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

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Abstract

This experiment was conducted to investigate the effects of dietary energy levels on growth performance and serum biochemical indices of Laoshan dairy goats during the rearing period. Thirty growing female Laoshan dairy goats with similar body weight [(18.43$\pm$0.76) kg] were selected and randomly allocated to 3 groups using a single-factor design, with 10 replicates per group and 1 goat per replicate. The goats were fed three diets with essentially consistent levels of crude protein, calcium, and phosphorus, but with digestible energy (DE) levels of 10.40, 11.47, and 12.51 MJ/kg, respectively. The results showed that: 1) The dry matter intake of the 10.40 MJ/kg group at 7 and 8 months of age was significantly lower than that of the 12.51 MJ/kg group ($P<0.05$), while there was no significant difference among the three groups at 9 months of age ($P<0.05$). 2) The body weight of the 10.40 MJ/kg group at 8 and 9 months of age was significantly lower than that of the 11.47 and 12.51 MJ/kg groups ($P<0.05$); the 10.40, 11.47, and 12.51 MJ/kg groups increased by 141.22%, 157.40%, and 158.09%, respectively, compared with pre-trial values. At 8 months of age, the chest girth and abdominal girth of the 10.40 MJ/kg group were significantly lower than those of the 12.51 MJ/kg group ($P<0.05$), and at 9 months of age, the chest girth and rump length of the 10.40 MJ/kg group were also significantly lower than those of the 12.51 MJ/kg group ($P<0.05$). 3) The serum urea nitrogen content of the 10.40 MJ/kg group was significantly higher than that of the 11.47 and 12.51 MJ/kg groups ($P<0.05$). The serum total cholesterol content of the 10.40 MJ/kg group was significantly lower than that of the 12.51 MJ/kg group ($P<0.05$). The serum triglyceride content of the 10.40 MJ/kg group was significantly lower than that of the 11.47 MJ/kg group ($P<0.05$) and extremely significantly lower than that of the 12.51 MJ/kg group ($P<0.01$). Based on the above results and considering feeding costs, the optimal dietary digestible energy level for dairy goats is 11.47 MJ/kg.

Full Text

Effects of Dietary Energy Level on Growth Performance and Serum Biochemical Indices of Growing Laoshan Dairy Goats

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Abstract

This experiment was conducted to investigate the effects of dietary energy level on growth performance and serum biochemical indices of growing Laoshan dairy goats. Thirty growing Laoshan dairy goat does with similar body weight [(18.43$±$0.76) kg] were randomly allocated to 3 groups using a single-factor design, with 10 replicates per group and 1 goat per replicate. The goats were fed three diets with consistent crude protein, calcium, and phosphorus levels but with digestible energy (DE) levels of 10.40, 11.47, and 12.51 MJ/kg, respectively. The results showed: 1) Dry matter intake (DMI) in the 10.40 MJ/kg group was significantly lower than in the 12.51 MJ/kg group at 7 and 8 months of age ($P<0.05$), with no significant differences among the three groups at 9 months of age ($P>0.05$). 2) Body weight in the 10.40 MJ/kg group was significantly lower than in the 11.47 and 12.51 MJ/kg groups at 8 and 9 months of age ($P<0.05$). Compared with pre-trial weights, the 10.40, 11.47, and 12.51 MJ/kg groups increased by 141.22%, 157.40%, and 158.09%, respectively. At 8 months, chest circumference and abdominal circumference in the 10.40 MJ/kg group were significantly lower than in the 12.51 MJ/kg group ($P<0.05$). At 9 months, chest circumference and rump length in the 10.40 MJ/kg group were also significantly lower than in the 12.51 MJ/kg group ($P<0.05$). 3) Serum urea nitrogen content in the 10.40 MJ/kg group was significantly higher than in the 11.47 and 12.51 MJ/kg groups ($P<0.05$). Serum total cholesterol content in the 10.40 MJ/kg group was significantly lower than in the 12.51 MJ/kg group ($P<0.05$). Serum triglyceride content in the 10.40 MJ/kg group was significantly lower than in the 11.47 MJ/kg group ($P<0.05$) and extremely significantly lower than in the 12.51 MJ/kg group ($P<0.01$). Based on these results and considering feeding costs, the optimal dietary digestible energy level for dairy goats is 11.47 MJ/kg.

