Postprint: Optimal Requirement of Standardized Ileal Digestible Lysine for Rongchang Lactating Sows

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Abstract

This experiment aimed to determine the appropriate requirement of standardized ileal digestible lysine (SID Lys) for lactating Rongchang sows by investigating the effects of different dietary lysine levels during lactation on reproductive performance, blood indices, and milk composition. Fifty Rongchang sows of parity 2–3 with similar genetic background were selected and randomly divided into 5 groups at day 110 of gestation according to body condition (10 replicates per group, 1 sow per replicate), and fed diets containing SID Lys levels of 0.60% (group 1), 0.70% (group 2), 0.80% (group 3), 0.90% (group 4), and 1.00% (group 5) during a 28-day lactation period. The results showed that: 1) Increasing dietary SID Lys level tended to reduce sow body weight loss (P=0.0689); high level (1.00%) of SID Lys significantly reduced the average daily feed intake of piglets aged 1–14 days compared with 0.60%–0.80% SID Lys (P<0.05), but dietary SID Lys level had no significant effect on piglet growth during the entire lactation period (P>0.05). 2) Serum urea nitrogen content of sows on day 14 of lactation decreased to varying degrees with increasing dietary SID Lys level, with groups 3–5 being significantly lower than group 1 (P<0.05). Dietary SID Lys level had no significant effects on serum insulin, insulin-like growth factor-I, luteinizing hormone, and follicle-stimulating hormone levels of sows on day 28 of lactation (P>0.05), but significantly affected serum estradiol level (P<0.05), with group 4 being significantly higher than groups 1, 2, and 5 (P<0.05). Dietary SID Lys level had no significant effect on colostrum composition indices (P>0.05), but solids-not-fat, milk protein content, and milk density in mature milk increased to varying degrees with increasing dietary SID Lys level, with groups 4 and 5 being significantly higher than group 1 (P<0.05). Through quadratic curve fitting of sow body weight change, serum urea nitrogen, and estradiol content during lactation, the appropriate dietary SID Lys level for lactating Rongchang sows was determined to be 0.83%–0.89%.

Full Text

Study on Optimal Requirement of Standard Ileal Digestible Lysine for Rongchang Lactating Sows

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Abstract

This experiment was conducted to investigate the effects of dietary lysine levels on the performance, blood indices, and milk composition of Rongchang sows during lactation, in order to estimate the standard ileal digestible lysine (SID Lys) requirement for Rongchang lactating sows. A total of 50 Rongchang sows (2 to 3 parities with proximity of descent) were randomly divided into 5 groups according to body condition on day 110 of gestation, with 10 replicates per group and 1 sow per replicate. Sows in the five groups were fed diets containing SID Lys levels of 0.60% (group 1), 0.70% (group 2), 0.80% (group 3), 0.90% (group 4), and 1.00% (group 5), respectively, during a 28-day lactation period. The results showed that: 1) Increasing dietary SID Lys levels tended to decrease sow weight loss during lactation (P=0.0689). The high level (1.00%) of SID Lys significantly reduced the average daily feed intake of piglets during days 1-14 compared with 0.60%-0.80% SID Lys (P<0.05), but dietary SID Lys levels had no significant effect on piglet growth throughout the entire lactation period (P>0.05). 2) Serum urea nitrogen content in sows on day 14 of lactation decreased to varying degrees with increasing dietary SID Lys levels, with groups 3-5 being significantly lower than group 1 (P<0.05). Dietary SID Lys levels had no significant effects on serum insulin, insulin-like growth factor-I, luteinizing hormone, or follicle-stimulating hormone levels in sows on day 28 of lactation (P>0.05), but significantly affected serum estradiol level (P<0.05), with group 4 being significantly higher than groups 1, 2, and 5 (P<0.05). Dietary SID Lys levels had no significant effects on colostrum composition indices (P>0.05), but the contents of solid non-fat and milk protein and milk density in mature milk increased to varying degrees with increasing dietary SID Lys levels, with groups 4 and 5 being significantly higher than group 1 (P<0.05). Through quadratic curve simulation of sow body weight change, serum urea nitrogen, and estradiol content, the optimal dietary SID Lys level for Rongchang lactating sows was determined to be 0.83%-0.89%.

