Asian-Aust. J. Anim. Sci.
Vol. 24, No. 8 : 1142 - 1147
August 2011

www.ajas.info
doi: 10.5713/ajas.2011.10449

Effects of Lysine Intake during Middle to Late Gestation (Day 30 to 110) on Reproductive Performance, Colostrum Composition, Blood Metabolites and Hormones of Multiparous Sows

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ABSTRACT : Lysine intake during gestation has a major impact on subsequent reproductive performance. The objective of this experiment was to determine the effect of lysine intake from mid-gestation until farrowing on the reproductive performance of multiparous sows. On day 30 of gestation, 200 Landrace×Large White sows were randomly assigned to one of four groups based on body weight and parity (n = 50). The gestation diets contained 0.46, 0.56, 0.65 or 0.74% lysine. Increasing dietary lysine concentration improved sow body condition at farrowing and increased litter weights ($p<0.05$). Dietary lysine level also had a significant effect on the dry matter ($p<0.05$) and protein content ($p<0.05$) of colostrum. Increased lysine intake increased serum insulin concentration ($p<0.05$) and there was a trend towards increased serum prolactin content (linear, $p = 0.07$). However, increased lysine tended to decrease blood urea N (quadratic, $p = 0.05$). These results suggest that higher lysine levels (0.65-0.75%) than those recommended by the National Research Council improved reproductive performance for multiparous gestating sows and this increase may be partially mediated through blood metabolites or metabolic hormone levels. (**Key Words :** Lysine, Gestation, Sows, Reproductive Performance)

INTRODUCTION

The nutrient supply for mature sows during gestation must satisfy their requirements for maintenance as well as for the development and growth of fetal tissue (NRC, 1998). Maternal nutrition plays a critical role in fetal growth and development as well as postnatal performance and health (Wu et al., 2004; Cerisuelo et al., 2009). In late gestation, fetal growth is at a very rapid rate (Trottier and Johnston, 2001) and mammary development also occurs in preparation for the upcoming lactation. Adequate maternal gain during gestation prevents excessive body weight loss after lactation and delayed returns to estrus (Trottier and Johnston, 2001). However, excessive maternal fat gain during gestation should be avoided because it decreases voluntary feed intake during lactation (Revell et al., 1998). Thus, the objective when feeding gestating sows is to obtain optimal fetal growth while maintaining appropriate maternal protein and fat gain (Ji et al., 2005).

Modern sows have larger body sizes and improved fertility due to improvements in genetics, nutrition, and environmental systems which have occurred during the past few decades (Yang et al., 2008). This has led to a growing emphasis on defining nutrient requirements for sows, especially dietary lysine. Several studies have demonstrated that dietary lysine levels during gestation influenced the subsequent reproductive performance of multiparous sows (Heo et al., 2008; Yang et al., 2009). Increasing the lysine intake of primiparous sows increased sow body gain and reduced fetal weight variation (Kim et al., 2009). Dietary lysine levels in excess of NRC (1998) recommendations maximized litter gain and reduced the weaning-to-estrus interval in multiparous sows (Yang et al., 2008). Therefore, a re-examination of the lysine requirements of gestating sows seems warranted. The objective of this study was to determine the effects of different dietary lysine concentrations during gestation on body condition, litter performance, blood metabolites and hormones in multiparous sows.

MATERIALS AND METHODS

All procedures used in the present experiment were

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Received December 11, 2010; Accepted March 4, 2011

approved by the Animal Care and Use Committee of China Agriculture University (Beijing, China).

Sows and treatments

A total of 200 multiparous, Landrace×Large White sows were housed in individual stalls (2.2 m×0.8 m) in an enclosed building. On day 30 of gestation, the sows were weighed and randomly assigned within parity to one of four treatments comprising different levels of lysine. Each treatment had fifty replicates. The gestation diets contained dietary lysine levels of 0.46, 0.56, 0.65 and 0.74%. All other essential amino acids were provided according to the ideal ratio of lysine as recommended by NRC (1998) to ensure that lysine was the first limiting amino acid in all diets.