Keywords: growing period; Laoshan dairy goat; growth performance; serum biochemical indices

1. Materials and Methods

1.1 Experimental Animals and Design

Thirty healthy Laoshan dairy goat does at approximately 170 days of age with body weight (18.43$±$0.76) kg were selected and randomly divided into three groups (A, B, and C) using a single-factor randomized design according to the principle of weight balance, with 10 replicates per group and 1 goat per replicate. The experiment was conducted at Qingdao Aote Dairy Goat Farm from August 2014 to November 2014, with a 100-day trial period consisting of a 10-day pre-trial period and a 90-day formal trial period.

1.2 Experimental Diets

Based on the digestible energy (DE) levels recommended by the NRC (2007) goat feeding standards, three experimental diets with consistent calcium, phosphorus, and protein levels were formulated with DE levels of 10.40, 11.47, and 12.51 MJ/kg, respectively. The composition and nutrient levels are shown in Table 1 . Diets were fed as total mixed rations.

Table 1 Composition and nutrient levels of experimental diets (DM basis) %

Items	Group A	Group B	Group C
Ingredients			
Corn silage			
Peanut vine			
Corn			
Soybean meal			
Wheat bran			
NaCl			
$CaHPO_4$			
Limestone			
Premix[1])			
Total			
Nutrient levels[2])			
DE/(MJ/kg)			
Crude protein CP			
Neutral detergent fiber NDF			
Acid detergent fiber ADF			
Calcium Ca			

[1]) Premix provided 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]) Nutrient levels were measured values.

1.3 Feeding Management

Experimental goats were housed individually in single pens and fed quantitatively at 06:30, 12:00, and 18:00 daily. They were driven to exercise in a playground during fixed time periods, provided with adequate clean drinking water, and the experimental site was kept clean. Deworming and immunization of experimental goats were carried out strictly according to the farm procedures. Feeding and management conditions were identical among all groups.

1.4 Digestion and Metabolism Trial

After the feeding trial, 5 goats from each group with body weight close to the group average were selected and housed in specialized digestion and metabolism cages. A digestion and metabolism trial was conducted using the total collection of feces and urine method, with a 7-day pre-trial period and a 3-day sampling period. Diet composition and feeding methods were the same as in the feeding trial. Feed intake and orts were recorded, and orts were collected and dried at 65 °C to make air-dried samples for storage. Feces and urine were collected continuously for 3 days. Fecal samples (10% of daily fecal output) were mixed with 10% tartaric acid solution (1/4 of fecal weight), dried to constant weight in a 65 °C oven, and preserved as air-dried samples with proper labeling and data recording. Daily urine was filtered through 8 layers of gauze, 10% H_2SO_4 was added, and finally 5% of the 3-day urine samples were mixed and preserved with proper labeling and stored at -20 °C.

1.5 Measurement Indicators and Methods

1.5.1 Determination of Dietary Nutrient Composition Dietary digestible energy was determined using an oxygen bomb calorimeter according to Zhang Liying [3]. Crude protein content was determined by the Kjeldahl method. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined according to the method proposed by Van Soest [4]. Calcium content was determined by potassium permanganate titration, and phosphorus content was determined by molybdenum yellow colorimetry.

1.5.2 Dry Matter Intake (DMI) Feeding amount and residual amount were accurately recorded before and after feeding daily. The initial water content of residual feed was determined within 2 hours of sampling to calculate dietary dry matter intake (DMI).

1.5.3 Body Weight and Body Size Measurements Experimental goats in all three groups were weighed and measured for body size on two consecutive days before morning feeding at the start of the trial and on days 30, 60, and 90 of the formal trial period, representing body weight and body size at 7, 8, and 9 months of age, respectively. Body weight gain and average daily gain (ADG) during the trial period were calculated.

