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Effect of Dietary Lysine Supplement on the Performance of Mong Cai Sows and Their Piglets

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ABSTRACT : The objective of this study was to determine optimal lysine requirement of lactating Mong Cai sows and their piglets. An experiment was conducted using 30 Mong Cai sows in a factorial randomized design with 5 dietary total lysine levels (0.60, 0.70, 0.85, 1.0 and 1.15%) for one-week pre-partum and 5 dietary total lysine levels (0.60, 0.75, 0.90, 1.05 and 1.2%) for lactation diets. Mong Cai sows were about 1 to 2 years old and had an initial body weight of 120 kg (sd = 2.5) after farrowing. Sows were restrictively fed 1.7 kg feed during gestation and were fed *ad libitum* during lactation. Diets of sows contained about 12% CP during pregnancy and about 14% CP for the lactation period. DE concentration of the diets ranged between 12.5-13.0 MJ of DE. Water was supplied at up to 8 liters per sow per day in a basin. Studied traits were related to both sows and their progeny. Sows were weighed at 107 days of gestation, after farrowing and at weaning. Sow back-fat depth was measured at 110 days of gestation, after farrowing, at 21 days of lactation and at weaning. Number of piglets born, at 24 h after birth, at 21 days of age and at weaning were recorded. Piglets were weighte at birth, at 21 days and at weaning. Supplying lysine one week pre-partum had no effect on the number of piglets born nor litter weight at birth ($p = 0.776$ and $p = 0.224$). A positive effect of increasing dietary lysine level during lactation from 0.60 to 1.20% was observed with regard to less sow weight loss, and increased piglet weight at 21 days and at weaning. The level of lysine that resulted in the lowest sow backfat loss and the highest weaned piglet weight was 1.05%; this may be the optimum level of lysine for the diet of lactating Mong Cai sows. At this lysine level, the number of weaned piglets was also highest. (**Key Words :** Mong Cai Sow, Lactation, Lysine, Requirements, Optimum, Piglets)

INTRODUCTION

Lactation is an important period in the life of sows. During a relatively short period, sows have to produce a large amount of milk and thus metabolic demands for nutrients and energy are high. Amino acids are important essential nutrients that affect the overall reproductive performance of breeding pigs. Lysine is the first limiting essential amino acid in most diets for lactating sows and daily lysine intake is a primary determinant of lactation performance (NRC 1998; Yang et al., 2000b; Kim et al., 2001).

The amino acid requirement during lactation is closely related to the amount and composition of sow's milk. Several studies have shown that the quantity of maternal reserves built up during gestation can have an effect on subsequent litter growth and reproductive performance (Jones and Stahly 1999; Clowes et al., 2003).

Jones and Stahly (1999) and Yang et al. (2007) reported that sows fed diets with a low protein level (8.3 to 13.1% CP) during lactation had a low milk production. Adequate dietary protein level (19.2% CP) during lactation diets can increase fat milk output (Scinclair et al., 2001), decrease the body weight losses of the sows during lactation (Johnston et al., 1993; Van den Brand, 2000; Sinclair, 2001). Doumard et al. (1998) reported that a high producing sows requires at least 55 g of dietary lysine/d for minimum weight loss and for maximal mammary gland growth (Kim et al., 1999b). The amount and composition of amino acids in the sow's diet can therefore be an indication of the optimal balance of amino acids ingested by the piglets (Verstegen et al., 1998). Touchette et al. (1998a) found that lactating sows require 48 g of digestible lysine per day for an adjusted litter size of 9 to 11 piglets, in order to minimize her own protein mobilization. Tritton et al. (1996) and Yang et al. (2000b)

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reported no effect on litter size at birth when lysine intakes during the first pregnancy lactation varied. Johnston et al. (1993), Touchette et al. (1998a) and Sinclaire et al. (2001), reported that protein/lysine levels in the lactation diets prevented sow weight loss but had no influence on sow backfat loss and did not improve daily litter weight gain. Yang et al. (2000a) found that a low amino acid intake (16 g/d) during lactation impaired follicular development and maturation during the subsequent pro-estrus period.

Bojcuková and Kratký (2006) noted that a higher litter weight at the age of 21 days in the sows group fed the highest dietary content of lysine (15.19 g compared to 8.15 g of lysine/kg feed).

Mong Cai sows are a local popular type of pig breed for smallholders throughout the entire country of Vietnam. Mong Cai sows are used as the major female line for crossing with exotic boars to produce hybrids F_1 (Large White or Landrace×Mong Cai) and F_2 ((Large White ×Mong Cai)×Landrace)) are common raised on smallholder pig farms. In rural area of Central Vietnam, smallholder farmers often feed their sows with locally available feed resources. Sows, however, do not receive sufficient amount of amino acids from these diets. Commonly lactation diet for Mong Cai sows contain from 0.6 to 0.9% lysine in lactation diet was commonly used in Vietnam. The current study was conducted to find the optimal lysine requirements of lactating Mong Cai sows and their piglets. The hypothesis was that Mong Cai sows have the highest response at optimum lysine levels in the diets.