Sows were individually fed 2.2 kg per day from day 30 to 80 of gestation and 3.0 kg per day from day 80 of gestation until farrowing. Sow body weight and back fat thickness were measured on day 30 and 110 of gestation. Back fat thickness (P2, 6 cm from the mid line at the head of the last rib) was measured with an ultrasonic device (Piglog105, SFK Technology A/S, Herlev, Denmark). On day 110 of gestation, the sows were moved to an environmentally controlled farrowing room and housed in individual farrowing stalls (2.2 m×1.5 m) until weaning. Piglets were counted and weighed at birth.

Blood sample collection and processing

Blood was collected on day 30 and 110 of gestation from the jugular vein using a 10 ml plain, blood collection tube (Greiner Bio-One GmbH, Kremsmunster, Australia). Blood samples were collected at 20 min intervals for 2 h. Blood samples were collected in ice-cold tubes and centrifuged at 3,000×rpm using TDL-5-A Shanghai Anting Scientific Instrument centrifuge, (Shanghai, China) at 4°C for 20 min and serum was harvested. The serum from the seven collections was pooled in an attempt to minimize diurnal fluctuations. Serum samples were stored at -20°C until assayed.

Multi-type reagents (Shanghai Kehua Biotechnology Incorporated, Shanghai, China) were available and used to determine glucose and serum urea nitrogen by an Automatic Biochemical Analyzer (Technicon RA-1000, Technicon Instrument Corporation, New York, NY). Serum insulin and prolactin were quantified in all samples by Radioimmunoassay using commercial kits supplied by the North of Beijing Biotechnology Research Institute (Beijing, China). Concentrations were determined in duplicate according to the manufacturer’s instructions. Intra- and inter-assay CV were less than 10 and 15% for both insulin and prolactin, respectively. The minimum detectable concentrations of insulin and prolactin were 2 μIU/ml and 1.88 ng/ml, respectively.

Milk sample collection and processing

Approximately 20 ml of colostrum was manually collected from 12 sows per treatment two days post partum to evaluate its composition. Samples were collected by infusing 10 IU oxytocin via the jugular catheter and then the

Table 1. Ingredient and chemical composition of gestation diets

	Dietary lysine supply level (%)			
	0.46	0.56	0.65	0.74
Ingredients (%)				
Corn	66.00	65.88	65.76	65.64
Wheat bran	16.50	16.50	16.50	16.50
Soybean meal	6.50	6.50	6.50	6.50
Corn gluten meal	5.50	5.50	5.50	5.50
Soybean oil	1.50	1.50	1.50	1.50
L-lysine HCl (98%)	0.00	0.12	0.24	0.36
Vitamin-mineral premix[1]	4.00	4.00	4.00	4.00
Analyzed composition				
Crude protein (%)	12.89	12.95	13.04	12.97
Lysine (%)	0.46	0.56	0.65	0.74
Threonine (%)	0.44	0.44	0.45	0.46
Methionine+cystine (%)	0.45	0.46	0.45	0.44
Calculated composition				
ME (kcal/kg)	3,026	3,022	3,018	3,014
Calcium	0.81	0.81	0.81	0.81
Available phosphorus	0.31	0.31	0.31	0.31

[1] Supplied per kg diet: 10,000 IU vitamin A, 2,000 IU vitamin D_3, 24 IU vitamin E, 2 mg vitamin K, 2 mg vitamin B_1, 6 mg vitamin B_2, 4 mg vitamin B_6, 0.024 mg vitamin B_{12}, 20 mg pantothenic acid, 30 mg niacin, 0.4 mg biotin, 3.6 mg folic acid, 120 mg zinc, 96 mg iron, 40 mg manganese, 8 mg copper, 0.56 mg iodine, 0.24 mg selenium.

Table 2. Effects of lysine level in gestation on sow body condition

	Dietary lysine level (%)				SEM	p-values		
	0.46	0.56	0.65	0.74		Treatment	Linear	Quadratic
Sow body weight								
Day 30 of gestation (kg)	227.1	227.7	224.8	220.3	2.9	0.80	0.36	0.61
Day 110 of gestation (kg)	263.6	272.1	271.0	268.2	4.4	0.87	0.87	0.71
Total body weight gain (kg)	36.5[a]	44.4[b]	46.2[b]	47.9[b]	1.2	0.04	<0.01	0.02
Sow back fat								
Day 30 of gestation (mm)	20.9	20.3	21.1	20.7	0.3	0.68	0.98	0.98
Day 110 of gestation (mm)	22.3	21.8	22.9	22.7	0.4	0.68	0.34	0.64
Total back fat gain (mm)	1.36[a]	1.53[ab]	1.79[b]	2.01[b]	0.1	<0.01	<0.01	<0.01

[a, b] Means within a row followed by same or no superscript do not differ (p>0.05).

third and fourth anterior mammary glands on one side of the sow were manually milked. Colostrum samples were immediately frozen at -20°C and analyzed using an Infrared Milk Analyzer (Milko Scan 133B Analyser, Foss Electric, Hillerød, Denmark).

