Effects of Dietary Calcium and Phosphorus Levels on Nutrient Digestion, Metabolism, and Plasma Physiological and Biochemical Indices in Lactating Yili Mares (Postprint)

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Abstract

This experiment was conducted to investigate the effects of dietary calcium and phosphorus levels on body weight, chest circumference, apparent digestibility and metabolism of nutrients, and plasma physiological and biochemical indices in lactating Yili mares, providing reference for determining appropriate calcium and phosphorus requirements during lactation. Twenty-five Yili mares in their second month of lactation with similar age (11-14 years), body weight [(371±21) kg], and parity (4-6) were selected and randomly divided into 5 groups with 5 mares per group. During the third month of lactation, calcium feeding levels for groups I, II, III, IV, and V were 45.03, 48.50, 51.96, 55.43, and 58.89 g/d, respectively, and phosphorus feeding levels were 30.05, 32.03, 34.01, 35.99, and 37.97 g/d, respectively; during the fourth and fifth months of lactation, calcium feeding levels for groups I, II, III, IV, and V were 43.60, 46.42, 49.25, 52.07, and 54.92 g/d, respectively, and phosphorus feeding levels were 27.63, 29.24, 30.86, 32.47, and 34.12 g/d, respectively. The experiment lasted for 90 days, with each 30-day period constituting one experimental period. The results showed that dietary calcium and phosphorus levels had no significant effects on mare body weight and chest circumference ($P>0.05$). Dietary calcium and phosphorus levels had no significant effects on apparent digestibility of dry matter, organic matter, and neutral detergent fiber ($P>0.05$). Group V had the highest apparent digestibility of crude protein, which was 12.26%, 12.37%, and 18.28% higher than groups II, III, and IV, respectively ($P<0.05$); Group I had the highest apparent digestibility of gross energy, which was 8.32%, 7.19%, and 11.24% higher than groups II, III, and IV, respectively ($P<0.05$); Groups I and III had calcium apparent digestibility 17.74% and 14.49% higher than group IV, respectively ($P<0.05$); Group III had the highest phosphorus apparent digestibility, which was 35.39% higher than group II ($P<0.05$). Di-

etary calcium and phosphorus levels had no significant effects on nitrogen and calcium metabolism in mares (P>0.05). Group I had metabolizable energy 7.95% and 11.33% higher than groups II and IV, respectively (P<0.05); Group I had energy retention rate 9.30%, 8.50%, and 12.10% higher than groups II, III, and IV, respectively (P<0.05); Groups I, III, and V had phosphorus retention significantly higher than group II (P<0.05), with group III being the highest among all groups, 42.59% higher than group II; Groups I and III had phosphorus retention rate significantly higher than groups II and IV (P<0.05), with group I being the highest among all groups, 49.67% and 46.32% higher than groups II and IV, respectively; Groups I, III, and V had phosphorus utilization rate significantly higher than group II (P<0.05), 17.74%, 18.80%, and 16.79% higher than group II, respectively. Dietary calcium and phosphorus levels had no significant effects on plasma levels of ionized calcium, phosphorus, calcitonin, osteocalcin, placental lactogen, pituitary prolactin, estradiol, progesterone, and estrone (P>0.05). Group III had plasma parathyroid hormone level significantly higher than groups IV and V (P<0.05), increased by 70.61% and 47.58%, respectively. It was concluded that the diet of group I (calcium and phosphorus feeding levels of 45.03 and 30.05 g/d during the third month of lactation, and 43.60 and 27.63 g/d during the fourth and fifth months of lactation, respectively) could meet the calcium and phosphorus requirements of Yili mares during lactation. Appropriate dietary calcium and phosphorus levels help maintain higher levels of apparent digestibility of energy and calcium, as well as energy and phosphorus deposition and utilization.