MATERIAL AND METHODS

Animals

Thirty Mong Cai sows (six sows per treatment) aged was about 1 to 2 years with a weight after parturition of approximately 120 kg and a parity number of 2 to 3 were used.

The treatments were designed according to dietary lysine level (0.6, 0.7, 0.9, 1.05 and 1.20% lysine in the DM). The sows remained in the experimental pen from pregnancy onwards and during farrowing and lactation. Weaning occurred at day 45 of lactation. The experiment was conducted during the cool season from September 2004 to March 2005 at the farrowing house at Trieu Hai Farm of the Central Pig Breeding Company, Quang Tri, Vietnam. Temperatures during this period ranged from 15 to 26°C.

Housing

The sows were housed individually in pens of 2.0 m length and 1.75 m wide. Pens were separated by brick walls, were 2.6 m height and had an insulated fibro-cement roof. The floor consisted of solid concrete except for a gutter (0.25 m width×1.50 m length×0.40 m deep) which was protected with an iron lattice-covered floor at the back of the pen. Each pen was equipped with a feeder and water drinker for the sows and an infrared light from an electric heating bulb to provide additional warmth for the piglets. Bedding material was not used. The farrowing house was open so that the inside temperatures followed the outside ambient temperature.

Feeding

A basal diet was fed from 107 days of pregnancy until farrowing which was formulated to contain 0.56% lysine from corn and fish meal. Lysine HCl (78.8% lysine) was supplemented with lysine and fishmeal to achieve dietary levels of 0.60, 0.70, 0.85, 1.0 and 1.15% lysine from the 107^{th} day of pregnancy to farrowing (one week before expected farrowing date).

Daily feed allowance during the last week of pregnancy was derived using data of Close et al. (1985) and Verstegen and den Hartog (1989) and requirement for production as proposed by Pettigrew and Young (1997). Feed allowance was constant from mating to the last week of gestation. Daily feed allowance during lactation was derived from the protein and energy requirement proposed by Pettigrew and Young (1987).

Lysine HCl (78.8% lysine) was supplemented to the basal diet to achieve a dietary level of 0.60 for basal, 0.75, 0.90, 1.05 and 1.20% lysine for post-farrowing until weaning at the 45±3 day. Sows received a high lysine level before farrowing also received a high lysine level during lactation. Mineral and vitamin supplied to the diets via trace vitamin-mineral premixes and 0.5% sodium chloride.

Sows were restrict fed during pregnancy with 1.7 kg of their gestation diet twice daily from mating until farrowing (Farrowing day d = 0). Feed composition of the gestation diet contained about 12% CP. Pigs were fed twice per day at 8 am and at 4 pm. After farrowing, sows were fed *ad libitum*. Feed composition of the basal lactation diet contained about 14% of CP. Digestible energy for both the gestation and lactation diet was 12.5 to 13.0 MJ of DE (Table 1). Water was supplied up to 8 L/sow/d in a basin.

Treatment

The diet was prepared with rice bran, cassava meal, corn meal, fishmeal and sweet potato vines. Feed was formulated to meet the requirements of lactating sows in terms of energy, crude protein, minerals and vitamins. Lysine was added to reach the desired lysine levels. The amounts and ratios between digestible essential amino acids and digestible lysine in the experimental diet were based on ideal CP at 14% as recommended by NIAH (2001) for lactating sows. The calculated compositions of the

Table 1. Feed composition of diet for lactation period

Ingredients (%)	Digestible lysine %[1]				
	0.60	0.75	0.90	1.05	1.20
Synthetic lysine HCl[1]	-	+	+	+	+
Rice bran	44	44	44	44	44
Corn meal	36	36	36	36	36
Cassava meal	9.4	9.4	9.4	9.4	9.4
Fish meal [2]	9	9	9	9	9
Sweet potato vine	0.10	0.10	0.10	0.10	0.10
Crude protein (g/kg DM)	141	143	145	144	142
Vitamin -Premix[3]	0.5	0.5	0.5	0.5	0.5
Mineral - Premix[4]	0.5	0.5	0.5	0.5	0.5
NaCl	0.5	0.5	0.5	0.5	0.5
ME (MJ/kg)[5]	13.68	14.08	14.16	14.14	14.09

[1] Manufactured by CJ CHEILJEDANG Cooperation, Seoul, Korea.
[2] Fish meal was supplied by Cargill, Minneapolis, MN, USA.
[3] Supplied per kg diet included: 0.24 mg acid folic, 150 IU vitamin A, 1 mg vitamin $B_{1,}$ 19 IU vitamin D_3, 0.5 mg vitamin E, 0.05 mg vitamin K.
[4] Supplied per kg diet: 52 mg Zn (as $ZnSO_4$), 47 mg Fe (as $Fe_2SO_45H_2O$), 60 mg Mn (as $MnSO_41H_2O$), 4 mg Cu (as $CuSO_45H_2O$), 0.96 mg I, 0.11 mg Co (as $CoSO_47H_2O$), 0.07 mg Se (as Na_2SeO_3), 2.0g dibasic calcium phosphate.
[5] Calculated using digestibility values of individual ingredients from the NIAH (2001).

experimental diets are shown in Table 1. Feed was offered to the sows after farrowing until weaning. Each morning, feed refusals were collected, and fresh feed was immediately provided. Feed consumption was determined as the difference between feed allowance and the refusals collected the next morning.

