Effects of Dietary Cation-Anion Balance on Growth Performance, Serum and Urinary Biochemical Parameters, and Incidence of Urinary Calculi in Liaoning Cashmere Goats (Postprint)

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Abstract

This study was conducted to investigate the effects of dietary cation-anion balance (DCAB) values on growth performance, serum and urine biochemical parameters, and the incidence of urinary calculi in cashmere goats. Fifty healthy Liaoning cashmere goats of similar age (approximately 1.5 years) and body weight (approximately 30 kg) were selected and randomly allocated into five groups, with DCAB values of 0 (Group I), 150 (Group II), 300 (Group III), 450 (Group IV), and 600 mEq/kg DM (Group V), respectively, with ten goats per group. The adaptation period lasted 15 days, followed by a 90-day experimental period. The results showed: 1) DCAB values had no significant effect on average daily gain ($P>0.05$); average daily feed intake exhibited an overall increasing trend with increasing DCAB values (except during days 75-90); regarding feed conversion ratio, Group I showed higher values during days 1-15 and 15-30, while Group V showed higher values during days 60-75 and 75-90. 2) On days 75 and 90, serum urea concentration was highest in Group V, whereas urine urea concentration was highest in Group III; serum creatinine concentration was highest in Group V on days 60 and 75, and highest in Group IV on day 90; urine creatinine concentration was highest in Group V on days 15, 30, and 45; serum uric acid concentration was highest in Group III on day 45, and highest in Group V on days 75 and 90; urine uric acid concentration was highest in Group V on days 15 and 30, and highest in Group III on days 75 and 90. 3) No goats in Groups I and II developed urinary calculi, whereas Groups III, IV, and V had 3, 4, and 5 goats with urinary calculi, respectively. In conclusion, a DCAB value of 150 mEq/kg DM is beneficial for maintaining certain related serum and urine biochemical parameters within normal ranges and for preventing the occurrence of urinary calculi in Liaoning cashmere goats.

Full Text

Effect of Dietary Cation-Anion Balance on Growth Performance, Biochemical Indices of Serum and Urine, and Incidence of Urolithiasis in Liaoning Cashmere Goats

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Abstract

This experiment was conducted to determine the effects of dietary cation-anion balance (DCAB) value on growth performance, biochemical indices of serum and urine, and incidence of urolithiasis in Liaoning cashmere goats. Fifty healthy Liaoning cashmere goats aged approximately 1.5 years with body weight of about 30 kg were selected and randomly divided into 5 groups (n=10 per group). DCAB values in different groups were 0 (Group I), 150 (Group II), 300 (Group III), 450 (Group IV), and 600 mEq/kg DM (Group V), respectively. The pretest lasted for 15 days, and the formal test lasted for 90 days. The results showed as follows: (1) DCAB value had no significant influence on average daily gain ($P>0.05$); with the increase of DCAB value, average daily feed intake tended to increase (except days 75 to 90); feed-to-gain ratio was higher in Group I during days 1-15 and 15-30, and higher in Group V during days 60-75 and 75-90. (2) On days 75 and 90, serum urea content in Group V was the highest, and urine urea content in Group III was the highest; on days 60 and 75, serum creatinine content was the highest in Group V, and on day 90, Group IV had the highest value; on days 15, 30, and 45, urine creatinine content was the highest in Group V; on day 45, serum uric acid content in Group III was the highest, and on days 75 and 90, Group V had the highest value; on days 15 and 30, urine uric acid content in Group V was the highest, and on days 75 and 90, Group III had the highest value. (3) No urolithiasis goats were found in Groups I and II, while 3, 4, and 5 goats with urolithiasis were found in Groups III, IV, and V, respectively. In conclusion, a DCAB value of 150 mEq/kg DM is beneficial for maintaining partial biochemical indices of serum and urine within normal ranges and for preventing urolithiasis in Liaoning cashmere goats.

