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Effects of Dietary Energy and Protein Levels on Growth Performance, Serum Biochemical Indices, Slaughter Performance, and Meat Quality of Shaanbei White Cashmere Goats (Postprint)

Authors: Tang Peng, Wang Yaoyue, Wang Guojun, Chen Yulin, Yuxin Yang

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Abstract

This study aimed to investigate the effects of dietary energy and protein levels on growth performance, serum biochemical indices, slaughter performance, and meat quality of Shaanbei white cashmere goats. Seventy-six Shaanbei white cashmere goats aged 8–9 months were selected and randomly divided into 2 groups, with 38 goats per group. The experimental group had a metabolizable energy of 9.24 MJ/kg and a crude protein content of 9.37%, while the control group had a metabolizable energy of 8.60 MJ/kg and a crude protein content of 8.73%. The experimental period lasted 65 days, with the first 10 days serving as a preliminary period. The results showed that average daily gain, dressing percentage, loin eye area, GR value, and crude fat content in the experimental group were significantly higher than those in the control group ($P<0.05$); no significant differences were observed between the two groups in other growth performance indices (final body weight, dry matter intake, feed conversion ratio), slaughter performance indices (carcass weight, carcass cuts and proportions), meat quality indices, or serum biochemical indices ($P>0.05$). These results suggest that during the fattening stage of Shaanbei white cashmere goats, increasing dietary crude protein content from 8.73% to 9.37% and metabolizable energy from 8.60 MJ/kg to 9.24 MJ/kg can significantly improve growth performance and slaughter performance.

Full Text

Effects of Dietary Energy and Protein Levels on Growth Performance, Serum Biochemical Indices, Slaughter Performance and Meat Quality of Shanbei White Cashmere Goats

TANG Peng, WANG Yaoyue, WANG Guojun, CHEN Yulin, YANG Yuxin*

College of Animal Science and Technology, Northwest A&F University, Yangling 712100, China

Abstract

This study investigated the effects of dietary energy and protein levels on growth performance, serum biochemical indices, slaughter performance, and meat quality of Shanbei white cashmere goats. Seventy-six healthy goats aged 8–9 months were randomly divided into two groups (38 goats per group). The experimental group received a diet with metabolizable energy of 9.24 MJ/kg and crude protein content of 9.37%, while the control group received 8.60 MJ/kg metabolizable energy and 8.73% crude protein. The 65-day trial included a 10-day preliminary period. Results showed that average daily gain, slaughter rate, loin muscle area, GR value, and ether extract content were significantly higher in the experimental group compared to the control group ($P<0.05$). No significant differences were observed between groups in other growth performance indices (final body weight, dry matter intake, feed-to-gain ratio), slaughter performance indices (carcass weight, carcass cuts and proportions), meat quality indices, or serum biochemical indices ($P>0.05$). These findings suggest that increasing dietary crude protein from 8.73% to 9.37% and metabolizable energy from 8.60 MJ/kg to 9.24 MJ/kg during the fattening stage can significantly improve growth and slaughter performance in Shanbei white cashmere goats.

Keywords: Shanbei white cashmere goat; energy level; protein level; growth performance; slaughter performance; meat quality

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Shanbei white cashmere goat is a unique local breed in northern Shaanxi Province, utilized for both cashmere and meat production. Developed by crossing Liaoning cashmere goats (male) with local black goats (female), this breed is characterized by high-quality cashmere fibers, high cashmere yield per unit body weight, and stable genetic traits [1]. The breed generates substantial income for local farmers and herders in northern Shaanxi and has become a key tool in poverty alleviation efforts. With improving living standards, goat meat has gained popularity among consumers due to its high protein, low fat, and low cholesterol characteristics [2]. To enhance the comprehensive economic benefits of Shanbei white cashmere goats, research is needed on how dietary energy and protein levels affect meat production performance under intensive feeding conditions, laying the foundation for developing the breed’ s meat production potential. Previous studies on Shanbei white cashmere goats have examined slaughter performance of castrated goats [3], growth curves of lactating lambs [4], and routine nutrient levels in yearling castrated goats [5], providing valuable guidance for goat feeding. However, few studies have comprehensively analyzed these indices together. This experiment systematically examined changes in growth performance, serum biochemical indices, slaughter performance, and meat quality of Shanbei white cashmere goats under different dietary energy and protein levels, providing theoretical guidance for production practices.