Measurement

Sows were weighed at serving day, 107 days of pregnancy, within 24 h after farrowing and at the 45th day of lactation (at weaning).

Back-fat thickness was measured by ultrasound at 107 day into gestation, 24 h after farrowing and at 21days of lactation using the Renco LEAN-METER® (Renco Corporation, Minneapolis, MN, USA). Two measurements were made at 6.5 cm from the dorsal midline on the right and left side of the animal at the level of the 10th rib (P2). Means obtained for the two sides were recorded for analyses. Ultrasonic evaluation was accomplished by using Vaseline oil and placing the probe directly on the skin of the pig. The outer layer thickness of fat was determined by measuring from the outer surface of the skin to the boundary of the outer and middle layer fat (Smith et al., 1992).

Within 24 h of farrowing, the number of live born, stillborn and mummified piglets as well as piglet weights were recorded. Needle teeth were clipped; ears were notched for identification, and piglets were given 1 ml of iron dextran (200 mg Fe/ml, Bomac Laboratory, New Zealand) and 1 ml Penicillin G (Bayer Company, Germany) as scouring preventative medication. The piglets were weighed and handled (tooth cutting, umbilical cord treatment, labeling and antibiotic administration) up to 7-10 days after birth. Males piglets were castrated within 7 to 10 days. The piglets were weighed at the 7th day, the 14th day and 21st day and at weaning. During the lactation period, piglets had no access to the sow feed but water was available through a low-pressure nipple drinker. Piglets were weaned at the 45th day of age into a conventional nursery.

At weaning, piglets were moved to the nursery of the farm, and sows were moved to a breeding facility and checked twice daily for signs of estrus, using detection coming into heat with a mature boar to detect the onset of heat. Estrus was recorded when sows stood to be mounted by the boar.

Statistical analysis

Data were analyzed by using the General Linear Model (GLM) procedure in SPSS 15.0. The model was:

$$Y_{ik} = \mu+L_j+\varepsilon_{ik} \quad (1)$$

in which Y_{jk} is the observed independent variable, μ is the overall mean of the observations, L_i is the main effect of the dietary lysine level (i = 0.60, 0.75, 0.90, 1.05 and 1.20% lysine) and ε_{ik} is the residual random component.

If the treatment effect was significant ($p<0.05$), differences between treatments were compared with Turkey's procedure (SPSS). Differences between means were tested by the Student-Newman- Keul's test. Differences were considered significant at $p<0.05$.

To predict the maximum litter weight at day 21 and at

Table 2. Effect of dietary lysine level on sow performance

Sows traits	Dietary lysine level					SEM	p value
	0.60	0.75	0.90	1.05	1.20		
No. of observation	6	6	6	6	6	-	-
Weight at mating (kg)	87.66[a]	86.67[a]	87.83[a]	87.67[a]	87.19	0.680	0.427
Weight at 107 days (kg)	120.00[a]	123[a]	120.83[a]	121.50[a]	121.83[a]	1.236	0.274
Weight 24 h after farrowing	96.83[a]	95.50[a]	95.60[a]	96.83[a]	96.67[a]	0.566	0.144
Weight at weaning (kg)	76.83[a]	78.85[b]	82.67[b]	86.33[b]	84.53[b]	1.108	0.028
Weight loss (kg)	20.00[a]	16.67[c]	13.83[c]	10.5[c]	12.33[c]	0.973	0.001
Feed intake (kg/d)	5.63[a]	5.80[a]	5.75[a]	5.87[a]	5.60[a]	0.069	0.054
ME intake (MJ of ME)	77.20	81.66	81.42	83.00	78.90	-	-
Sow back fat measurement (mm)							
At farrowing*	33.63[a]	33.1[a]	33.31[a]	33.68[a]	32.93[a]	0.316	0.157
21d of lactation	30.37[a]	29.73[b]	29.95[b]	29.81[b]	29.85[b]	0.279	0.021
At weaning	28.01[a]	28.08[a]	28.37[b]	29.27[c]	28.30[c]	0.183	0.001
Back fat loss	-5.61[a]	-5.23[b]	-4.95[c]	-4.38[c]	- 4.60[c]	0.133	0.001
Weaning to estrus interval	10.5	6.3	5.8	5.5	5.9	0.09	0.001

[a, b, c] Means within rows for genotype and dietary crude protein level with different superscripts differ ($p<0.05$).

weaning, litter weight gain or minimum sow backfat losses, a curvilinear response curve was fitted using one of the following equation

$$Y = aX^2+bX+c \quad (2)$$

$$Y = aX^3+bX^2+cX+d \quad (3)$$

where Y is response criteria (sow backfat loss, sow weight loss, litter weight and litter weight gain), x is dietary protein and a, b, c, d represent components of the curvilinear equation (Unrynek and Burazewsca, 2003). Quadratic and cubic polynomial contrast was carried out for several traits to determine the optimum dietary lysine levels.