1.5.4 Serum Biochemical Indices Blood samples were collected on days 1 and 90 of the trial. Jugular blood (5 ml) was collected using heparin sodium anticoagulant tubes, centrifuged at 3,818×g for 10 minutes, and the supernatant was transferred to 2 mL centrifuge tubes and stored at -80 °C. After the trial, total protein (TP), albumin (ALB), globulin (GLB), urea nitrogen (UN), total cholesterol (TC), and triglyceride (TG) contents, as well as glutamic-pyruvic transaminase (GPT) and glutamic-oxaloacetic transaminase (GOT) activities were determined using kits and methods provided by Nanjing Jiancheng Bioengineering Institute.

1.5.5 Gross Energy Digestibility, Gross Energy Metabolic Rate, and Digestible Energy Metabolic Rate Based on the determination results of gross energy in the three diets and their feces and urine, combined with methane energy estimation results, the following formulas were used for calculation:

Gross energy digestibility (%) = (GE - FE) / GE × 100
Gross energy metabolic rate (%) = (GE - FE - UE - ECH_4) / GE × 100
Digestible energy metabolic rate (%) = (GE - FE - UE - ECH_4) / (GE - FE) × 100

Where: GE = gross energy; FE = fecal energy; UE = urinary energy; ECH_4 = methane energy, calculated using the Blaxter (1965) method, ECH_4 (% GE) = 3.67 + 0.062D (D is the apparent digestibility of gross energy intake of experimental does). It was estimated that the average value for the three groups in this trial was 7.15 times the gross energy.

1.6 Data Statistics and Analysis

Experimental data were organized using Excel software and analyzed using SPSS 20.0.0 software for variance analysis. LSD and Duncan' s methods were used for inter-group difference significance tests. Experimental data were expressed as "mean ± standard error" .

2. Results

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

2.1.1 Effects of Dietary Energy Level on DMI of Growing Laoshan Dairy Goats As shown in Table 2 , DMI of goats in group A at 7 and 8 months of age was significantly lower than that in group C ($P<0.05$), with no significant difference from group B ($P>0.05$). There was no significant difference in feed intake among the three groups at 9 months of age ($P>0.05$).

Table 2 Effects of different energy levels on DMI of Laoshan dairy goats kg/(d · goat)

Items	Pre-test period	7-month-old	8-month-old	9-month-old	Average
Group A	0.78±0.02	0.98±0.25^a	1.23±0.03^a	1.34±0.04	1.08±0.25
Group B	0.80±0.03	1.01±0.29^{ab}	1.30±0.02^{ab}		

In the same row, values with no letter or the same letter superscripts mean no significant difference (P>0.05), while different small letter superscripts mean significant difference (P<0.05), and different capital letter superscripts mean significant difference (P<0.01). The same as below.

2.1.2 Effects of Dietary Energy Level on Body Weight of Growing Laoshan Dairy Goats As shown in Table 3 , weight gain in group A was relatively low at 7 months, but showed a significant increasing trend at 8 and 9 months. Body weight of goats in group A at 8 and 9 months of age was significantly lower than that in groups B and C (P<0.05). Groups A, B, and C increased by 41.22, 57.40, and 58.09 kg compared with pre-trial weights, respectively. ADG in groups B and C was significantly higher than in group A (P<0.05).

Table 3 Effects of different energy levels on body weight of Laoshan dairy goats

Items	Pre-test	7-month-old	8-month-old	9-month-old	ADG (g)
Group A	18.10±0.67	18.20±0.64	20.94±0.99^a	25.56±0.56^a	63.43±5.67^a
Group B	18.85±0.55	18.90±0.53	23.3		

2.1.3 Effects of Dietary Energy Level on Body Size of Growing Laoshan Dairy Goats As shown in Table 4 , chest circumference and abdominal circumference of goats in group A at 8 months of age were significantly lower than those in group C (P<0.05). At 9 months of age, chest circumference and rump length of goats in group A were also significantly lower than those in group C (P<0.05). Dietary energy level had no significant effect on body height, body length, chest depth, chest width, sacral width, rump height, or cannon bone circumference among the three groups (P>0.05).