1.1 Experimental Animals and Design

Seventy-six healthy Shanbei white cashmere goats aged 8–9 months were selected and divided into two groups according to a randomized block design [control group: (19.40±3.71) kg; experimental group: (18.99±4.45) kg] for a 65-day feeding trial (including a 10-day preliminary period). Experimental diets were formulated according to the *Feeding Standard of Meat Sheep* (NY/T 816-2004) to meet the nutritional requirements of fattening lambs with body weight of 20 kg and daily gain of 100 g. The control diet contained 8.60 MJ/kg metabolizable energy and 8.73% crude protein, while the experimental diet contained 9.24 MJ/kg metabolizable energy and 9.37% crude protein. Diet composition and nutrient levels are presented in Table 1 . Nutrient levels were calculated based on the *Feed Composition and Nutritive Values in China (27th Edition, 2016)*. Before the trial, the goat house was thoroughly cleaned. Goats were fed twice daily at fixed times with free access to feed and water.

Table 1 Composition and Nutrient Levels of Experimental Diets (DM Basis)

Items	Content
	Control group
Ingredients	
Corn	
Wheat bran	
Soybean meal	
Soybean oil	
Corn stalks	
Dried alfalfa hay	
Limestone	
CaHPO ·2H O	
NaCl	
Premix[1]	
Total	
Nutrient levels[2]	
Crude protein (CP)	

Items	Content
Metabolizable energy (ME) [MJ/kg]	
Ether extract (EE)	
Nitrogen-free extract (NFE)	
Neutral detergent fiber (NDF)	
Acid detergent fiber (ADF)	

[1]The premix provided per kg of diet: VA 600,000 IU, VD 200,000 IU, VE 2,000 IU, Fe 15 g, Zn 15 g, Cu 4.5 g, I 200 mg, Mn 10 g.
[2]Nutrient levels are calculated values.

1.2 Sample Collection and Measurement

Goats were fed equal amounts at 08:30 and 16:00 daily, with feed intake recorded each day. Initial body weight was recorded at the start of the trial, and final body weight was recorded at the end. Twelve goats (six randomly selected from each group) were slaughtered after 24-hour fasting and 2-hour water restriction. Blood samples were collected before slaughter.

Blood was collected from the jugular vein into vacuum tubes containing coagulation accelerator, left to stand for 15 minutes, then centrifuged at 1,509.3×g for 10 minutes. The serum supernatant was stored at -20°C and sent to Yangling Demonstration Zone Hospital in Xianyang, Shaanxi Province for subsequent determination of serum biochemical indices using an automatic biochemical analyzer. Measured indices included total protein (TP), albumin (ALB), globulin (GLO), urea nitrogen (UN), glucose (GLU), triglyceride (TG), and total cholesterol (TC) concentrations.

1.2.2 Slaughter Index Measurement **Carcass weight:** After slaughter and bloodletting, the carcass was skinned and removed of internal organs, head, and parts below the front knee joint and hind toe joint, then weighed after standing for 30 minutes [6].

GR value: The tissue thickness measured at 11 cm from the dorsal midline between the 12th and 13th ribs [6].

Slaughter rate: The proportion of carcass weight to live body weight.

Loin muscle area: The outline of the longissimus dorsi muscle between the first and second to last ribs was traced on sulfuric acid drawing paper, and the area was measured using a CS-1 planimeter [7].

1.2.3 Meat Quality Measurement Meat quality indices were measured according to reference methods [8].

pH: The pH of the meat was measured 45 minutes and 24 hours post-mortem.

Water loss rate: The proportion of water lost after applying external pressure for a certain period relative to the pre-pressed weight.

Cooking loss rate: The proportion of weight retained after high-temperature cooking relative to the original weight. Meat samples were cooked on a 2,000 W induction cooker for 45 minutes, removed, cooled at room temperature for 30 minutes, and the retained weight was recorded.

Drip loss: The amount of fluid lost from meat samples without external force. Meat samples were suspended in an inflated plastic bag and stored at 4°C for 24 hours; drip loss was calculated as the ratio of water lost to initial weight.

Tenderness: Measured using a C-LM muscle tenderness meter.

Meat color: Measured using a carcass muscle color meter (OPTO-STAR, Matthaus, Germany).