RESULTS

In Table 2, the result of dietary lysine levels and the performance of the experimental sows are given. Sow feed intake (ADFI), was clearly affected by lysine level from 0.60 to 1.20 ($p>0.05$). The sow's body weight on day 107 of gestation and 24 h after farrowing was not statistically significant between diets ($p = 0.134$). Sow's body weight loss during lactation decreased drastically when dietary lysine level was increased. It is apparent that there was a greater weight loss of sows at the three lower levels of lysine (0.60, 0.75 and 0.90%) than that at two higher levels (1.05 and 1.20%). Sow's weight losses were highest at the 0.60% and 0.75% lysine levels and lowest at levels of 1.05 and 1.2%, respectively. Weaning to estrus interval ranged between 4.2 and 5.9 days, and was influenced ($p<0.05$) by dietary lysine and ME intake levels during the preceding lactation.

The number of piglets born per litter in the group was determined within 24 h after birth was 11.0±0.5 piglets. Dietary lysine and ME levels did not influence the total born and born alive piglets ($p>0.05$). Similarly, the number of piglets in groups did not differ within 7 days after birth ($p>0.05$). The number of piglets at the 21st day differed slightly between treatment groups ($p<0.049$), (Table 3).

The average number of weaned piglets at weaning at the 45th day was highest with the 1.05% lysine and lowest with the basal diet (Table 3). The differences in piglet numbers at weaning between groups were statistically significant ($p<0.001$).

The average weight of piglets in the different groups was determined by weighing individual piglets immediately after farrowing and in the various weeks after birth. The average birth weight of piglets was about 0.6 kg and there was no significant difference between the groups. The average weight in different treatment groups at the 7th day postpartum not different. At the 21st day of age, the average weights of piglets in the individual groups were 2.67 kg with diet1; 2.87 kg with diet 2; 3.13 kg with diet 3; 3.19 kg with diet 4 and 3.10 kg with diet 5. Obviously, there was a statistically significant difference between treatments ($p<0.001$). Similarly, the weaning weights between different group were also statistically significant ($p<0.001$) since the average weights of piglets in the different treatment groups at 45 days of age were 7.59 kg with diet 1; 7.80 kg with diet 2; 9.37 kg with diet 3; 9.70 kg with diet 4 and 9.08 kg with diet 5. Daily litter weight gains were 1.56, 1.71, 2.03, 2.17 and 2.02 kg/d corresponding to dietary lysine levels of 0.60, 0.75, 0.90, 1.05 and 1.2% lysine respectively (Table 3).

Table 3. Effect of dietary lysine level of sow's diet on litter performance

Traits	Dietary lysine level					SEM	p value
	0.60	0.75	0.90	1.05	1.20		
Litter size							
No. piglet born	11.41	11.33	11.83	11.67	11.50	0.297	0.766
No. piglet after 24 h	10.83	11.00	11.50	11.33	11.16	0.238	0.325
No. Of piglet at 7 d	10.67	10.83	11.16	11.33	11.00	0.238	0.158
No. Of piglet at 21 d	10.41	10.75	11.00	11.25	10.92	0.186	0.049
At weaning	9.87[a]	10.75[c]	10.87[c]	11.16[c]	10.91[c]	0.175	0.001
Total litter weight (kg)							
At birth	6.63	6.80	7.20	7.06	6.94	0.183	0.224
At 7 d	11.92	12.79	13.40	13.99	12.90	0.470	0.062
At 21 d	32.05	32.88[b]	34.35[b]	37.07[b]	35.76[b]	1.110	0.023
At weaning	78.04[a]	83.76[c]	98.46[c]	105.42[c]	99.10[c]	3.798	0.001
Average weight of piglet (kg)							
At birth	0.58	0.60	0.61	0.61	0.60	0.011	0.470
At 7 d	1.10	1.16	1.15	1.23	1.16	0.031	0.107
At 21 d	2.67	2.87[a]	3.13[b]	3.19[c]	3.10[b]	0.066	0.041
At weaning	7.59[a]	7.80[b]	9.37[c]	9.70[c]	9.08[c]	0.320	0.001
Litter daily gain (kg/d)	1.56[a]	1.71[b]	2.03[c]	2.17[c]	2.02[c]	0.077	0.001

[a, b, c] Means within rows for genotype and dietary crude protein level with different superscripts differ ($p<0.05$).

Figure 1 to 5 present the minimal and maximal traits for Feed intake (Figure 1) Sow backfat loss (Figure 2), Litter daily gain (Figure 3), Litter weight at 21 days lactation (Figure 4) and litter weight at weaning (Figure 5) at each lysine level and the best fit curve.