Keywords: dietary cation-anion balance value; growth performance; biochemical indices; urolithiasis; Liaoning cashmere goats

Introduction

In recent years, with the rapid development of ruminant nutrition research, dietary cation-anion balance (DCAB) has received increasing attention regarding its effects on animal health and production performance [1-5]. Gazi et al. [6] demonstrated that reducing dietary phosphate content could decrease the incidence of urolithiasis in calves. Wang et al. [7] successfully induced urolithiasis in goats by increasing dietary DCAB values through supplementation with potassium, phosphorus, and magnesium. However, the effects of DCAB values on the incidence of urolithiasis in sheep and goats remain unclear. This experiment was designed to investigate the effects of DCAB values on growth performance and serum and urine biochemical indices in Liaoning cashmere goats, thereby establishing a foundation for elucidating the influence of dietary DCAB values on urolithiasis development in goats.

Materials and Methods

1.1 Experimental Design and Management

Fifty healthy Liaoning cashmere goats of similar age (approximately 1.5 years) and body weight (around 30 kg) were selected and randomly divided into five groups (n=10 per group), with each goat housed individually. The basal diet composition and nutrient levels are presented in Table 1 . The DCAB value was calculated using the formula: DCAB value = (Na + K + 0.38 Ca^2 + 0.3 Mg^2) - (Cl + 0.6 S^2 + 0.5 P^3) [8]. Five experimental diets with DCAB values of 0 (Group I), 150 (Group II), 300 (Group III), 450 (Group IV), and 600 mEq/kg DM (Group V) were formulated by adding ammonium chloride (NH Cl), sodium bicarbonate (NaHCO), and magnesium oxide (MgO). Peanut straw and corn straw were chopped to approximately 1 cm length. Before feeding, concentrates and roughage were mixed thoroughly according to the formulation. Goats were fed twice daily at 08:00 and 14:00 in individual troughs with free access to water. The experiment consisted of a 15-day pre-trial period followed by a 90-day formal trial period.

1.2 Determination and Calculation of Dietary Nutrient Content

Dry matter content was determined using the national standard method (GB/T 6435-2006). Crude protein content was measured by the Kjeldahl nitrogen determination method. Calcium content was determined by EDTA complexometric titration. Phosphorus content was measured by molybdenum yellow colorimetry [9] using a UV-5500 spectrophotometer. Sulfur content was determined by barium sulfate turbidimetry using a UV-5500 spectrophotometer. Chloride content was measured using the national standard method (GB/T 6439-92). Sodium, potassium, and magnesium contents were determined by atomic absorption spectroscopy [10] using a Hitachi Z-2000 atomic absorption spectrophotometer.

Dietary digestible energy levels were calculated from the digestible energy values of individual feed ingredients, which were obtained from the *Chinese Feed Composition and Nutritive Value Table (21st Edition)*.

1.3 Collection of Serum and Urine Samples

On the first day of the formal trial period (Day 1) and every 15 days thereafter, 10 mL of blood was collected from the jugular vein of each goat in the morning while fasting. Serum was prepared and aliquoted into 2 mL centrifuge tubes. Urine samples were collected at the same time and stored at -20°C for later analysis.

1.4 Index Determination

1.4.1 Growth Performance Measurement Residual feed was collected and weighed daily before morning feeding to accurately record daily feed consumption and calculate average daily feed intake (on an air-dry basis) for each period. Goats were weighed every 15 days starting from Day 1 of the formal trial period while fasting in the morning. Average daily gain was calculated for each group, and feed-to-gain ratio was determined.

1.4.2 Determination of Serum and Urine Biochemical Indices Serum and urine urea content (urease UV rate method), uric acid content (uricase UV method), and creatinine content (enzymatic method) [11] were measured using a Roche c702 automatic biochemical immunoassay analyzer. Urea, uric acid, and creatinine assay kits were purchased from Roche (catalog numbers 05171873190, 05171857190, and 05168589190, respectively).

1.4.3 Determination of Urolithiasis Incidence Clinical signs were observed daily for symptoms of urolithiasis. Goats showing urinary retention for 1-2 days were euthanized for necropsy, and urinary calculi were collected. All remaining goats were euthanized at the end of the trial period to examine the urinary tract for calculi.

1.5 Statistical Analysis

Experimental data were analyzed using one-way ANOVA with SPSS 17.0 software, and Duncan' s multiple range test was used for post-hoc comparisons. $P<0.05$ and $P<0.01$ were used as criteria for significant and highly significant differences, respectively. Data are presented as means ± standard error.