1.2.4 Determination of Routine Nutrient Composition in Meat **Dry matter content:** A meat sample of known weight was placed in a clean, dry weighing bottle and dried in an oven at 105°C for 8 hours until the difference between two consecutive weighings was less than 0.0005 g. The resulting weight represented the dry matter content of the sample.

Gross energy: Determined using an oxygen bomb calorimeter on dried meat samples.

Crude protein content: Determined using a semi-Kjeldahl nitrogen analyzer.

Ether extract: Determined using the Soxhlet extraction method.

1.2.5 Carcass Segmentation and Cutting The goat carcasses were divided into 10 parts: fore shank, hind shank, neck, breast, belly, shoulder, back, loin, rump, and chump. The segmentation method followed the *Technical Specification for Mutton Cutting* (NY/T 1564-2007) [9]. According to Zhao Youzhang [10], these 10 parts can be classified into different commercial grades: shoulder, back, loin, rump, and chump are premium cuts; neck, breast, and belly are second-grade cuts; and fore shank and hind shank are third-grade cuts [11]. The proportions of premium, second-grade, and third-grade cuts were calculated as the weight of each category relative to carcass weight.

1.3 Data Processing

Experimental data were analyzed using SPSS 20.0 statistical software with a one-way ANOVA model and Duncan' s multiple comparison tests. Results are expressed as mean ± standard deviation, with $P<0.05$ considered statistically significant.

2.1 Effects of Dietary Energy and Protein Levels on Growth Performance

As shown in Table 2 , initial body weight did not differ significantly between the control and experimental groups (P>0.05), confirming successful randomization. Average daily gain (ADG) was significantly higher in the experimental group than in the control group (P<0.05). No significant differences were observed in average daily feed intake or feed-to-gain ratio between the two groups (P>0.05).

Table 2 Effects of Dietary Energy and Protein Levels on Growth Performance of Shanbei White Cashmere Goats

Items	Control group	Test group
Initial body weight (kg)	19.40±3.71	18.99±4.45
Final body weight (kg)	24.78±3.91	25.19±4.85
Average daily gain (g)	81.06±9.85	95.37±9.48
Dry matter intake (kg/d)	1.13±0.14	1.14±0.15
Feed-to-gain ratio	13.43±0.78	12.05±0.59

Values in the same row with different letter superscripts differ significantly (P<0.05). The same applies below.

2.2 Effects of Dietary Energy and Protein Levels on Serum Biochemical Indices

Table 3 shows that no serum biochemical indices differed significantly between the control and experimental groups (P>0.05), although serum TP and GLO concentrations tended to increase with higher dietary energy and protein levels.

Table 3 Effects of Dietary Energy and Protein Levels on Serum Biochemical Indices of Shanbei White Cashmere Goats

Items	Control group	Test group
Total protein (TP) (g/L)	59.30±4.83	66.53±2.19
Albumin (ALB) (g/L)	27.08±2.81	27.90±1.36
Globulin (GLO) (g/L)	32.73±1.79	38.67±3.75
ALB/GLO ratio	0.79±0.08	0.75±0.07
Urea nitrogen (UN) (mmol/L)	4.95±1.43	4.69±0.57
Glucose (GLU) (mmol/L)	2.28±0.48	2.03±0.46
Triglyceride (TG) (mmol/L)	0.39±0.12	0.39±0.15
Total cholesterol (TC) (mmol/L)	2.10±0.22	2.35±0.40

2.3 Effects of Dietary Energy and Protein Levels on Slaughter Performance

As shown in Table 4 , slaughter rate was significantly higher in the experimental group than in the control group ($P<0.05$). Carcass weight was slightly higher in the experimental group but did not differ significantly ($P>0.05$). Both loin muscle area and GR value were significantly higher in the experimental group ($P<0.05$).

Table 4 Effects of Dietary Energy and Protein Levels on Slaughter Performance of Shanbei White Cashmere Goats

Items	Control group	Test group
Carcass weight (kg)	11.17±1.64	13.28±2.08
Slaughter rate (%)	44.04±0.87	48.79±0.31
Loin muscle area (cm^2)	19.55±0.85	21.72±0.47
GR value (mm)	7.39±0.70	9.18±0.49

2.4 Effects of Dietary Energy and Protein Levels on Meat Quality

Table 5 shows that compared with the control group, meat color lightness value tended to decrease in the experimental group ($P>0.05$), while redness and yellowness values showed no significant changes ($P>0.05$). Water loss rate and tenderness tended to increase in the experimental group compared with the control group, but these differences were not significant ($P>0.05$). No significant differences were observed between groups in cooking loss rate, drip loss, pH , or pH ($P>0.05$).