Feed samples and analyses

Samples of gestation diets were taken from every batch of feed mixed and the samples were pooled and sub-samples were analyzed for crude protein and amino acid composition. The concentration of crude protein was carried out by the procedures of AOAC (1996). Amino acid content of the diets were assayed using ion-exchange chromatography with an automatic amino acid analyser (L-8800 Hitachi Automatic Amino Acid Analyzer, Tokyo, Japan) after hydrolyzing with 6 mol/L HCl at 110°C for 24 h. Cystine was determined as cysteic acid and methionine as methionine sulfone after preoxidation with performic acid and precolumn derivation using phenylisothiocyanate (L-8800 Hitachi Automatic Amino Acid Analyzer, Tokyo, Japan). Tryptophan was determined after hydrolyzing with 4 mol/L NaOH at 110°C for 22 h using phenylisothiocyanate (Model 76337, Agilent Technologics, Waldbronn, Germany).

Statistical analyses

Statistical analysis was conducted using the General Linear Model (GLM) procedures of SAS (version 9.0) and SAS Program Software. Data were expressed as least squares means. Probability values less than 0.05 were considered statistically significant. The means were separated using Duncan's Multiple Range test. Preplanned single degree of freedom comparisons were made to measure the linear and quadratic effects of increasing lysine concentration.

RESULTS

Sow body condition

Gestation body weight was increased by lysine level (linear, p<0.01; quadratic, p = 0.02; Table 2) with sows fed 0.56, 0.65 and 0.74% lysine gaining 21.6, 26.6, and 31.2% more body weight than sows fed 0.46% lysine respectively (p<0.05). Increasing dietary lysine level also increased back fat thickness (p<0.01) with sows fed 0.65 or 0.74% lysine diets gaining 31.6 and 47.8% more backfat than sows fed 0.46% lysine.

Litter characteristics

Higher lysine intake did not affect the total number of pigs born or pigs born alive per litter (Table 3; p>0.05), but increased total litter weights (p<0.01) and average piglet birth weights (p<0.01) when compared with sows fed low lysine diets.

Colostrum composition

The dry matter and protein content of colostrum were increased by dietary lysine level (Table 4). Increasing the dietary lysine level linearly increased dry matter (p<0.05) and protein content (p = 0.01) in colostrum. However, the fat and lactose content were not affected by the lysine level

Table 3. Effects of dietary lysine on piglet numbers and birth weights

	Dietary lysine level (%)				SEM	p-values		
	0.46	0.56	0.65	0.74		Treatment	Linear	Quadratic
Total pigs born	11.13	10.94	10.69	11.00	0.22	0.92	0.76	0.82
Total pigs born alive	9.56	9.50	9.63	9.88	0.22	0.94	0.58	0.81
Total litter weight at birth (kg)	11.98[a]	12.75[ab]	13.93[bc]	14.32[c]	0.26	<0.01	<0.01	<0.01
Average piglet weight at birth (kg)	1.28[a]	1.35[a]	1.46[b]	1.47[b]	0.02	<0.01	<0.01	<0.01

[a-c] Means within a row followed by same or no superscript do not differ (p>0.05).

Table 4. Effects of dietary lysine on colostrum composition in multiparous sows

	Dietary lysine level (%)				SEM	p-values		
	0.46	0.56	0.65	0.74		Treatment	Linear	Quadratic
Dry matter (%)	20.27[a]	21.17[ab]	22.38[b]	22.02[b]	0.30	<0.01	<0.01	<0.01
Protein (%)	11.32[a]	11.61[ab]	11.92[b]	11.82[b]	0.15	0.04	0.01	0.02
Fat (%)	4.17	4.16	4.24	4.25	0.04	0.82	0.38	0.68
Lactose (%)	3.63	3.58	3.71	3.80	0.05	0.35	0.12	0.23

[a, b] Means within a row followed by same or no superscript do not differ (p>0.05).

of diets (p>0.05).