Results

2.1 Growth Performance

As shown in Table 2 , DCAB value had no significant effect on average daily gain throughout the trial period ($P>0.05$). Average daily feed intake was significantly or highly significantly higher in Group V compared to the other four groups during days 1-15, 15-30, 30-45, 45-60, and 60-75 ($P<0.05$ or $P<0.01$). During days 75-90, no significant difference was observed between Groups I and V ($P>0.05$), but both were highly significantly higher than Groups II, III, and IV ($P<0.01$). Feed-to-gain ratio was highly significantly higher in Group I during days 1-15 ($P<0.01$), significantly or highly significantly lower than Groups I and III during days 15-30 ($P<0.05$ or $P<0.01$), and significantly or highly significantly higher in Group V during days 60-75 and 75-90 ($P<0.05$ or $P<0.01$).

In the same row, values with no letter or the same letter superscripts indicate no significant difference ($P>0.05$), different lowercase letter superscripts indicate significant difference ($P<0.05$), and different uppercase letter superscripts indicate highly significant difference ($P<0.01$). The same applies to Table 3 , Table 4 , and Table 5 .

2.2.1 Serum and Urine Urea Content

As shown in Table 3 , serum urea content in Group V was highly significantly higher than the other four groups on days 75 and 90 ($P<0.01$). On day 90, Group IV was significantly or highly significantly higher than Groups I and II ($P<0.05$ or $P<0.01$). Urine urea content was highest in Group III and lowest in Group V on days 75 and 90. On day 75, Group III was significantly or highly significantly higher than Groups I, II, and V ($P<0.05$ or $P<0.01$), with no significant difference from Group IV ($P>0.05$). On day 90, Group III was highly significantly higher than the other four groups ($P<0.01$), and Group IV was significantly higher than Group V ($P<0.05$).

2.2.2 Serum and Urine Creatinine Content

As shown in Table 4 , serum creatinine content was highest in Group V on days 60 and 75, followed by Group IV, with Group V being significantly or highly significantly higher than the other four groups ($P<0.05$ or $P<0.01$). On day 90, serum creatinine content in Group IV was significantly or highly significantly higher than the other four groups ($P<0.05$ or $P<0.01$). Urine creatinine content was highest in Group V on days 15, 30, and 45, being significantly or highly significantly higher than Groups I, II, and III on day 15 ($P<0.05$ or $P<0.01$), significantly higher than Group III on day 30 ($P<0.05$), and significantly higher than Group II on day 45 ($P<0.05$).

2.2.3 Serum and Urine Uric Acid Content

As shown in Table 5 , serum uric acid content in Group III was significantly higher than Group V on day 45 ($P<0.05$). On days 75 and 90, serum uric acid content was highest in Group V and lowest in Group II, with Group V being significantly higher than the other four groups ($P<0.05$ or $P<0.01$). Urine uric acid content in Group V was significantly higher than the other four groups on days 15 and 30 ($P<0.05$ or $P<0.01$). On days 75 and 90, urine uric acid content in Group III was significantly higher than the other four groups ($P<0.05$ or $P<0.01$).

2.3 Urolithiasis Incidence

As shown in Table 6 , no urolithiasis occurred in Groups I and II, while 3, 4, and 5 goats developed urolithiasis in Groups III, IV, and V, respectively. The first case appeared in Group V on day 38.

Discussion

3.1 Effect of DCAB Value on Growth Performance of Liaoning Cashmere Goats

Tucker et al. [12] reported that feed intake decreased with decreasing DCAB values. Some researchers have suggested that feed intake is highest when the DCAB value for lambs is 450 mEq/kg DM [13]. The lower average daily feed intake observed at DCAB values of 0 and 150 mEq/kg DM compared to 600 mEq/kg DM may be attributed to the generally poor palatability of anionic salts, which can affect animal feed intake [14].

