in Table 3, dietary lysine at different concentrations did not affect loin color (p = 1.00) and loin marbling score (p = 0.51) which is in agreement with Witte *et al*. (2000) who reported that there was no differences in the marbling score and the subjective meat color between two levels of dietary lysine. Although, the loin weight was just numerically increased (p = 0.14) with increased dietary lysine concentrations, it was found that the loin eye area was in a quadratic relationship (p = 0.04) with dietary lysine concentration in which the loin eye areas of pigs fed diets 2 and 3 were increased by 6.2 cm^2 (18%) and 3.2 cm^2 (9%), respectively when compared with the pigs fed diet 1. This result was supported by Goodband *et al*. (1990) who observed a similar quadratic relationship between loin eye area and dietary lysine concentration. That the lysine-deficient diet decreased loin eye area is in agreement with two previous studies that reported reductions in loin eye area of pigs fed low-lysine diets (Witte *et al*., 2000; Bidner *et al*., 2004). Loin eye area has a direct relation to the body lean mass accretion (Zobrisky *et al*., 1959) and the increased loin eye area in the pigs fed the lysine-adequate or lysine-excess diet relative to the lysine-deficient diet must be a result of the improved protein accretion and muscle growth.

While the belly weight was not changed (p = 0.37) by the dietary lysine level, both Boston butt and picnic weights tended to increase ($p\leq0.10$) with the increased dietary lysine concentrations (Table 3). Both the trimmed and untrimmed ham weights increased linearly ($p<0.01$) in accordance with the dietary lysine concentrations and numerically both the trimmed and untrimmed ham weights of the pigs fed diets 2 and 3 increased by approximately, 21% compared to the pigs fed diet 1. It was reported that within a certain range among somatotropin treated finishing pigs the ham weights were increased with increasing dietary lysine level (Goodband *et al*., 1990) and this report (Goodband *et al*., 1990) supports our result regarding the ham weights affected by lysine in this study.

The total lean cut weight increased linearly (p = 0.04) along with increased dietary lysine concentrations (Table 3). That the adequate and excess dietary lysine linearly increases the dressing percentage and total lean cut weigh but not back-fat thickness, holds a very important significance in terms of pork quality and human nutrition and health. In addition to the linearly-increased total lean cut weight and the tendency of increasing carcass weight, the lean cut percentage appeared to be linearly increased (p = 0.07) with the increased dietary lysine concentrations. Considering that the market value of a pig carcass is greatly affected by the weight and percentage of the total lean cut, a higher concentration of dietary lysine than the NRC (2012) recommended level for pigs at late finishing stage might further increase the market value of modern pigs.

CONCLUSION

Increasing dietary lysine concentration linearly increased the carcass dressing percentage, the ham weights and the total lean cut weight of the late stage finishing pigs. These results not only confirmed the importance of dietary lysine supply for the carcass quantity and quality of market pigs but also indicated that there may still be an opportunity for further improving the overall carcass merit via increasing dietary lysine supply. This conclusion further suggests that more dietary lysine supply over the NRC (2012) recommended level for the finishing pigs at the late production stage might further benefit swine and meat industries by improving the market value of the pig.

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