# Effects of Dietary Energy Level on Production Performance and Energy Utilization Efficiency of Laoshan Dairy Goats during Lactation: Postprint

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## Abstract

This experiment aimed to investigate the energy requirements of lactating Laoshan dairy goats using feeding trials and digestion-metabolism experiments. Thirty healthy second-parity Laoshan dairy goats in lactation with similar body condition, body weight [(53.80$\pm1.62)kg], and milk yield [(1.80\pm$0.19) kg/d] were selected and randomly divided into 3 groups using a single-factor randomized design, with 10 goats per group and each goat serving as one replicate. They were fed three experimental diets with consistent calcium, phosphorus, and crude protein levels, but with digestible energy levels of 9.71, 10.80, and 11.61 MJ/kg, respectively. A 70-day feeding trial was conducted (with the first 10 days as a preliminary period); after the feeding trial, 3 goats were selected from each group for a 17-day digestion-metabolism experiment (with the first 10 days as a preliminary period). The results showed that: 1) During the experimental period, as dietary energy level increased, the gross energy digestibility of the three groups of experimental goats increased sequentially; the digestible energy metabolic rate and methane energy of the 9.71 MJ/kg group were significantly lower than those of the 10.80 and 11.61 MJ/kg groups (P<0.05), while there were no significant differences in gross energy, fecal energy, and urinary energy among the three groups (P>0.05); 2) The regression equations for the relationship between digestible energy and metabolizable energy requirements of lactating Laoshan dairy goats with metabolic body weight, average daily gain, and milk yield were: DE (MJ/d)=0.487W0.75+0.354ADG+6.120M (P=0.028, R2=0.870); ME (MJ/d)=0.394W0.75+0.312ADG+5.281M (P=0.031, R2=0.873) (where DE is digestible energy, W0.75 is metabolic body weight, ADG is average daily gain, M is milk yield, and ME is metabolizable energy). This experiment successfully established models for the digestible energy and metabolizable energy requirements of lactating Laoshan dairy goats.

# Full Text

## Effects of Dietary Energy Level on Production Performance and Energy Utilization Efficiency of Lactating Laoshan Dairy Goats

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### Abstract

This experiment was conducted to determine the energy requirements of lactating Laoshan dairy goats using feeding trials and digestion-metabolism experiments. Thirty healthy second-parity Laoshan dairy goats in lactation with similar body condition, average body weight [(53.80$±1.62)kg], andmilkyield[(1.80±0.19)kg/d]wereselectedandrandomlyallocatedintothreegroups(n = 10pergroup, onegoatperreplicate)usingasingle−factorrandomizeddesign.Thethreegroupswerefedexperimen dayfeedingtrialwasconducted(includinga10−daypreliminaryperiod).Followingthefeedingtrial, threegoatsf daydigestion−metabolismtrial(includinga10−daypreliminaryperiod).Theresultsshowedthat : 1)Withincreasingdietaryenergylevel, thegrossenergy(GE)digestibilityofgoatsinthethreegroupsincreasedseq 0.05), whilenosignificantdifferenceswereobservedinGE, fecalenergy(FE), andurinaryenergy(UE)amongth 0.05).2)Regressionequationsfordigestibleenergyandmetabolizableenergy(ME)requirementsoflactatingLaos DE(MJ/d) = 0.487W{0}·{75}$ + 0.354ADG + 6.120M (P=0.028, $R^2$=0.870); ME (MJ/d) = 0.394$W^{0.75}$ + 0.312ADG + 5.281M (P=0.031, $R^2$=0.873) (where DE is digestible energy, $W^{0.75}$ is metabolic body weight, ADG is average daily gain, M is milk yield, and ME is metabolizable energy). This study successfully established models for digestible energy and metabolizable energy requirements of lactating Laoshan dairy goats.

**Keywords:** lactation period; Laoshan dairy goat; energy; requirement

### Introduction

Laoshan dairy goats are characterized by robust physique, strong disease resistance, tolerance to roughage, and good milk performance, representing one of the premium dairy goat breeds in China. Currently, Laoshan dairy goat farming has entered a process of large-scale production. As the primary source of nutrition, dietary composition and nutrient content significantly influence the production performance and metabolic processes of dairy goats. In recent years, numerous studies have investigated energy requirements in various goat breeds [1-2], but few have focused on Laoshan dairy goats. Previous research has demonstrated that appropriately increasing dietary energy levels can significantly improve milk yield in dairy goats [3-4], suggesting the potential to enhance milk production in local goat breeds through dietary energy manipulation. This experiment utilized lactating Laoshan dairy goats as subjects to investigate their energy requirements, thereby providing a theoretical basis for establishing feeding standards and scientific feeding practices for Laoshan dairy goats.

## Materials and Methods

**Experimental Animals and Design** Thirty healthy second-parity Laoshan dairy goats in peak lactation with similar body condition, average body weight [(53.80$±1.62)*kg*],*andmilkyield*[(1.80±$0.19) kg/d] were selected from the Qingdao Aote Laoshan Dairy Goat Original Breed Farm. Using a single-factor experimental design, the goats were randomly allocated into three groups (A, B, and C) with 10 goats per group, where each goat served as one replicate. The three groups were fed diets with DE levels of 9.71, 10.80, and 11.61 MJ/kg, respectively. The feeding trial lasted for 70 days, including a 10-day preliminary period and a 60-day formal experimental period. Following the feeding trial, three goats from each group with milk yields closest to the group average were selected for a digestion-metabolism trial lasting 17 days, comprising a 10-day preliminary period and a 7-day formal collection period.