Keywords: lysine; performance; blood indices; milk composition; Rongchang lactating sow

Introduction

Adequate mammary gland development and sufficient milk production in lactating sows are prerequisites for ensuring rapid growth of suckling piglets. As the first limiting amino acid in corn-soybean meal diets, meeting the lysine requirement of lactating sows is crucial for the performance of both sows and piglets. Previous studies have found that appropriately increasing dietary lysine levels for lactating sows can reduce sow weight loss, alter blood hormone levels, and shorten the weaning-to-estrus interval [1-2], while also improving piglet performance by affecting milk yield and composition [3-5]. The NRC (2012) [6] recommends SID Lys requirements for lactating sows based on parity, sow weight loss during lactation, and piglet daily gain: for primiparous sows with feed intake of 5.65–5.67 kg/d, dietary SID Lys level should be 0.75%–0.87%, corresponding to 42.5–49.2 g/d SID Lys requirement; for multiparous sows with feed intake of 6.30 kg/d, dietary SID Lys level should be 0.72%–0.84%, corresponding to 45.3–52.9 g/d SID Lys requirement. Additionally, differences in body size and litter size among different sow breeds also affect lysine requirements during lactation [7].

Currently, research on lysine nutritional requirements for lactating sows has focused primarily on exotic breeds such as Landrace × Large White, with studies on Chinese local breeds being quite scarce. This experiment will therefore investigate the effects of different dietary SID Lys levels during lactation on the performance, blood indices, and milk composition of Rongchang sows—a fine local breed in China—to evaluate the optimal SID Lys requirement for Rongchang lactating sows and provide an experimental basis for scientific feeding of Rongchang sows and revision of feeding standards.

1.1 Experimental Animals and Treatments

A total of 50 Rongchang sows (2–3 parities with proximity of descent and relatively concentrated estrus timing) were selected. After estrus detection, they were artificially inseminated with Landrace boar semen. After mating, all sows were fed the same diet: 1.5 kg/d per head during early gestation ($ $90 d) and 2.0 kg/d per head during late gestation (91–110 d). On day 110 of gestation, the experimental sows were randomly divided into 5 groups according to body condition and fed five lactation diets with different SID Lys levels: 0.60% (group 1), 0.70% (group 2), 0.80% (group 3), 0.90% (group 4), and 1.00% (group 5). Each group had 10 replicates with 1 sow per replicate. Feed was gradually reduced 5 days before farrowing. During the 28-day lactation period, sows were allowed ad libitum access to feed and water. Pig houses were kept clean and disinfected once weekly. Experimental sows were mated during May–June 2015 and farrowed during October–November 2015. Gestation and lactation housing was in the same facility. After farrowing, piglet heating boxes were warmed with infrared lamps, and the average room temperature was maintained at 20–

22°C. Piglets were managed according to routine procedures including umbilical cord clipping, teeth clipping, and ear notching. Piglets consumed sufficient colostrum within 2 h after birth, received 1.5 mL iron dextran injection on day 3, and were provided creep feed on day 7.

1.2 Experimental Diets

The basal lactation diet was formulated according to the Rongchang Pig Feeding Standard (GB/T 7223-2008) and Chinese Feeding Standard of Swine (NY/T 65-2004), with a metabolizable energy (ME) content of 13.50 MJ/kg and crude protein level of 15.51%. The ideal amino acid pattern referenced NRC (2012) [6]. The gestation diets had ME contents of 11.75 and 12.50 MJ/kg for early and late gestation, respectively, with SID Lys levels of 0.55% and 0.70%. The composition and nutrient levels of experimental diets are shown in Table 1 .

1.3.1 Sow Performance

Sow body weight was measured within 24 h after farrowing and within 24 h after lactation ended to calculate body weight change during lactation. Feed intake during lactation, number of live-born piglets, number of stillborn piglets, cross-fostering status, and number of weaned piglets were recorded to calculate piglet mortality during lactation. Piglet birth weight and weights at days 14 and 28 were measured to calculate average daily gain (ADG). Post-weaning estrus status was observed, and the weaning-to-estrus interval was recorded.