Metabolites and metabolic hormones

Dietary lysine level lowered the concentration of serum urea nitrogen (p<0.05; Table 5). Glucose content of blood was not affected by dietary lysine level. Increasing lysine intake increased serum concentrations of insulin (linear, p = 0.01; quadratic, p = 0.03), and had a tendency to increase the serum content of prolactin (linear, p = 0.07; quadratic, p = 0.08).

DISCUSSION

The objective of the present study was to determine the optimum dietary lysine concentration for gestating sows. Lysine is considered as the first limiting amino acid in typical corn-soybean meal gestating diets and daily lysine intake is a primary factor determining sow performance (Johnston et al., 1993).

This experiment showed that increasing dietary lysine level from 0.45% to 0.65 or 0.75% during gestation resulted in increases in sow body weight gain and back fat thickness. These results are consistent with Yang et al. (2009) who reported that feeding 0.8% dietary lysine to multiparous sows resulted in a higher body weight gain during gestation than feeding 0.6% dietary lysine. Similar results were also reported by Kusina et al. (1999a) who found that primiparous sows consuming 16 g of lysine per day had higher body weight gains during gestation compared with sows fed 8 g of lysine per day. In contrast, Cooper et al. (2001) supplied two levels of lysine (0.44% vs. 0.55%) in gestating sows, and found no differences of sow body weight gain and backfat.

When feeding sows in the mid-gestation, the main objectives are to provide sufficient nutrients to allow for growth of the developing fetus, to allow young sows to reach their mature body size or to replenish body stores lost during the previous lactation. The growth of the fetuses and mammary glands is very rapid at this stage in order to prepare for the upcoming farrowing and lactation phases (Trottier and Johnston, 2001).

Lysine level did not affect the number of pigs born. The experiment started at d 30 of gestation after embryos are implanted (den Hartog and van Kempen, 1980). This may partly explain the results of the present study that higher lysine intake did not influence the number of pigs born.

Litters from sows fed 0.65-0.74% lysine had higher litter birth weights compared with litters from sows fed 0.46% lysine. This finding is in agreement with the finding of Mahan et al. (1998), who evaluated two levels of lysine (0.55% vs. 0.75%). Similarly, Yang et al. (2009) supplied two levels of lysine (0.6% vs. 0.8%) in gestating sows and found that sows fed higher lysine had improved litter performance.

Sows supplemented with 0.65 or 0.74% lysine had higher dry matter and protein content in colostrum

Table 5. Effects of dietary lysine on blood metabolites and hormones in multiparous sows

	Dietary lysine level (%)				SEM	p-values		
	0.46	0.56	0.65	0.74		Treatment	Linear	Quadratic
Day 30 of gestation								
Glucose (mg/dl)	58.62	57.08	56.63	57.92	0.92	0.88	0.77	0.72
Urea N (mg/dl)	7.31	7.17	7.26	7.45	0.25	0.99	0.81	0.92
Insulin (μIU/ml)	12.74	11.87	12.35	12.28	0.32	0.83	0.76	0.79
Prolactin (ng/ml)	3.54	3.47	3.89	3.26	0.08	0.87	0.56	0.37
Day 110 of gestation								
Glucose (mg/dl)	74.60	75.68	78.08	76.85	1.12	0.74	0.37	0.59
Urea N (mg/dl)	9.41[a]	8.71[b]	7.94[c]	8.29[bc]	0.23	<0.01	<0.01	<0.01
Insulin (μIU/ml)	14.13[a]	14.87[ab]	15.53[b]	15.71[b]	0.31	<0.01	0.01	0.03
Prolactin (ng/ml)	12.73[a]	14.06[b]	14.43[b]	14.17[b]	0.38	0.01	0.07	0.08

[a-c] Means within a row followed by same or no superscript do not differ (p>0.05).

