Effects of Dietary Phosphorus Level on Growth Performance, Serum Biochemical Indices, and Phosphorus Excretion in Growing Laoshan Dairy Goats (Postprint)

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Abstract

This experiment was conducted to investigate the effects of dietary phosphorus levels on growth performance, serum biochemical indices, and phosphorus excretion in growing Laoshan dairy goats. Thirty growing Laoshan dairy goat bucks with a body weight of (21.07$±$0.30) kg were selected and randomly allocated to 3 groups using a single-factor experimental design, with 10 replicates per group and 1 goat per replicate. Each group was fed diets with essentially consistent energy and protein levels, but with phosphorus levels of 0.25%, 0.35%, and 0.45%, respectively. The experimental period lasted 105 days, including a 15-day preliminary period and a 90-day formal experimental period. The results showed: 1) Dietary phosphorus level had no significant effect on dry matter intake in growing Laoshan dairy goats (P>0.05). Dietary phosphorus level had no significant effect on body weight or average daily gain of Laoshan dairy goats at 7, 8, and 9 months of age (P>0.05). 2) Dietary phosphorus level had no significant effect on serum calcium, phosphorus, urea nitrogen contents, or alkaline phosphatase activity in growing Laoshan dairy goats (P>0.05). 3) In terms of phosphorus intake, fecal phosphorus, urinary phosphorus, total phosphorus excretion, and retained phosphorus, the 0.45% group was extremely significantly higher than the 0.25% and 0.35% groups (P<0.01), and the 0.35% group was extremely significantly higher than the 0.25% group (P<0.01). It can be concluded that dietary phosphorus level had no significant effect on dry matter intake, body weight, or serum biochemical indices in growing Laoshan dairy goats; however, a dietary phosphorus level of 0.25% could significantly reduce fecal and urinary phosphorus excretion, thereby decreasing environmental pollution. Under the conditions of this experiment, a dietary phosphorus level of 0.25% is recommended for growing Laoshan dairy goat bucks.

Full Text

Effects of Dietary Phosphorus Level on Growth Performance, Serum Biochemical Indices, and Phosphorus Excretion of Growing Laoshan Dairy Goats

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Abstract

This experiment was conducted to investigate the effects of dietary phosphorus level on growth performance, serum biochemical indices, and phosphorus excretion in growing Laoshan dairy goats. Thirty growing Laoshan dairy goat bucks with an average body weight of (21.07$±$0.30) kg were randomly allocated into three groups using a single-factor experimental design, with 10 replicates per group and one goat per replicate. The goats were fed diets with consistent energy and protein levels but varying phosphorus levels of 0.25%, 0.35%, and 0.45%. The experiment lasted for 105 days, including a 15-day pre-trial period and a 90-day formal trial period.

The results showed that: (1) Dietary phosphorus level had no significant effect on dry matter intake (P>0.05) or on body weight and average daily gain at 7, 8, and 9 months of age (P>0.05). (2) Dietary phosphorus level had no significant effect on serum calcium, phosphorus, urea nitrogen contents, or alkaline phosphatase activity (P>0.05). (3) For phosphorus intake, fecal phosphorus, urinary phosphorus, total phosphorus excretion, and retained phosphorus, the 0.45% group was extremely significantly higher than both the 0.25% and 0.35% groups (P<0.01), while the 0.35% group was extremely significantly higher than the 0.25% group (P<0.01). These findings indicate that dietary phosphorus level did not significantly affect dry matter intake, body weight, or serum biochemical indices in growing Laoshan dairy goats. However, a dietary phosphorus level of 0.25% significantly reduced fecal and urinary phosphorus excretion, thereby decreasing environmental pollution. Under the conditions of this experiment, a dietary phosphorus level of 0.25% is recommended for growing Laoshan dairy goat bucks.

Keywords: growing period; Laoshan dairy goats; growth performance; serum biochemical indices; phosphorus excretion

Introduction

Phosphorus is the second most abundant macroelement in goats after calcium and is essential for normal skeletal development during the growing period. Long-term deficiency or improper calcium-to-phosphorus ratios in diets can cause skeletal diseases such as rickets and osteomalacia. Excessive phosphorus excretion into the environment can lead to surface water pollution and eutrophication. Economically, excessively high dietary phosphorus levels also increase feeding costs. Therefore, phosphorus requirements for Laoshan dairy goats must balance the need to ensure growth performance and health while minimizing phosphorus excretion [1].