1.3.2 Serum Biochemical Indices and Hormones

On days 14 and 28 of lactation, 10 mL of fasting blood was collected from the anterior vena cava of each sow and divided into two 5-mL vacuum coagulation-promoting tubes. After centrifugation at 3,000 r/min for 20 min, serum was collected and stored at -20°C for analysis of serum biochemical indices and hormone levels. Serum total protein, albumin, urea nitrogen, glucose, cholesterol, and immunoglobulin G (IgG) contents were determined using an automatic biochemical analyzer (Hitachi 7020) with reagent kits purchased from Sichuan Maccura Biotechnology Co., Ltd. Serum insulin, insulin-like growth factor-I, estradiol, luteinizing hormone, and follicle-stimulating hormone levels were determined by radioimmunoassay (r-911 automatic radioimmunoassay counter) with hormone kits purchased from Beijing Huaying Biotechnology Research Institute.

1.3.3 Colostrum Amino Acid Content

On the day of farrowing (colostrum) and day 28 of lactation (mature milk), 5 sows were randomly selected from each group. Milk samples were collected from anterior, middle, and posterior teats and mixed, with approximately 10 mL per sow, then stored at -20°C for analysis. Amino acid content in colostrum was determined using an automatic amino acid analyzer.

1.4 Data Processing and Statistical Analysis

Data were preprocessed using Excel 2010. Variance analysis was performed using the General Linear Model (GLM) procedure in SAS 9.0. When variance analysis was significant, differences among means were compared using the LSD method. Statistical significance was set at $P<0.05$.

Results

2.1 Effects of Dietary Lysine Levels on Performance of Lactating Sows and Growth Performance of Suckling Piglets

As shown in Table 2 , there were no significant differences in sow farrowing weight or number of live-born piglets among groups ($P>0.05$). Dietary SID Lys level significantly affected sow weaning weight ($P<0.05$), with group 5 being significantly higher than groups 1 and 2 ($P<0.05$). Sow weight loss during lactation decreased to varying degrees with increasing dietary SID Lys levels, showing a quadratic curve relationship: $Y = -71.4X^2 + 127.4X - 69.9$ ($r = 0.89$), with minimum weight loss occurring at 0.89% dietary SID Lys level. Sow daily feed intake and daily ME intake during lactation were not significantly affected by dietary SID Lys level ($P>0.05$), though groups 3 and 4 showed a decreasing trend. The weaning-to-estrus interval also did not differ significantly among groups ($P>0.05$), with group 4 showing the shortest interval numerically.

As shown in Table 3 , there were no significant differences in average piglet birth weight or mortality during lactation among groups ($P>0.05$). Dietary SID Lys level had no significant effect on piglet ADG during days 15–28 or days 1–28 ($P>0.05$), but significantly affected ADG during days 1–14 ($P<0.05$), with group 5 being significantly lower than groups 1, 2, and 3 ($P<0.05$).

2.2 Effects of Dietary Lysine Levels on Serum Biochemical Indices and Hormone Levels of Lactating Sows

As shown in Table 4 , dietary SID Lys levels had no significant effects on serum total protein, glucose, total cholesterol, or IgG contents on days 14 or 28 of lactation ($P>0.05$). Serum albumin content showed no significant changes among groups on day 14 ($P>0.05$), but on day 28, group 4 had significantly higher serum albumin content than groups 1, 2, and 5 ($P<0.05$). Serum urea nitrogen content on day 14 of lactation decreased to varying degrees with increasing dietary SID Lys levels, with groups 3–5 being significantly lower than group 1 ($P<0.05$). Further analysis revealed a significant quadratic relationship: $Y = 14.9X^2 - 26.3X + 14.0$ ($r = 0.87$, $P<0.01$), with the lowest serum urea nitrogen content occurring at 0.88% dietary SID Lys level. However, on day 28 of lactation, there were no significant differences in serum urea nitrogen content among groups ($P>0.05$), with group 3 showing the lowest value numerically.