compared with sows fed 0.46% lysine, but lysine level did not alter the concentration of fat and lactose in colostrum. Gestation diets for sows are very important in determining colostrum production and litter weight gain especially in early lactation, (Kusina et al., 1999). Head et al. (1991) showed that high energy and low protein diets for gestating sows seemed to impair mammary development and subsequent milk production. Colostrum secretion occurs during the key transition period from the anabolic metabolism of gestation to the catabolic metabolism of lactation (Bauman and Currie, 1980). Gestation diets could affect colostrum production both via mammary gland development and via mechanisms controlling colostrum secretion in late gestation (Farmer and Quesnel, 2009). King et al. (1996) saw no changes in the chemical composition of colostrum from sows that were fed a protein-restricted diet (8 vs. 18% CP) throughout pregnancy. Feeding 2.5 kg of a diet containing either 23.6 or 18.6 CP in late-gestation also did not alter protein or total solids in colostrum (Almatubsi et al., 1998). However, increasing dietary lysine intake (0.8% instead of 0.6%) in late gestation increased total solids and protein content of colostrum in sows (Heo et al., 2008; Yang et al., 2008). King et al. (2000) found that dietary lysine level significantly influenced lactating sow milk production and gain of piglets.

Serum urea nitrogen concentration can be used as an indicator of protein intake in lactating sows (King et al., 1993). The results of the present experiment showed that increasing dietary lysine level from 0.45% to 0.65% decreased serum urea concentration, while further increasing dietary lysine level from 0.65% to 0.75% increased serum urea level. Since lysine is the first limited amino acid in a typical corn-soybean meal based diet for sows, 0.65% dietary lysine level may be optimum amino acid balance. The reason for the lowest serum urea concentration happens in the 0.65% lysine group is that the dietary lysine meets the requirement of amino acids balance and most of the amino acids in the feeds are used to synthesize muscle proteins and other functionally important proteins, compared to 0.46% and 0.56% group. When the dietary lysine increased from 0.65% to 0.75%, lysine may become too much considering the amino acids balance and get into the circulation, therefore, increase the serum urea level. This observation was consistent with the finding of Kim et al. (2009) who reported that higher dietary lysine intake decreased serum urea concentration for gestation sows. Enhanced protein synthesis and reduced amino acid oxidation result in a low circulating concentration of urea (Wu and Morris, 1998). In contrast, Yang et al. (2008), found that an increased lysine intake (0.6% vs. 0.8%) increased serum urea nitrogen concentration in gestating and lactating sows.

Insulin is known to promote tissue growth by stimulating the uptake of amino acids and glucose by tissues as well as enhancing lipogenesis and glycogenesis (Newsholme, 1977). Positive effects of insulin for fetal growth have been reported for most mammalian species studied (Vanassche and Aerts, 1979). During late pregnancy, insulin plays a major role in partitioning nutrient flow to reduce nutrient uptake by the peripheral tissues of the dam in order to ensure an adequate nutrient supply to the fetus (Bauman and Currie, 1980). Lactogenesis is accomplished by the preparturient withdrawal of progesterone and an increase in prolactin (de Passillé et al., 1993). Insulin may play a role in partitioning nutrients toward mammary tissue (Bauman and Currie, 1980). The results of the present experiment suggest that the improved yields of colostrum components due to higher lysine intake may be partly explained by the increased insulin levels. The conclusion agrees with the work of Kusina et al. (1999), Yang et al. (2000) and Yang et al. (2008).

The present experiment showed that increased lysine intake had a tendency to increase serum prolactin concentrations. With regard to prolactin, a pre-partum peak is essential for the initiation of lactation in sows (Farmer and Rushen, 1998). However, Foisnet et al. (2010), found no relationship between variations in circulating prolactin concentrations in sows around parturition and piglet growth rate.

IMPLICATIONS

The results of our study support the idea that the dietary lysine levels recommended by NRC (1998) for multiparous gestating sows (0.52-0.54%) do not maximize body condition of the sows, piglet birth weight or colostrum quality. Based on our results, the optimum dietary level of lysine for multiparous gestating sows to maximize these parameters is 0.65% lysine. Although further increases in body condition of sows, piglet birth weight or colostrum quality were obtained by feeding 0.75% lysine, these differences were not significant and feeding such levels would lower economic efficiency. Our results did not show any effect of lysine level in gestation on litter size. Therefore, when implementing feeding strategies for improving sow reproductive performance, the appropriate lysine intake for pregnant sows must be considered and depending on producer objectives, feeding higher lysine levels than those currently recommended by NRC (1998) may be considered.

ACKNOWLEDGMENTS

The authors sincerely acknowledge the Novus Company and the Special Fund for Agro-scientific Research in the

Public Interest, China.

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