Table 4 Effects of different energy levels on body size of Laoshan dairy goats cm

Items	Month of age	Group A	Group B	Group C
Body height	7	54.5±0.90	54.45±0.48	53.6±0.92
	8	56.78±1.24	55.28±0.78	55.83±0.98
	9			

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

As shown in Table 5 , there were no significant differences in serum GPT and GOT activities or TP, ALB, and GLB contents on days 1 and 90 (P>0.05). On day 90, serum UN content in group A was significantly higher than in groups B and C (P<0.05), with no significant difference between groups B and C (P>0.05). Serum TC content in group A was significantly lower than in group C (P<0.05), but not significantly different from group B (P>0.05). Serum TG content in group A was significantly lower than in group B (P<0.05) and extremely significantly lower than in group C (P<0.01), with no significant difference between groups B and C (P>0.05).

Table 5 Effects of different energy levels on serum biochemical indices of Laoshan dairy goats

Items	Day 1	Day 90
GPT (U/L)	94.55$±8.89¦92.67±5.61¦¦$GOT(U/L)$¦93.00±10.21¦88.63±4.61¦¦$TP(g/L)$¦94.50±4.76¦	

2.3 Effects of Different Energy Levels on Digestion and Metabolism of Laoshan Dairy Goats

As shown in Table 6 , the gross energy intake of goats in groups A, B, and C was 14.25, 16.20, and 17.07 MJ/d, respectively, with significant differences among groups (P<0.05). Fecal energy excreted by goats in groups A, B, and C was 5.80, 6.14, and 6.31 MJ/d, respectively, increasing with dietary energy level, with significant differences among groups (P<0.05). With increasing dietary energy level, methane energy emission showed an increasing trend, with groups B and C being significantly higher than group A (P<0.05), but no significant difference between groups B and C (P>0.05). The gross energy digestibility, gross energy metabolic rate, and digestible energy metabolic rate of the three groups increased with dietary energy level, with group A being significantly lower than group C (P<0.05), but not significantly different from group B (P>0.05).

Table 6 Effects of different energy levels on digestion and metabolism of Laoshan dairy goats

Items	Group A	Group B	Group C
GE (MJ/d)	14.25$±0.15$[a]¦16.20±0.10[b] [illegible] (MJ/d)		

3. Discussion

3.1 Effects of Different Energy Levels on Growth Performance of Growing Laoshan Dairy Goats

Different dietary energy levels had certain effects on the growth performance of growing Laoshan dairy goats. Appropriately increasing the dietary energy level of Laoshan dairy goats was beneficial for body weight gain and reduced feed-to-gain ratio.

3.1.1 Effects of Different Energy Levels on DMI of Growing Laoshan Dairy Goats Ruminant DMI is affected by many factors, and dietary energy level is an important factor affecting ruminant DMI from the perspective of dietary nutritional factors. Studies have shown that within a certain range, DMI increases with increasing energy level, but will not continue to increase and may even decrease when exceeding a certain threshold [5]. Xue Jianfeng et al. [6] found that when studying the effects of energy level on dietary digestibility of Zhongwei goat wethers, the DMI of Zhongwei goat wethers with energy levels of 9.53 and 10.41 MJ/kg was higher than that with 8.71 MJ/kg, but the difference was not significant. Zhou Hanlin et al. [7] found that when studying growing Hainan black goats, the DMI of goats with dietary energy level of 13.02 MJ/kg was greater than that with 11.72 MJ/kg when protein level was 10.71%. These results are consistent with the findings of this experiment.