As shown in Table 5 , dietary SID Lys levels had no significant effects on serum insulin, insulin-like growth factor-I, luteinizing hormone, or follicle-stimulating

hormone levels in sows on day 28 of lactation (P>0.05), but significantly affected serum estradiol level (P<0.05), with group 4 being significantly higher than groups 1, 2, and 5 (P<0.05). Further analysis revealed that serum estradiol level showed a quadratic curve relationship with dietary SID Lys level: $Y = -73.4X^2 + 122.1X - 40.2$ ($r = 0.86$, P<0.01), with the highest estradiol level occurring at 0.83% dietary SID Lys. Moreover, the pattern of serum estradiol level changes was opposite to that of weaning-to-estrus interval, and correlation analysis revealed a significant negative correlation between them ($r = 0.95$, P<0.01).

2.3 Effects of Dietary Lysine Levels on Milk Composition of Lactating Sows

As shown in Table 6 , dietary SID Lys levels had no significant effects on any measured composition indices in colostrum (P>0.05), but the contents of solid non-fat, milk fat, milk protein, lactose, and milk density in colostrum were all significantly higher than those in mature milk. There were no significant differences in milk fat and lactose contents in mature milk among groups (P>0.05), but solid non-fat, milk protein contents, and milk density increased to varying degrees with increasing dietary SID Lys levels. The solid non-fat content in groups 4 and 5 was significantly higher than in group 1 (P<0.05), and milk protein content and milk density in groups 3, 4, and 5 were significantly higher than in group 1 (P<0.05). These results indicate that dietary SID Lys level can significantly alter the composition of mature milk in sows.

Discussion

3.1 Effects of Dietary Lysine Levels on Performance of Lactating Sows

Excessive body tissue loss in lactating sows is an important cause of reduced reproductive performance and shortened service life. Studies have shown that increasing lysine intake in lactating sows by elevating dietary lysine levels can reduce mobilization of body protein reserves, decrease weight loss during lactation, shorten the weaning-to-estrus interval, and thereby improve reproductive performance [4,8-9]. When lysine intake is insufficient, appropriately increasing dietary lysine levels can reduce weight loss during lactation and tends to shorten the weaning-to-estrus interval [9]. Shi et al. [8] fed primiparous Landrace × Large White lactating sows five diets with different SID Lys levels and found that dietary SID Lys level had no significant effect on weaning-to-estrus interval or conception rate in the subsequent parity, but significantly reduced sow weight loss during lactation, with the response following a quadratic curve. This experiment also found that weight loss in multiparous Rongchang sows during lactation showed a quadratic curve relationship with increasing dietary SID Lys level, though no significant differences were observed among groups. The discrepancy in results may be attributed to differences in breed and parity. Yang et al. [10] studied primiparous and multiparous lactating sows and found that increasing dietary total lysine level from 1.02% to 1.34% significantly

reduced weight loss during lactation in sows of different parities, with the reduction being more pronounced in primiparous than in multiparous sows.

The results of this experiment showed that, with no significant differences in number of live-born piglets or birth weight among groups, adding 0.60%–1.00% SID Lys to Rongchang lactating sow diets had no significant effects on ADG or mortality of piglets during days 1–28, which is similar to the findings of Shi et al. [8]. In their study with Landrace × Large White lactating sows, with no significant differences in initial litter weight or litter size, dietary SID Lys supplementation of 0.76%–1.14% had no significant effects on litter weight gain or mortality of piglets during days 1–28. This experiment also found that when dietary SID Lys level was increased to 1.00%, ADG of piglets during days 1–14 decreased significantly, which is consistent with the findings of Dong et al. [11] that dietary lysine levels exceeding 1.00% significantly reduced litter weight gain and ADG at 21-day weaning.

3.2 Effects of Dietary Lysine Levels on Serum Biochemical Indices and Hormone Levels of Lactating Sows

Serum urea nitrogen is the end product of protein and amino acid metabolism in animals, and its concentration can serve as an important indicator for evaluating protein or lysine intake in lactating sows [2,12]. The results of this experiment showed that dietary SID Lys level had no significant effect on serum urea nitrogen content in Rongchang sows on day 28 of lactation, but significantly affected serum urea nitrogen content on day 14, which decreased quadratically with increasing dietary SID Lys level. This is similar to the findings of Coma et al. [12]. Under the conditions of this experiment, serum urea nitrogen content on day 14 of lactation was lowest when dietary SID Lys level was 0.88%.