3.2 Effect of DCAB Value on Serum and Urine Biochemical Indices of Liaoning Cashmere Goats

Studies have shown that abnormally elevated serum urea content often indicates abnormal renal function [15]. In this experiment, when the DCAB value was 600 mEq/kg DM, serum urea content was highly significantly higher than at DCAB values of 0, 150, 300, and 450 mEq/kg DM on days 75 and 90, while urine urea content was highly significantly lower than at a DCAB value of 300 mEq/kg DM on day 75 and significantly or highly significantly lower than other groups on day 90. Since urea is filtered by the glomeruli and excreted in urine, decreased glomerular filtration rate due to renal parenchymal damage can increase serum urea content and decrease urine urea content. Therefore, the observed results may be attributed to abnormal renal function. The DCAB value of 150 mEq/kg DM resulted in smaller fluctuation ranges and lower levels of serum urea content compared to DCAB values of 0, 300, 450, and 600 mEq/kg DM, along with higher average daily gain, possibly because this diet improved amino acid balance in the goats and enhanced protein utilization [16].

Sun et al. [17] considered increased serum creatinine content as a marker of impaired glomerular filtration function, representing renal dysfunction or failure. In this experiment, no significant differences in serum creatinine content were observed among groups during days 0-45. On day 75, serum creatinine content at DCAB values of 450 and 600 mEq/kg DM was higher than at DCAB values of 0, 150, and 300 mEq/kg DM, significantly exceeding normal levels [18]. This may be because creatinine is primarily filtered by the glomeruli and excreted in urine. Due to strong renal compensatory capacity, serum creatinine may remain at normal levels during early or mild glomerular damage, but increases rapidly when glomerular filtration function severely declines, while urine creatinine content decreases. Therefore, these results suggest that renal function may have been severely impaired or failed at DCAB values of 450 and 600 mEq/kg DM.

Most uric acid in the body is excreted by the kidneys through urine. Under normal conditions, the rate of uric acid production and renal excretion is in dynamic equilibrium, maintaining relatively constant serum uric acid levels [19-20]. This experiment found that at a DCAB value of 600 mEq/kg DM, serum uric acid content was significantly or highly significantly higher than at DCAB values of 0, 150, 300, and 450 mEq/kg DM on days 75 and 90, while urine uric acid content was lower. This may be because kidney damage disrupts this balance, reducing uric acid excretion and causing retention in the body, which elevates serum uric acid content. High serum uric acid content indicates accelerated protein catabolism and decreased synthesis of nitrogenous substances, which is detrimental to growth.

3.3 Effect of DCAB Value on Urolithiasis Incidence in Liaoning Cashmere Goats

Renal damage can cause increased serum urea, creatinine, and uric acid content [15]. In this experiment, goats fed diets with DCAB values of 300, 450, and 600 mEq/kg DM showed abnormal serum and urine urea, creatinine, and uric acid content. Urea and creatinine are primarily excreted through glomerular filtration. When renal parenchyma is damaged, decreased or impaired glomerular filtration function can rapidly increase serum urea and creatinine content while decreasing urine urea and creatinine content, potentially causing renal damage in goats. This leads to reduced uric acid excretion, retention of uric acid in the body, and increased serum uric acid content. Concurrently, renal dysfunction or failure impairs glomerular filtration and tubular reabsorption, easily altering the internal environment and causing metabolic disorders of various minerals and nutrients, thereby promoting urolithiasis formation.

Conclusion

1. DCAB value affected average daily feed intake but not average daily gain in Liaoning cashmere goats. High DCAB values increased average daily feed intake, while a DCAB value of 150 mEq/kg DM resulted in lower feed-to-gain ratio.
2. With increasing DCAB values, serum urea and creatinine content increased in Liaoning cashmere goats. At a DCAB value of 150 mEq/kg DM, serum and urine urea content showed smaller fluctuation ranges and lower levels, while creatinine content remained relatively constant.
3. Liaoning cashmere goats developed urolithiasis at DCAB values of 300, 450, and 600 mEq/kg DM, while no urolithiasis occurred at DCAB values of 0 and 150 mEq/kg DM.

4. Comprehensive analysis indicates that a DCAB value of 150 mEq/kg DM is beneficial for maintaining normal levels of certain serum and urine biochemical indices and for preventing urolithiasis in Liaoning cashmere goats.

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