Numerous studies have reported on the effects of dietary phosphorus levels on growth performance, serum biochemical indices, and phosphorus excretion in lactating cows, lactating dairy goats, and growing pigs. In a two-year trial by Wu et al. [2], dietary phosphorus levels of 0.38% and 0.48% showed no significant difference in dairy cow growth performance but substantially reduced phosphorus excretion. Wang et al. [3] found that dietary phosphorus levels between 0.29% and 0.41% could meet the phosphorus requirements of lactating Laoshan dairy goats, though total phosphorus excretion was significantly higher at 0.41% compared to 0.29%. Zhang et al. [4] reported that increasing dietary phosphorus levels did not significantly affect growth performance in growing pigs. However, research on phosphorus requirements for growing Laoshan dairy goats remains limited.

Based on the feeding standards for growing goats recommended in China' s "Feeding Standard of Meat-Producing Sheep and Goats" (NY/T 816–2004), this experiment formulated three diets with different phosphorus levels to investigate their effects on growth performance, serum biochemical indices, and phosphorus excretion in growing Laoshan dairy goats. The objective was to determine the appropriate phosphorus level to improve dietary phosphorus utilization and provide reference data for production practices.

Materials and Methods

1.1 Experimental Animals and Design

Thirty healthy Laoshan dairy goat bucks approximately 165 days old, with an average body weight of (21.07$±$0.30) kg, were used in a single-factor randomized design. According to the principle of balanced body weight, the goats were randomly divided into three groups with 10 replicates per group and one goat per replicate. The experiment was conducted at Qingdao Aote Special Goat Farm from August 2016 to November 2016, lasting 105 days with a 15-day pre-trial period and a 90-day formal trial period.

1.2 Experimental Diets and Nutrient Levels

Experimental diets were formulated according to China' s "Feeding Standard of Meat-Producing Sheep and Goats" (NY/T 816–2004) for growing goats (recommended phosphorus level of 0.35%). The three groups (A, B, and C) were fed diets with phosphorus levels of 0.25%, 0.35%, and 0.45%, respectively, while maintaining consistent protein and energy levels. Diet composition and nutrient levels are presented in Table 1. Diets were provided as total mixed rations (TMR).

Notes:
1) The premix provided the following per kilogram of diet: VA 17,500 IU, VE 43 mg, VD_3 3,500 IU, VB_5 25.74 mg, Mn (as manganese sulfate) 31 mg, Zn (as zinc sulfate) 92.5 mg, Cu (as copper sulfate) 30 mg, Co (as cobaltous sulfate) 0.72 mg, I (as potassium iodide) 1.25 mg, Se (as sodium selenite) 1.00 mg.
2) Digestible energy (DE) was a calculated value obtained by multiplying the DE value [5-6] of each raw material by its proportion in the dietary formula and summing the results; other values were measured.

1.3 Feeding Management

Goats were housed individually in single pens and fed at 06:30, 12:00, and 18:00 daily. They were moved to exercise areas during fixed time periods and provided with adequate clean drinking water. Goat houses were regularly disinfected to maintain cleanliness, and deworming and immunization were performed strictly according to the farm's routine procedures. Feeding and management conditions were identical across all groups.

1.4 Digestion and Metabolism Trial

A digestion and metabolism trial was conducted on day 40 of the feeding experiment, consisting of a 7-day pre-trial period and a 3-day formal collection period. Three goats from each group with body weights close to the group average were selected and housed in specialized metabolism cages. The total collection method was used for feces and urine. Diet composition and feeding methods were identical to those in the feeding trial. Feed intake and orts were accurately recorded, with orts dried at 65 °C to produce air-dry samples for storage. Feces were collected continuously for 3 days, with 10% of the daily fecal output taken, mixed with 10% tartaric acid solution at 1/4 of fecal weight, and dried at 65 °C to constant weight to produce air-dry samples. All daily urine was filtered through 8 layers of gauze, acidified with 10% H_2SO_4, and 5% of the 3-day composite urine sample was stored at -20 °C for later analysis.

1.5 Measurements

1.5.1 Dietary Nutrient Composition and Fecal/Urinary Phosphorus Determination Dietary dry matter content was determined according to

methods in "Feed Analysis and Feed Quality Detection Technology" edited by Zhang Liying [7]. Crude protein content was determined by the Kjeldahl method, calcium content by potassium permanganate titration, and phosphorus content in diets, feces, and urine by the molybdate yellow colorimetric method. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined according to the method of Van Soest et al. [8].

1.5.2 Dry Matter Intake (DMI) Feed offered and refused were accurately recorded daily, with orts collected and dry matter content determined within 2 hours to calculate DMI and determine actual intake per goat.

1.5.3 Body Weight and Average Daily Gain (ADG) Goats in all three groups were weighed consecutively for 2 days before morning feeding at the end of the pre-trial period and on days 30, 60, and 90 of the formal trial period, representing body weights at the end of pre-trial and at 7, 8, and 9 months of age. Body weight and ADG during the trial period were calculated.