3.1.2 Effects of Different Energy Levels on Body Weight of Growing Laoshan Dairy Goats Dietary energy level plays a key role in animal growth and development. Studies have shown that providing weaned lambs with diets containing higher energy levels is beneficial for their weight gain, and the higher the energy level in the diet, the faster the weight gain of goats [8]. Zhang Shuanlin et al. [9] showed that ADG of all experimental goats increased with increasing dietary energy level, with sheep ADG being significantly higher than that of goats, and ADG in the high-energy group being extremely significantly higher than in the low-energy group. He Renchun et al. [10] studied the effects of different digestible energy levels on growth performance of growing black goats and found that as dietary digestible energy level increased, goat ADG first increased and then decreased, with ADG of goats fed diets with digestible energy levels of 11.20, 11.50, and 11.77 MJ/kg being 122, 134, and 132 g, respectively. These results are not consistent with the findings of this experiment, possibly due to differences in experimental animal breeds and feeding environments. Cui Xiang [11] studied the effects of dietary energy level on growth, digestion, metabolism, and rumen environment of 4-6 month old calves fed diets with 6.24, 7.04, 7.53, and 7.85 MJ/kg, and found that ADG of the four groups was 0.64, 0.75, 0.78, and 0.84 kg, respectively, with no significant differences among groups, but at 6 months of age, ADG in the 7.85 MJ/kg group was significantly higher than in the 6.24 MJ/kg group. Zhang Rong et al. [12] also found that ADG of calves fed diets with 19.66 MJ/kg energy level was higher than those fed 18.51 and 20.80

MJ/kg, which is similar to the results of this experiment. Qiao Zhi [13] studied the effects of different energy levels of concentrate on growth performance and nutrient apparent digestibility of 1-year-old housed yaks and found that ADG of goats in the 6.20 MJ/kg and 6.90 MJ/kg groups was significantly higher than in the 5.50 MJ/kg group, but there was no significant difference between the 6.20 MJ/kg and 6.90 MJ/kg groups, which is consistent with the results of this experiment.

3.1.3 Effects of Different Energy Levels on Body Size of Growing Laoshan Dairy Goats Animal body size indices are important indicators of animal growth and development, showing the relationship between nutritional status and genetic potential [14]. In this experiment, all body size indices of Laoshan dairy goats increased with increasing dietary energy level. Among the increases in various body size indices, chest circumference showed the greatest increase, followed by abdominal circumference and body length. It was also found that dietary energy level had no significant effect on serum GPT, GOT, TP, ALB, and GLB contents.

3.2 Effects of Different Energy Levels on Serum Biochemical Indices of Growing Laoshan Dairy Goats

The metabolic patterns of blood biochemical substances can effectively reflect the status of nutrient supply. Dietary nutritional level directly affects serum GPT and GOT activities and UN, TP, ALB, GLB, TG, and TC contents. Changes in TP, ALB, and UN contents in serum reflect protein metabolism and absorption in the animal body and are closely related to animal growth performance.

3.2.1 Effects of Different Energy Levels on Serum GPT and GOT Activities of Growing Laoshan Dairy Goats GPT and GOT are widely present in animal liver cells, and their activity changes are two important indicators reflecting liver cell and heart cell damage. Under normal conditions, GPT and GOT activities are relatively stable. When heart and liver tissue cells undergo inflammation, necrosis, poisoning, etc., causing cell damage or under heat/cold stress conditions, transaminases are released into the blood, increasing serum transaminase activity [15]. Under the conditions of this experiment, both GPT and GOT activities were within the normal range, indicating that the experimental diets had no adverse effects on the liver of experimental goats.

3.2.2 Effects of Different Energy Levels on Serum UN Content of Growing Laoshan Dairy Goats Blood UN in ruminants originates from ammonia nitrogen absorbed through the rumen wall and protein breakdown in body tissues and is related to ammonia nitrogen concentration in the rumen [16]. Serum UN reflects protein metabolism and amino acid balance in animals. When its content decreases, it indicates higher protein synthesis rate and good amino acid balance. When its content is too high, nitrogen is excreted in the form of urea or gas, reducing nitrogen utilization efficiency in feed. UN content is negatively correlated with nitrogen deposition rate, protein or amino acid utilization rate, and has a certain relationship with dietary energy level [17]. Malmolf et al. [18] found that serum UN content can accurately reflect protein metabolism and amino acid balance in animals, with lower UN content indicating higher nitrogen utilization efficiency. Gong Feng et al. [19] studied the effects of different dietary energy levels on growth performance and serum biochemical indices of fattening dairy goat wethers and found that serum UN content in goats fed 9.29 MJ/kg was significantly higher than in those fed 10.00 and 10.70 MJ/kg. In this experiment, under the same protein level condition, dietary energy level in group A was lower than in groups B and C, and serum UN content in group A was significantly higher than in groups B and C, proving that high-energy diets can significantly improve serum biochemical indices and further demonstrating that high-energy diets are beneficial for improving growth performance of dairy goats. This is also basically consistent with the results of Hu Weilian [20] in studying the effects of saponins on rumen fermentation, methane production, and animal growth performance.