Full Text

Effects of Dietary Calcium and Phosphorus Levels on Nutrient Digestion and Metabolism, and Plasma Physiological-Biochemical Indices in Yili Mares during the Lactation Period

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Abstract

To establish reference values for calcium (Ca) and phosphorus (P) requirements in Yili mares during lactation, we examined the effects of dietary Ca and P levels on body weight, heart girth, nutrient apparent digestibility, metabolism, and plasma physiological-biochemical indices. Twenty-five Yili mares at the end of their second lactation month were selected based on similar age (11-14 years), body weight [(371±21) kg], and parity (4-6 parities), and allocated to five groups (n=5 per group). In the third lactation month, dietary Ca levels

were 45.03, 48.50, 51.96, 55.43, and 58.89 g/d, and P levels were 30.05, 32.03, 34.01, 35.99, and 37.97 g/d for Groups 1–5, respectively. In the fourth and fifth lactation months, Ca levels were 43.60, 46.42, 49.25, 52.07, and 54.92 g/d, and P levels were 27.63, 29.24, 30.86, 32.47, and 34.12 g/d for Groups 1–5, respectively. The 90-day trial consisted of three 30-day test cycles.

The results showed that dietary Ca and P levels had no significant effects on body weight, heart girth, or apparent digestibility of dry matter (DM), organic matter (OM), and neutral detergent fiber (NDF) ($P>0.05$). Group 5 exhibited the highest crude protein (CP) apparent digestibility, which was 12.26%, 12.37%, and 18.28% higher than Groups 2, 3, and 4, respectively ($P<0.05$). Group 1 showed the highest gross energy (GE) apparent digestibility, exceeding Groups 2, 3, and 4 by 8.32%, 7.19%, and 11.24%, respectively ($P<0.05$). The Ca apparent digestibility of Groups 1 and 3 was higher than Group 4, with increases of 17.74% and 14.49%, respectively ($P<0.05$). Group 3 demonstrated the highest P apparent digestibility, 35.39% greater than Group 2 ($P<0.05$).

Dietary Ca and P levels did not significantly affect nitrogen or Ca metabolism ($P>0.05$). Group 1 had higher metabolizable energy (ME) than Groups 2 and 4, with increases of 7.95% and 11.33%, respectively ($P<0.05$). The energy retention rate of Group 1 exceeded that of Groups 2, 3, and 4 by 9.30%, 8.50%, and 12.10%, respectively ($P<0.05$). P retention in Groups 1, 3, and 5 was significantly higher than in Group 2 ($P<0.05$), with Group 3 showing the highest value—42.59% greater than Group 2 ($P<0.05$). The P retention rate of Groups 1 and 3 was significantly higher than Groups 2 and 4, with Group 1 achieving the highest values, exceeding Groups 2 and 4 by 49.67% and 46.32%, respectively ($P<0.05$). The P utilization rate of Groups 1, 3, and 5 was significantly higher than Group 2 ($P<0.05$), showing increases of 17.74%, 18.80%, and 16.79%, respectively.

Plasma levels of ionized calcium (Ca2+), phosphorus, calcitonin, bone gla protein, placental lactogen, prolactin, estradiol, progesterone, and estrone did not differ significantly among groups ($P>0.05$). However, plasma parathyroid hormone (PTH) levels in Group 3 were significantly higher than in Groups 4 and 5, with increases of 70.61% and 47.58%, respectively ($P<0.05$).

In conclusion, the diet with Ca and P levels of 45.03 and 30.05 g/d in the third lactation month, and 43.60 and 27.63 g/d in the fourth and fifth lactation months (Group 1) meets the Ca and P requirements of Yili mares during lactation. Appropriate dietary Ca and P levels help maintain higher apparent digestibility of gross energy and calcium, as well as improved phosphorus retention and energy utilization.

Keywords: Yili mare; calcium; phosphorus; digestion; metabolism; hormones

Introduction

Calcium and phosphorus are essential minerals for lactating mares, playing critical roles in milk production, skeletal health, and metabolic function. Determining optimal dietary requirements is crucial for the health and productivity of Yili mares, a prominent breed in Xinjiang, China. This study investigated the effects of varying dietary Ca and P levels on nutrient utilization and physiological responses to establish science-based feeding recommendations.

Materials and Methods

Experimental Animals and Design Twenty-five Yili mares at the end of their second lactation month were selected based on similar age (11–14 years), body weight [(371±21) kg], and parity (4–6 parities). Mares were randomly allocated to five dietary treatment groups (n=5 per group). The 90-day feeding trial was conducted in three 30-day phases, corresponding to the third, fourth, and fifth months of lactation.