Results of the quadratic and cubic regression equations that predict optimum dietary lysine concentration of maximum litter weaning weight, litter daily growth rate or minimum sow's weight and backfat loss during lactation are shown in Table 4. Optimum dietary lysine levels for maximum litter weight at the 21st day and at weaning weight were approximate 1.05%. Optimum dietary lysine for minimum weight loss of sows was 1.05% and the optimum for backfat loss during lactation was 1.02%.

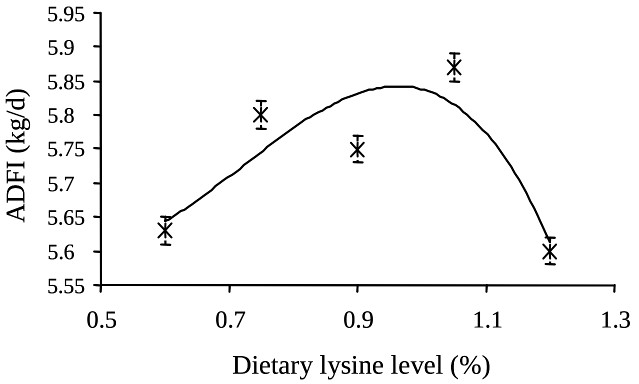

Figure 1. Effect of dietary lysine levels on ADFI of MC sows.

DISCUSSION

The result of the present study indicates that increasing dietary lysine from 0.60 to 1.20% did affect feed intake, sow weight loss and backfat thickness at weaning, number of weaned piglets, litter weight at the 21st day and at weaning.

Sow feed intake was lower when the 0.60% lysine diet was fed and sow ADFI was highest on the 1.05% lysine diet. However, the differences of sow feed intake were not significant between treatment groups ($p>0.05$). The feed intake of lactating sows is influenced by several factors e.g. feeding during gestation, body weight, litter size, environmental temperature and the energy and protein

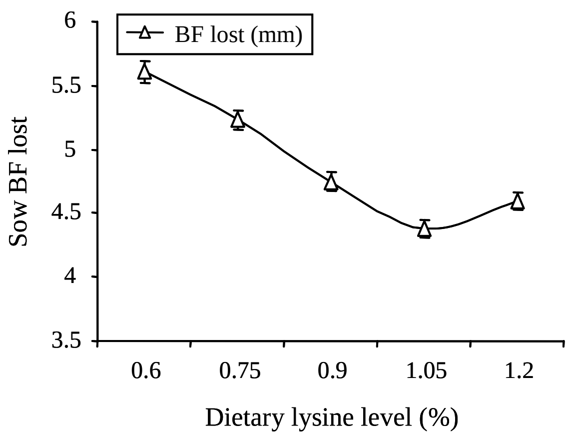

Figure 2. Effect of dietary lysine levels on backfat loss during lactation period of MC sows.

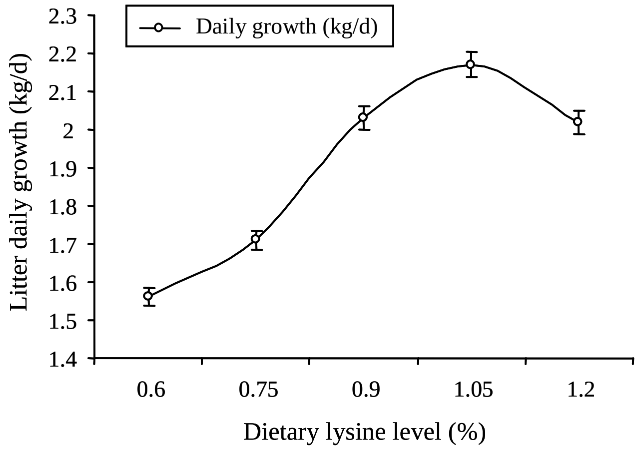

Figure 3. Effect of dietary levels on litter daily growth rate.

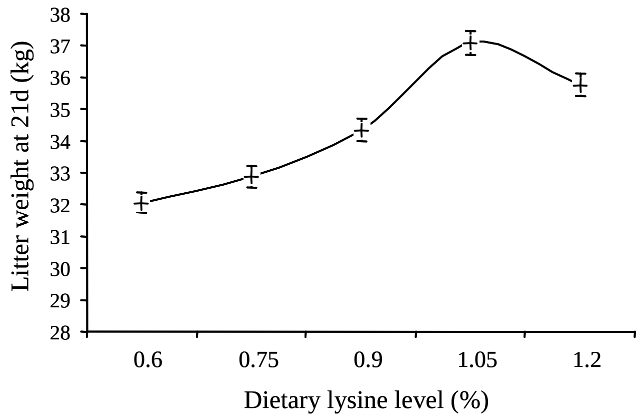

Figure 4. Effect of dietary lysine levels on piglets weight at 21 days of Mong Cai sows.