3.2.3 Effects of Different Energy Levels on Serum TP, ALB, and GLB Contents of Growing Laoshan Dairy Goats TP includes ALB and GLB. High TP content is beneficial for improving metabolic level and immunity. It is generally believed that TP content is related to animal protein nutritional supply status and body growth performance. Its increase is a manifestation of vigorous protein metabolism, which is beneficial for protein absorption and utilization in the body, thereby reducing feed consumption [21]. Cheng Zhigang et al. [22] showed that blood TP can reflect animal digestion and metabolism levels of nutrients to a certain extent, and higher TP content in blood indicates enhanced protein utilization efficiency in animals. This experiment found that with increasing dietary energy level, serum TP, ALB, and GLB contents did not change significantly, and the reasons need further study.

3.2.4 Effects of Different Energy Levels on Serum TG and TC Contents of Growing Laoshan Dairy Goats Blood TG and TC are both blood lipids and are closely related to energy metabolism. TG is the most abundant lipid in the body and is the main form of energy storage in animals. It can be utilized and decomposed by various tissues in the animal body to provide energy and can be synthesized and stored in tissues such as liver and fat. Blood TC mainly comes from endogenous synthesis, with a small portion from exogenous (feed) absorption [23]. Serum TG and TC contents reflect lipid metabolism status in the body, and their increase often causes diseases in kidneys, cardiovascular system, and cerebrovascular system. From the perspective of modern animal husbandry development and human demand for animal products, how to reduce body fat and TC content has become an urgent problem in livestock production. Studies have shown that increasing dietary energy level can significantly increase plasma TG and TC contents [24]. Zhai Zhenzhen et al. [25] showed that with increasing concentrate level and dietary energy level, serum TG content in dairy cows gradually increased. Li Xin et al. [26] also found that TC and TG contents in Saanen goats showed an increasing trend with increasing dietary energy level. This is similar to the finding of this experiment that serum TC and TG contents gradually increased with increasing energy level.

3.3 Effects of Different Energy Levels on Digestion and Metabolism of Growing Laoshan Dairy Goats

Under normal conditions, with increasing dietary energy level, the excretion of fecal energy and urinary energy also increases accordingly. Zhang Zhenwei [27] studied Zhongwei goat growing does and found that increasing dietary energy level significantly improved gross energy digestibility and metabolic rate. Wang Hui [28] showed that both gross energy metabolic rate and digestible energy metabolic rate of non-pregnant Northern Shaanxi white cashmere goat does increased significantly with increasing dietary energy level, which is consistent with the results of this experiment. Zhao Minmeng et al. [29] fed Qingshan goat wethers diets with digestible energy levels of 8.91, 9.79, and 10.62 MJ/kg and found that under the 9.79 MJ/kg energy level, digestible energy and metabolic energy intake were relatively high, which was a more suitable energy level.

Within a certain range of dietary energy levels, increasing the energy level of growing Laoshan dairy goats can increase ADG and reduce feed-to-gain ratio. Considering feeding costs, under the conditions of this experiment, the recommended dietary digestible energy level is 11.47 MJ/kg. Dietary energy level has significant effects on serum UN, GPT, ALB, TG, and TC contents in Laoshan dairy goats. To maintain serum biochemical indices of dairy goats, 11.47 MJ/kg is optimal in this experiment.

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