1.5.4 Serum Biochemical Indices Blood samples were collected on day 90 of the formal trial period. Five milliliters of jugular venous blood were collected before morning feeding, allowed to stand for 2 hours, then centrifuged at 1,369 × g for 10 minutes. The supernatant was transferred to 2 mL centrifuge tubes and stored at -20 °C. Serum calcium, phosphorus, urea nitrogen contents, and alkaline phosphatase activity were measured using a Hitachi 7600 automatic biochemical analyzer. Serum calcium was determined by arsenazo III colorimetry using kits from Beijing Leadman Biochemistry Co., Ltd. Serum phosphorus was determined by phosphomolybdic acid UV spectrophotometry using kits from the same company. Serum alkaline phosphatase activity was determined by continuous monitoring using kits from Sichuan Maccura Biotechnology Co., Ltd. Serum urea nitrogen was determined by urease continuous monitoring using kits from the same company.

1.5.5 Calculation Formulas

- Fecal phosphorus excretion = daily fecal output × phosphorus content in feces
- Urinary phosphorus excretion = daily urine output × phosphorus content in urine
- Total phosphorus excretion = fecal phosphorus excretion + urinary phosphorus excretion

1.6 Data Processing and Analysis

Experimental data were processed using Excel 2007. SPSS 17.0 software was used for one-way ANOVA, and Duncan' s multiple comparison test was used

for inter-group difference significance testing. $P<0.05$ and $P<0.01$ were considered statistically significant and extremely significant, respectively. Results are expressed as mean ± standard error.

Results

2.1 Effects of Dietary Phosphorus Level on Growth Performance of Growing Laoshan Dairy Goats

As shown in Table 2 , dietary phosphorus level had no significant effect on DMI of Laoshan dairy goats at 7, 8, or 9 months of age ($P>0.05$). However, Group C showed the lowest DMI among the three groups at all ages. Dietary phosphorus level had no significant effect on body weight at 7, 8, or 9 months of age ($P>0.05$), though Group B had relatively higher body weight while Group C had lower body weight. Dietary phosphorus level also had no significant effect on ADG throughout the experimental period ($P>0.05$).

Note: In the same row, values with different lowercase superscripts indicate significant difference ($P<0.05$), different uppercase superscripts indicate extremely significant difference ($P<0.01$), and same or no letters indicate no significant difference ($P>0.05$). The same applies below.

2.2 Effects of Dietary Phosphorus Level on Serum Biochemical Indices of Growing Laoshan Dairy Goats

As shown in Table 3 , dietary phosphorus level had no significant effect on serum calcium, phosphorus, urea nitrogen contents, or alkaline phosphatase activity ($P>0.05$). Although serum phosphorus content showed an increasing trend with higher dietary phosphorus levels, the difference was not significant ($P>0.05$).

2.3 Effects of Dietary Phosphorus Level on Phosphorus Excretion of Growing Laoshan Dairy Goats

As shown in Table 4 , for phosphorus intake, fecal phosphorus excretion, urinary phosphorus excretion, total phosphorus excretion, and retained phosphorus, Group C was extremely significantly higher than Groups A and B ($P<0.01$), while Group B was extremely significantly higher than Group A ($P<0.01$).

Discussion

3.1 Effects of Dietary Phosphorus Level on Growth Performance of Growing Laoshan Dairy Goats

Dry matter intake in ruminants is influenced by multiple factors. Si et al. [9] found that calcium and phosphorus levels in concentrate supplements had no

significant effect on total feed intake of pastoral lambs during winter and spring. Sun et al. [10] reported that increasing dietary phosphorus level from 0.25% to 0.35% had no significant effect on DMI of young dairy cows. The current study found no significant effect of dietary phosphorus levels (0.25%, 0.35%, and 0.45%) on DMI of growing Laoshan dairy goats, consistent with the above results. However, DMI tended to decrease at the 0.45% phosphorus level compared to 0.25% and 0.35%. Xu et al. [11] found that dietary phosphorus level had no significant effect on DMI of Simmental crossbred heifers, though higher phosphorus levels tended to reduce DMI, which aligns with our findings. This suggests that animals have a certain range of phosphorus requirement or tolerance, and when dietary phosphorus exceeds the optimal level, it may affect appetite and reduce feed intake. Therefore, under the conditions of this experiment, dietary phosphorus level had no significant effect on feed intake of growing Laoshan dairy goats, and the diet in Group A could meet the animals' growth requirements.

Erickson et al. [12] fed calves [(265.0$±$16.6) kg] diets with different phosphorus levels (0.16%, 0.22%, 0.28%, 0.40%) at the same calcium level (0.62%) and found no significant effect on ADG. Huang [13] reported that different dietary phosphorus levels with the same phosphorus source and calcium level had no significant effect on ADG of finishing pigs. Our results indicate that the phosphorus levels in Groups A and B could meet the body weight gain requirements of Laoshan dairy goats, while higher phosphorus levels actually decreased ADG.