concentration of feeds (Verstegen et al., 1998). In the literatures, ADFI has not always been shown to be affected by increases in lysine from 0.62 to 1.05% (Johnston et al., 1993), from 0 .67 to 1.25% (Touchette et al., 1998), 0.80 to 1.06% (Cooper et al., 2001). Yang et al. (2000b) recorded that a linear decreases (p<0.01) in ADFI was observed in first, second and third lactations as dietary protein (lysine) increased (from 0.4 to 1.5%). Studies of Schneider et al. (2004), Lenehan et al. (2004) and Fu et al. (2003) recorded no changes in feed intake with increasing dietary lysine (0.9, 1.1 and 1.4%). Feed intake by sows fed a high-protein diet

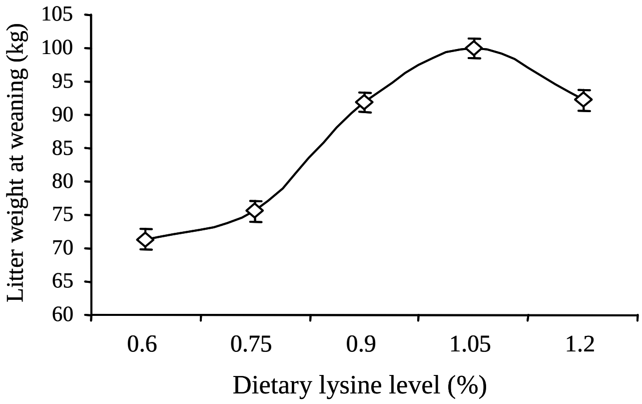

Figure 5. Effect of dietary lysine levels on piglets weight at weaning of Mong Cai sows.

during lactation may have been driven by high milk production, because these sows also produced more milk than sows fed the low-protein diet during lactation. In contrast, Shields et al. (1985) reported a positive quadratic relationship between dietary protein concentration (5, 14, and 23%) and lactational feed intake of first-litter sows. Several other workers (Mahan and Mangan, 1975; O'Grady et al., 1985) have observed this positive relationship between dietary protein concentration of lactation diets (12 to 20% CP) and sow feed intake during lactation only when the protein density of the gestation diets was low. José et al. (2006) recorded that increasing lysine from 0.75% to 1.2% resulted in higher feed intake at higher energy density in lactation diets (14.3 vs. 13.6 MJ/kg). In the present study, Mong Cai sows consumed a gestation diets containing 12% CP and 13.6 MJ/kg.

Our study demonstrated that increasing dietary lysine levels reduced the sow's weight loss and the weight loss was minimal at a lysine level of 1.05%. Stahly et al. (1990), Johnston et al. (1993) and Kusina et al. (1999) found that increasing CP reduced lactation weight loss. Jones and Stahly (1999), Yang et al. (2000c) recorded that losses of body weight during lactation were significantly affected by lysine supplied to the sow's diets.

Several studies show that when the daily intake of lysine can be increased, body weight losses can be decreased (Van den Brand et al., 2000; Sinclair et al., 2001).

Table 4. Best fit models describing the effect of dietary lysine content on growth performance and carcass characteristic variables for Mong Cai sows in Central Vietnam

Variables	X^3	X^2	X	Intercept	MSE	R^2	Optimum (%)
Sow weight loss (kg)		45.175	- 94.988	60.991	0.973	0.98	1.05
Sow BF* loss (mm)		4.1587	-9.399	9.8174	0.113	0.95	1.04
Litter weight (kg)							
at 21 day	-115.31	301.71	-246.32	96.218	1.110	0.97	1.04
at weaning	- 689.88	1760.4	- 1395.5	423.74	3.798	0.99	1.03
Litter growth rate (kg/d)	- 11.358	28.19.2	- 21.354	6.6737	0.077	0.98	0.99

* BF = Backfat thickness.

Eissen et al. (2003) found that an increase in intake of 1 kg per day reduced daily sows' weight loss of sows by 0.13 kg (13%) at a litter size of 10 piglets. Weight loss was reduced by 0.015 kg/d (1%) at a litter size of 14 piglets. Results in Table 3 indicated that without a supplementation of dietary lysine above a level of 0.60%, the sow weight loss of sows was highest in our study. At this low lysine level diet, Mong Cai sows have mobilized significant amounts of body protein to maintain milk production.

According to Mullan and Williams, (1989), Dourmad (1991) and Meija et al. (2002) nutrient intake, body reserve losses, and absolute amount of maternal reserves at farrowing interact to influence reproductive performance. Yang et al. (1989), Dourmad (1991) and Charette et al. (1995) observed that the weaning-to-estrus interval after first lactation was closely related to body protein or body weight at weaning, with heavy primiparous sows having weaning-to-estrus intervals similar to that of multiparous sows. The mechanism which affects this interval seems to be associated with high LH concentrations during lactation (Shaw and Foxcroft, 1985). King and Martin (1989) found a lowe mean LH concentration immediately prior to weaning and after weaning in sows on a low protein intake during lactation, as would have been the case with sows in the present experiment (Foxcroft et al., 1996). Tokacht et al. (1992) and Yang et al. (2000c) recorded that increases in lysine intake are associated with increases in LH. Pulsatile secretion of LH is an important factor in stimulating follicular development and resumption of estrus postweaning (Shaw and Foxcroft, 1985; King and Martin, 1989; Yang et al., 2000c). Furthermore, LH pulse frequency during mid- to late lactation was related to weaning-to-estrus interval (Tokach et al., 1992; Koketsu 1996a; Yang et al., 2000c). With relatively low numbers of sows in each treatment, subsequent litter size data are of limited importance. However, differences in subsequent litter size seemed to respond both directly to effects of dietary lysine level in sow's lactation diets.