Dietary Treatments Diets were formulated to provide graded levels of Ca and P while maintaining similar energy and protein content. Diet composition is presented in . In the third lactation month, dietary Ca levels were 45.03, 48.50, 51.96, 55.43, and 58.89 g/d, and P levels were 30.05, 32.03, 34.01, 35.99, and 37.97 g/d for Groups 1–5, respectively. In the fourth and fifth lactation months, Ca levels were 43.60, 46.42, 49.25, 52.07, and 54.92 g/d, and P levels were 27.63, 29.24, 30.86, 32.47, and 34.12 g/d for Groups 1–5, respectively.

Sample Collection and Analysis Body weight and heart girth were measured at the end of each test cycle. Feed and fecal samples were collected during the last 3 days of each period for apparent digestibility calculations. Blood samples were collected via jugular venipuncture at 08:00–09:00 on the final day of each period, centrifuged at 3,500 r/min for 10 minutes, and plasma was stored at -20°C for subsequent analysis of Ca2+, P, parathyroid hormone (PTH), calcitonin (CT), bone gla protein (BGP), placental lactogen (PL), prolactin (PRL), estradiol (E2), progesterone (P), and estrone (E1) concentrations.

Statistical Analysis Data were analyzed using SPSS 18.0 software with General Linear Model (GLM) procedures. Duncan' s multiple range test was used for post-hoc comparisons. Significance was declared at $P<0.05$. D: effect of diet; ML: effect of lactation month; D×ML: interaction effect.

Results

Body Weight and Heart Girth Dietary Ca and P levels had no significant effects on body weight or heart girth ($P>0.05$). However, both parameters were significantly affected by lactation month ($P<0.05$), with values increasing from the third to fifth month. Results are summarized in .

Nutrient Apparent Digestibility Apparent digestibility of DM, OM, and NDF was not significantly influenced by dietary Ca and P levels ($P>0.05$). How-

ever, significant differences were observed for CP, GE, Ca, and P digestibility. Group 5 showed the highest CP digestibility, while Group 1 exhibited the highest GE digestibility. Ca digestibility was elevated in Groups 1 and 3 compared to Group 4. Group 3 demonstrated the highest P digestibility. Detailed results are presented in .

Energy and Nitrogen Metabolism Dietary treatments did not significantly affect nitrogen retention or Ca metabolism ($P>0.05$). However, ME and energy retention rates were significantly higher in Group 1 compared to other groups. P retention, retention rate, and utilization rate were significantly improved in Groups 1, 3, and 5 compared to Group 2. Complete metabolic data are shown in .

Plasma Physiological-Biochemical Indices Plasma concentrations of Ca2+, P, CT, BGP, PL, PRL, E2, P, and E1 were not significantly different among dietary groups ($P>0.05$). Plasma PTH levels were significantly elevated in Group 3 compared to Groups 4 and 5 ($P<0.05$). Plasma indices are reported in .

Discussion

The findings indicate that moderate dietary Ca and P levels (Group 1) are sufficient to meet the requirements of lactating Yili mares without compromising nutrient digestibility or metabolic efficiency. Higher mineral levels did not confer additional benefits and may alter hormonal regulation, as evidenced by elevated PTH in Group 3. The lack of significant effects on most plasma parameters suggests homeostatic regulation of mineral metabolism across a range of dietary intakes.

Conclusion

Dietary Ca and P levels of 45.03 and 30.05 g/d during the third lactation month, and 43.60 and 27.63 g/d during the fourth and fifth lactation months, respectively, meet the Ca and P requirements of Yili mares during lactation. These levels support optimal nutrient digestibility, energy utilization, and phosphorus retention while maintaining normal plasma biochemical profiles.

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Tables

Composition and nutrient levels of diets (air-dry basis) %

Effects of dietary calcium and phosphorus levels on body weight and heart girth of Yili mares during lactation period

Effects of dietary calcium and phosphorus levels on nutrient apparent digestibility of Yili mares during lactation period

Effects of dietary calcium and phosphorus levels on metabolism of energy, N, Ca and P of Yili mares during lactation period

Effect of dietary calcium and phosphorus levels on plasma physiological-biochemical indices of Yili mares during lactation period

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