3.2 Effects of Dietary Phosphorus Level on Serum Biochemical Indices of Growing Laoshan Dairy Goats

Serum calcium, phosphorus, urea nitrogen contents, and alkaline phosphatase activity are commonly used to estimate calcium and phosphorus nutritional status and requirements in animals. Puggaard et al. [14] reported that when dietary phosphorus levels met the requirements of dairy cows, serum biochemical indices were not affected by dietary phosphorus level. Conversely, if requirements were not met, serum biochemical indices would show significant differences and phosphorus deficiency symptoms would appear. Lu [15] reported normal reference values for cashmere goats as: serum calcium 2.2–3.1 mmol/L, serum phosphorus 1.6–4.4 mmol/L, serum alkaline phosphatase activity 45–125 U/L, and serum urea nitrogen 4–12 mmol/L. The measured data in our experiment showed that all three groups had serum calcium, phosphorus, urea nitrogen contents, and alkaline phosphatase activity within the normal range, consistent with several other studies. Wang [16] found that different dietary calcium and phosphorus levels and ratios had no significant effect on serum calcium and phosphorus contents in weaned lambs of Shanbei white cashmere goats. Sun et al. [10] reported that dietary phosphorus level had no significant effect on serum alkaline phosphatase activity in 11–15-month-old young dairy cows. Ge et al. [17] found that different dietary phosphorus levels had no significant effect on serum urea nitrogen content in Laoshan dairy goats. Therefore, under the conditions of

this experiment, serum calcium, phosphorus, urea nitrogen contents, and alkaline phosphatase activity could not be used to determine which phosphorus level best met the requirements of growing Laoshan dairy goats.

3.3 Effects of Dietary Phosphorus Level on Phosphorus Excretion of Growing Laoshan Dairy Goats

Compared to cattle and sheep, fewer reports exist on phosphorus metabolism in goats, though such studies are essential for establishing phosphorus requirements. In livestock production, 60% of phosphorus in excreta comes from ruminants [18]. However, phosphorus emissions from pig and chicken manure cannot be ignored, and some studies have shown that phosphorus intake and excretion are closely related [19]. Zhang et al. [20] found that when dietary phosphorus level in growing pigs increased from 0.44% to 0.69%, total phosphorus excretion increased extremely significantly. Hua [21] reported that dietary phosphorus level significantly increased phosphorus intake and total phosphorus excretion in broiler chickens. Zhao [22] found that dietary phosphorus level significantly affected total phosphorus excretion in 25–29 kg non-fleece-producing cashmere goats, with total phosphorus excretion and retained phosphorus increasing significantly as dietary phosphorus level increased. Cerosalette et al. [23] found that the most effective measure to reduce phosphorus pollution in dairy production was to reduce inorganic phosphorus supplementation in dairy diets. Zhang et al. [24] reported that dietary phosphorus level significantly affected phosphorus excretion in dairy cow feces, with fecal phosphorus excretion gradually increasing as dietary phosphorus level increased.

In this experiment, as dietary phosphorus level increased, fecal phosphorus excretion, urinary phosphorus excretion, total phosphorus excretion, and retained phosphorus increased significantly, with total phosphorus excretion being mainly composed of fecal phosphorus. These results are consistent with the above findings, indicating that in terms of phosphorus excretion, monogastric animals are similar to ruminants and this is not related to the unique endogenous urea nitrogen mechanism of ruminants. In summary, the most effective measure to reduce total phosphorus excretion is to reduce phosphorus feeding rates while meeting normal growth and production requirements of dairy goats. Excess phosphorus in the diet is not fully absorbed by the body, with a large portion being excreted through feces, entering various water bodies through surface rivers and causing eutrophication of algae in rivers and lakes, leading to oxygen depletion and massive death of aquatic organisms, especially fish. Additionally, excessive phosphorus entering the soil is converted to phosphate, causing soil hardening. Although retained phosphorus increased significantly with increasing dietary phosphorus levels, it did not affect the growth performance of growing Laoshan dairy goats. Therefore, reducing phosphorus levels in dairy goat diets while meeting body phosphorus requirements can not only reduce environmental pollution but also conserve significant amounts of non-renewable phosphate rock resources.

Conclusion

Dietary phosphorus level had no significant effect on DMI, body weight, or serum biochemical indices of growing Laoshan dairy goats. However, a dietary phosphorus level of 0.25% significantly reduced fecal and urinary phosphorus excretion, thereby decreasing environmental pollution. Under the conditions of this experiment, a dietary phosphorus level of 0.25% is recommended for growing Laoshan dairy goat bucks.

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