The current study showed that dietary lysine level has an effect on sow's backfat loss. Stahly et al. (1990) recorded that backfat of sows at weaning were not affected by increases in lysine from 0.42 to 0.92%. This is similar to Johnston et al. (1993) who increased lysine from, 0.62 to 1.05%, Monegue et al., (1993) using a range of 0.60 to 0.90% and Weeden et al. (1994) varying lysine from 0.60 to 0.70%. José et al. (2006) recorded that increased dietary lysine from 0.75 to 1.20%, decreased backfat loss during lactation at two dietary energy levels (3,250 kcal/kg and 3,400 kcal/kg) and sows had the lowest backfat loss at 1.05% of lysine. When a sow does not receive adequate amounts of dietary amino acids, maternal tissue protein (particularly skeletal muscle proteins) is mobilized to support milk production (Kim et al., 2005). Excessive maternal protein mobilization often results in reproduction failure for the next parity (Jones and Stahly, 1999). Doumard et al. (1998) reported that a high producing sows requires at least 55 g of dietary lysine/d for minimum weight loss as well as maximal mammary gland growth (55 g) suggested by Kim et al. (1999).

The weight and backfat thickness changes observed in our sows during lactation are related to a reduced feed intake. When feed intake does not provide the nutritional demands for maintenance and milk production, there will be extra weight losses. The severity of weight and backfat thickness losses has been related to lactation period, litter size and weight gain, sow body composition at farrowing, parity order, and environmental conditions (Close and Cole, 2000). According to Close and Cole (2000), a high energy intake can minimize this variation in weight and backfat thickness. The results of the present study can not show the influence of feed energy density because we only used one density. In our study, the daily ME intake (77.2 MJ ME/d) observed in all diets were above the minimum level recommended by NRC (1998).

Dourmad (1991) reported that reduction in feed intake was most pronounced during the first week of lactation and they estimated a relationship between backfat depth at farrowing and lactation feed intake. They found that every 1Ib (455 g) extra feed intake prevented 95 g of weight loss per day per millimeter of backfat loss during the first week of lactation and -63 g/d per millimeter of backfat losses during the entire lactation period.

Our result showed that the difference between sow backfat loss on day 21 and at weaning was not significant among lysine levels from 0.60 to 1.05%. High intake of lysine and ME had a positive effect ($p<0.05$) on the weaning weight and backfat thickness, as well as on the weight and backfat thickness changes during lactation. In this study, the greater ME density led to an increase ($p<0.05$) in the daily feed intake from 5.63 kg (13.68 MJ ME/kg) to 5.87 kg (14.14 MJ ME/kg); this corresponded to 77.3 MJ ME/d and 83.0 MJ ME/d, respectively. Piglet weaning weight (ranging between 7.6 and 9.5 kg/pig) was influenced ($p<0.05$) by lysine and/or ME levels.

Our data showed that increasing lysine level during lactation increased piglets weight at day 21 and at weaning. Yang et al. (2000b) found that the dietary lysine intake were 44, 55 and 56g/d in parities 1, 2 and 3 for maximal litter growth rate (2.06, 2.36 and 2.49 kg/d for parities 1, 2, and 3 respectively). Parity influences the lysine (protein) requirement of lactating sows and the response of subsequent litter size to previous lactation lysine (protein) intake (Yang et al., 2000b).

Result given by Zhang et al. (2001), namely the litter weight increases in piglets at an age of 20 and 35 days with increasing protein and lysine intake. Bojcuková and Kratký

(2006) reported that litter weight at the age of 21days was highest in the sow group fed the highest dietary content of lysine. In contrast, Peters and Mahan (2001) concluded that feeding lysine levels above NRC (1998) recommendation did not affect litter performance.

Optimal analysis

Mullan and William (1989) found a linear relationship between backfat depth and fat content of primiparous sows. Johnston (1993) and Toutchette et al. (1998) recorded that back fat change was not affected by lysine level in the diet. According to Yang et al. (2000b) increasing dietary lysine (protein) concentration tended to increase backfat loss linearly in parity 1 ($p<0.01$) but had no effect on sow backfat change in parities 2 and 3 ($p>0.1$).