Table 5 Effects of Dietary Energy and Protein Levels on Meat Quality of Shanbei White Cashmere Goats

Items	Control group	Test group
Meat color		
Lightness (L*)	37.32±3.55	35.62±1.71
Redness (a*)	11.28±1.52	12.76±1.62
Yellowness (b*)	9.07±1.97	9.68±2.03
Water loss rate (%)	2.26±0.50	3.01±1.01
Tenderness (kgf)	6.36±0.91	8.48±2.07
Cooking loss rate (%)	60.10±1.83	57.42±3.38
Drip loss (%)	13.33±1.66	14.61±1.43
pH	6.53±0.10	6.62±0.12
pH	5.81±0.14	5.72±0.14

2.5 Effects of Dietary Energy and Protein Levels on Routine Nutrient Composition of Meat

As shown in Table 6 , ether extract content in meat was slightly higher in the experimental group than in the control group, but this difference was not significant (P>0.05). No significant differences were observed between groups in dry matter, crude protein content, or gross energy (P>0.05).

Table 6 Effects of Dietary Energy and Protein Levels on Routine Nutrient Composition of Shanbei White Cashmere Goat Meat (DM Basis)

Items	Control group	Test group
Dry matter (%)	24.86±1.19	24.88±0.77
Ether extract (%)	2.89±0.34	4.40±0.67
Crude protein (%)	19.48±0.68	19.24±0.70
Gross energy (MJ/kg)	26.05±0.97	27.13±0.99

2.6 Effects of Dietary Energy and Protein Levels on Carcass Cuts

Table 7 shows that the weights of neck, fore shank, shoulder, back, and loin were lower in the experimental group than in the control group, while breast, belly, rump, chump, and hind shank were slightly higher, though none of these differences were significant (P>0.05). The proportion of premium cuts was slightly higher in the experimental group compared with the control group, with corresponding decreases in second-grade and third-grade proportions.

Table 7 Effects of Dietary Energy and Protein Levels on Carcass Cuts of Shanbei White Cashmere Goats

Items	Control group	Test group
Neck (kg)	0.37±0.11	0.35±0.09
Fore shank (kg)	0.19±0.02	0.18±0.04
Shoulder (kg)	1.49±0.27	1.41±0.21
Back (kg)	0.59±0.11	0.54±0.17
Breast (kg)	0.65±0.04	0.68±0.13
Belly (kg)	0.22±0.48	0.27±0.15
Loin (kg)	0.89±0.19	0.75±0.25
Rump (kg)	0.66±0.15	0.75±0.17
Chump (kg)	0.72±0.12	0.90±0.14
Hind shank (kg)	0.29±0.03	0.31±0.02
Premium cut (kg)	4.38±0.75	4.38±0.78
Second-grade cut (kg)	1.25±0.19	1.32±0.32
Third-grade cut (kg)	0.55±0.04	0.49±0.05
Premium cut proportion (%)	70.68±1.76	71.45±0.81

Items	Control group	Test group
Second-grade cut proportion (%)	21.22±1.97	20.38±0.30
Third-grade cut proportion (%)	9.22±2.65	8.07±0.55

3.1 Effects of Dietary Energy and Protein Levels on Growth Performance

Previous research indicates that within a certain range, animals adjust feed intake according to dietary energy levels, with intake decreasing as energy density increases [12]. The present results demonstrate that increasing dietary energy and protein levels significantly improved ADG in Shanbei white cashmere goats without significantly affecting dry matter intake. However, Yu et al. [13] reported that ADG in goats did not change significantly with different dietary energy levels, possibly due to breed differences. For instance, Zhao [14] found that ADG in cashmere goats increased with dietary energy levels within a certain range. Another influencing factor may be protein level, as Atti et al. [15] showed that increasing dietary crude protein significantly improved ADG in goats. Our results suggest that elevating dietary energy and protein levels benefits growth performance in Shanbei white cashmere goats. The rumen plays a crucial role in ruminants, as rumen microorganisms are primarily responsible for digesting crude fiber and constitute the main site of nutrient digestion. Increasing dietary energy and protein provides adequate nutrients for microorganisms, thereby enhancing their ability to degrade crude fiber [16]. However, excessive energy and protein levels can cause rumen acidosis, disrupt the rumen environment, reduce digestive function [17], and seriously threaten animal health. Plaizier et al. [18] and Pacheco et al. [19] found that excessively high dietary energy and protein levels reduce digestibility in ruminants because they generate large amounts of short-chain fatty acids, lowering rumen pH. Low rumen pH affects normal rumen motility and substantially alters the microbial community. Therefore, when increasing dietary energy and protein levels, careful consideration must be given to animal age, body condition, environment, and other factors to avoid excessive supplementation [20].