Serum total protein content is an important indicator reflecting protein metabolism in animals; higher total protein content indicates greater protein deposition in the body. Serum albumin, the main component of serum total protein, can serve as an indicator of nutritional status to some extent [13-14]. This experiment showed that dietary SID Lys level had no significant effects on serum total protein content on days 14 and 28 or serum albumin content on day 28 of lactation, but supplementation with 0.90% SID Lys significantly increased serum albumin content on day 28. This is similar to the findings of Zhao et al. [15], who reported that dietary lysine supplementation of 0.80%–1.00% had no effect on serum total protein content on days 14 and 21 or serum albumin content on day 21, but significantly increased serum albumin content on day 21 of lactation. These results suggest that the effect of dietary lysine on serum albumin in lactating sows is mainly manifested in late lactation.

Estradiol, primarily secreted by the ovaries, is the most active estrogen and an important hormone indicator for evaluating ovarian function [16-17]. Studies have shown that serum estradiol levels in lactating sows increase initially and then decrease with increasing dietary total lysine levels, with a significant

decline observed when dietary total lysine level reaches 1.00% [11]. This experiment also found that serum estradiol levels in Rongchang lactating sows were significantly affected by dietary SID Lys level, showing a quadratic curve relationship, with the highest estradiol level occurring at 0.83% dietary SID Lys. Furthermore, serum estradiol level was significantly negatively correlated with weaning-to-estrus interval ($r = 0.95$, $P<0.01$), suggesting that dietary lysine during lactation may affect sow reproductive performance by altering sex hormone levels. The observed serum insulin, insulin-like growth factor-I, luteinizing hormone, and follicle-stimulating hormone levels in this experiment were not significantly affected by dietary SID Lys level, which is consistent with previous studies [8,18]. However, Dong et al. [11] reported that serum insulin levels in lactating sows decreased significantly when dietary lysine level exceeded 1.00%. The reason for this discrepancy is currently unclear and requires further investigation.

3.3 Effects of Dietary Lysine Levels on Milk Composition of Lactating Sows

Lysine intake in lactating sows is primarily used for milk synthesis to meet the needs of rapidly growing piglets. Dietary lysine levels can alter milk composition by affecting plasma lysine concentration [19-21]. Increasing dietary lysine levels from late gestation to lactation has been shown to significantly affect the composition of both colostrum and mature milk [3,10]. The results of this experiment showed that different dietary SID Lys levels had no significant effects on colostrum composition but significantly altered mature milk composition on day 28, suggesting that the effect of dietary SID Lys on milk composition strengthens as lactation progresses, which supports the viewpoint of Tokach et al. [22].

This experiment found that supplementation with 0.90%–1.00% SID Lys significantly increased the contents of solid non-fat and milk protein in mature milk on day 28, while milk fat and lactose contents were not significantly affected. These findings are consistent with previous studies [8,11]. When dietary SID Lys level was increased to 0.94%–1.14%, dry matter and protein contents in mature milk on day 21 increased significantly, while milk fat and lactose remained unchanged [8]. Dong et al. [11] also found that dietary lysine supplementation of 1.00%–1.05% significantly increased total solids and milk protein contents in mature milk on day 14, with no significant effects on milk fat and lactose contents. These results indicate that dietary lysine in lactating sows mainly affects milk protein, total solids, or solid non-fat contents in mature milk, with minimal effects on milk fat and lactose.

Conclusion

Supplementation with appropriate lysine levels can reduce weight loss in Rongchang lactating sows to some extent and significantly affect serum urea nitrogen, albumin, and estradiol levels, as well as mature milk composition.

Through quadratic curve simulation and evaluation, the optimal dietary SID Lys level for Rongchang lactating sows under the conditions of this experiment is 0.83%-0.89%, with an average feed intake of 3.0 kg/d, corresponding to a daily SID Lys requirement of 24.9-26.7 g.

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Note: Figure translations are in progress. See original paper for figures.