A metabolic model of lactating sow was used by Pettigrew et al. (1992) and modified by Pettigrew et al. (1993). Lewis et al. (1981) found a quadratic response with regard to ADFI and gain when nursery pigs were fed 6 concentrations of lysine from 0.95 to 1.45%, with a plateau at 1.25% lysine. Martinez and Knabe (1990) also observed a quadratic ADFI response to lysine supplementation in the diets. Our data showed that ADFI response of Mong Cai sows to dietary lysine level and they had an maximum ADFI at 1.0% (Figure 1).

Our data indicates that increasing dietary lysine level from 0.60 to 1.20% affected the interval between weaning and estrus ($p<0.001$). Johnston et al. (1993), Jones and Stahly (1999) reported that increasing protein/lysine levels for lactation sows had an effect on the interval between weaning and estrus. Yang et al. (2000b) Mejia et al. (2002) and José et al. (2006) reported that post weaning interval to estrus was not influenced by dietary protein/lysine treatment for sows. Our study revealed that sows fed lysine level of 0.60% had a longer weaning-to- estrus interval compared to sows with a higher dietary lysine level. The weaning-to-estrus interval is directly related to lactation period (lactation length, nutritional and feeding strategies, parity, litter number, weight and backfat thickness change), facilities, genetics and season (Koketsu et al., 1996; Zak et al., 1997; Boyd et al., 2002), as well as estrus detection and reproductive management.

Our result showed that sows body weight loss was minimum at 1.05% lysine in lactation diets. Touchette et al. (1996) demonstrated the lysine requirement for minimizing weight loss (54 g/d) or loin muscle loss (58 g/d) were considerably higher than the amount needed to maximize litter weaning weights.

More importantly from an economic perspective, increasing lysine concentration of the lactation diet increased size of the subsequent litter (Campbell, 1995). The present study shows that increasing dietary lysine level affected the number of piglets at 21 days of lactation and at weaning. Previous studies of Stahly (1990), Johnston (1993) and Monnegue (1993) recorded that increasing dietary lysine level resulted in an increase in the number of weaned piglets. Triton et al. (1996) reported that sows fed 60 to 80 g/d of total lysine during the first lactation had 10.6 and 11.1 total pigs born. In contrast, Touchette et al. (1998) recorded that a decrease of body protein by increasing lysine intake from 32 to 59 g/d during the first lactation and an associated decrease in subsequent litter size. Yang et al. (2000a) concluded that subsequent litter size of different parities had a different response to high lysine (protein) concentrations during the previous lactation. Cheng et al. (2001) reported that a corn-soybean meal diet containing 13% crude protein and 0.6% lysine did not significantly affect litter size and survival rate of weaning piglets compared with the 15% crude protein and 0.75% lysine diet.

Our data indicated that a lysine level of 1.05% in the lactation diets leads to maximal litter weight at 21 days of lactation and at weaning. Our data are in agreement with the results of Zhang et al. (2001) that litter weight increases in piglets at the age of 20 and 35 days with increasing protein and lysine intake. Stahly (1990) and Jones and Stahly (1999) recorted a positive effect of lysine/protein intake during lactation on litter weight gain. Yang et al. (2000) rerecorded that litter weight gain responded quadratically ($p<0.05$) to increasing daily lysine intake during lactation in all three parities. In contrast, Johnston (1993), Touchette et al. (1998) and José et al. (2006) stated that there was no improvement in litter performance with greater lysine intake.

In agreement with Cooper et al. (2001), our study shows that there was no significant protein (lysine level) effect during pregnancy on piglet birth weight. In addition, sows fed dietary lysine from 0.60 to 1.05% had better potential milk production, which is in accordance with Knabe (1996) who recorded that increasing dietary lysine resulted in increases in piglet weight at the 21^{st} day. José et al. (2006), recorded that lysine levels of 0.75%, 0.90%, 1.05% and 1.20% seemed to meet the requirements of lactating sows for subsequent litter size. The present results show that at the highest lysine level (1.20%), sows did not have the largest litter size and weight. There may be a limit the effect of lysine content because at the highest dietary lysine content (1.20%), our Mong Cai sows lost more weight and piglets did not perform the best. Besides, the amino acids absorption process in the small intestine may become relatively less effective when high amounts of synthetic amino acids are added to the diet (José et al., 2006).

IMPLICATION

The experiment showed that increasing dietary lysine level has a positive effect on the performance of Mong Cai sows and their piglets. Increasing dietary lysine level from 0.75 to 1.20% resulted in a decrease in sow weight loss compared to sows fed without supplying lysine. The result indicated that increasing dietary lysine levels led to an increase in the average piglet's weight at 21 days (from 0.20 to 0.52 kg/piglet) and average weaning weight (from 0.30 to 1.95 kg/piglet) compared to piglets born from sows fed without supplemental lysine in their diet. From these result, the optimum lysine level for the best performance of Mong Cai sows and their piglets is 1.05% of Lysine in the sow's diet. Together with supplying lysine in the sow diets, it is suggested to study the effect of supplementing lysine combined with other limiting amino acids on performance of Mong Cai sows and piglets.

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