3.2 Effects of Dietary Energy and Protein Levels on Serum Biochemical Indices

After digestion and absorption, dietary nutrients are transported via blood circulation to various tissues, organs, and cells, making blood biochemical indices important indicators of nutritional status [21]. Numerous studies have shown that altering dietary nutrient composition and levels affects energy metabolism, which is reflected in blood biochemical indices. Inadequate dietary energy intake may lead to decreased blood GLU concentration [22-24], while Chelikani et al. [23] found that increasing dietary energy levels in cattle elevated serum GLU concentration. UN is the end product of protein metabolism, and serum UN concentration serves as an indicator of protein and amino acid metabolism

[22,24]. In this study, no significant differences in serum biochemical indices were observed between groups, possibly due to breed differences or because the increase in energy and protein levels did not reach a critical threshold. Nevertheless, serum TP and GLO concentrations showed an upward trend, which requires further investigation.

3.3 Effects of Dietary Energy and Protein Levels on Slaughter Performance

The results indicate that improved dietary nutrient levels significantly increased slaughter rate in Shanbei white cashmere goats, suggesting that increasing energy and protein during fattening promotes muscle growth and fat deposition. The significant changes in GR value and loin muscle area support this conclusion, consistent with previous findings [25]. The most important factor affecting slaughter rate is the proportion of internal organ weight to pre-slaughter live weight [14]. Under conditions of increased dietary energy and protein, accelerated muscle growth and fat deposition reduce the relative proportion of internal organs, thereby increasing slaughter rate. GR value is an indicator of carcass fat content, with higher values representing greater fat content. The experimental group' s significantly higher GR value was expected, as animals store excess energy as fat.

3.4 Effects of Dietary Energy and Protein Levels on Meat Quality

This study found no significant changes in meat quality of Shanbei white cashmere goats with altered dietary nutrient levels. Previous research has shown that dietary energy and protein levels can affect meat quality [26], and our study observed some trend changes such as increased tenderness. The lack of significant effects may be because the changes in dietary energy and protein levels were insufficient to substantially impact meat quality.

3.5 Effects of Dietary Energy and Protein Levels on Routine Nutrient Composition of Meat

The results showed no significant differences in routine nutrient composition between groups, although ether extract content tended to be higher in the experimental group, consistent with the slaughter performance results. Liu and Zhou [27] reported that increasing dietary energy and protein within a certain range enhances intermuscular fat deposition and fat content. Intramuscular fat content is also an important factor affecting meat quality, influencing tenderness and juiciness [28]. It can be speculated that further increases in dietary energy and protein levels would elevate muscle fat content. Provided the rumen microbial environment is not compromised, high energy and protein supply adequate nutrients for microorganisms, increasing the synthesis rate of microbial protein. Sufficient microbial protein enables animals to enhance deposition rates of fat and protein in muscle [29].

3.6 Effects of Dietary Energy and Protein Levels on Carcass Cuts

Proper carcass segmentation is used to evaluate carcass quality and increase its value. Dietary energy and protein levels influence various carcass cuts. Previous studies on Tan sheep showed that different dietary energy and protein levels caused differences in carcass segmentation [7], with similar results reported in yak [30]. Our results indicate that increasing dietary energy and protein levels tended to increase the proportion of premium cuts, possibly due to rapid muscle growth in the hindquarters. The proportion of premium cuts may vary with different fat deposition sites across body weight ranges. During the fattening stage, increasing dietary energy and protein levels can effectively improve the proportion of premium cuts [7].

4 Conclusion

During the fattening stage of Shanbei white cashmere goats, increasing dietary crude protein content from 8.73% to 9.37% and metabolizable energy from 8.60 MJ/kg to 9.24 MJ/kg significantly improves growth performance and slaughter performance, with upward trends in meat quality and the proportion of premium cuts.

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