**Experimental Diets and Nutrient Levels** The experimental diets were formulated according to NRC (2007) guidelines, with three diets containing DE levels of 9.71, 10.80, and 11.61 MJ/kg while maintaining consistent other nutrient levels. The composition and nutrient levels are presented in Table 1. Diets were provided as total mixed rations (TMR).

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

*Note: 1) The 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) DE was a calculated value, while others were measured values.*

**Animal Management** Goats were housed individually in pens and fed at 06:30, 11:30, and 17:30 daily, with free access to feed and clean water. Machine milking was performed at 06:00 and 18:00 daily, with feed intake and herd health status recorded. All management conditions were identical across groups.

**Digestion-Metabolism Trial** Three goats from each group with milk yields closest to the group average were housed in specialized digestion-metabolism cages. A total collection method for feces and urine was employed during the 17-day trial (including a 10-day preliminary period). Diet composition and feeding methods were identical to the feeding trial, with feed offered and refused recorded. Refused feed was collected, dried at 65 °C to produce air-dry samples, and stored. Fecal samples (10% of daily fecal output) were mixed with 10% tartaric acid solution (1/4 of fecal weight), then dried to constant weight in a 65 °C oven, prepared as air-dry samples, labeled, and recorded. Daily urine was filtered through 8-layer gauze, acidified with 10% $H_2SO_4$ to pH $< 3$, and 5% of the 7-day composite urine sample was stored, labeled, and kept at -20 °C for later analysis.

**Measurements and Calculations** **Body Weight:** Body weight was measured at the beginning and on day 60 of the formal feeding trial to calculate average daily gain (ADG).

**Dry Matter Intake (DMI):** Feed offered and refused was recorded daily, with moisture content in refused feed measured within 2 hours to calculate dietary DMI.

**Milk Yield:** Daily morning and evening milk yields were recorded throughout the trial period. Feed-to-milk ratio was calculated based on DMI and milk yield or 4% fat-corrected milk (FCM) yield. 4% FCM was calculated as: 4% FCM = $0.4 \times$ milk yield + $15 \times$ milk fat.

**Routine Components in Diets, Feces, and Urine:** Routine components in diets were determined using standard methods, while fecal and urinary energy were measured according to methods described by He Jianhua [5].

**Gross Energy Digestibility, Gross Energy Metabolic Rate, and Digestible Energy Metabolic Rate:** Based on measured GE in feed, FE, UE, and estimated methane energy, calculations were performed using the following formulas [6]:

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

Where: GE = gross energy; FE = fecal energy; UE = urinary energy; DE = digestible energy; ME = metabolizable energy; $ECH_4$ = methane energy. In this study, methane energy was estimated using the method of Blaxter et al. [7]:

$ECH_4$ (%) = $3.67 + 0.062D$

Where: D = apparent digestibility of gross energy consumed by experimental does. The estimated average methane energy for the three groups was 7.15% of GE.

**Digestible and Metabolizable Energy Intake:** Digestible and metabolizable energy intake were calculated based on experimental records and laboratory analysis using the following formulas:

DE (MJ/d) = Σ(F × C × D )
ME (MJ/d) = Σ(F × C × M )

Where: DE and ME represent digestible energy and metabolizable energy intake for group i; F represents the actual daily intake of diet j by group i; C represents the gross energy of feed j in the diet; D and M represent the gross energy digestibility and gross energy metabolic rate for group i, respectively.

**Statistical Analysis** Experimental data were organized using Excel software and analyzed using SPSS 20.0 software for analysis of variance (ANOVA). Differences among groups were tested for significance using the LSD method. Data are presented as "mean ± standard error."

## Results

**Effects of Dietary Energy Level on Energy Utilization Efficiency** As shown in Table 2 , the gross energy intake of goats in groups A, B, and C was 21.14, 23.60, and 24.84 MJ/d, respectively, with no significant differences among groups (P>0.05). Fecal energy excretion was 9.11, 9.51, and 9.71 MJ/d for groups A, B, and C, respectively, showing an increasing trend with dietary energy level but without significant differences (P>0.05). Methane energy excretion tended to increase with dietary energy level, with groups B and C being significantly higher than group A (P<0.05), though no significant difference was observed between groups B and C (P>0.05). The gross energy digestibility ranged from 56.90% to 60.90% across the three groups, increasing with dietary energy level but without significant differences (P>0.05). The digestible energy metabolic rate in group C was significantly higher than in group A (P<0.05) but did not differ significantly from group B (P>0.05).

**Table 2** Effects of dietary energy level on energy utilization efficiency of lactating Laoshan dairy goats

*Note: 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). The same as below.*

**Effects of Dietary Energy Level on Production Performance** As shown in Table 3 , the digestible energy and metabolizable energy intake of goats in groups A, B, and C increased sequentially, with group A being significantly lower than group C (P<0.05). Average daily gain in group A was significantly lower than in groups B and C (P<0.05), while no significant difference was observed between groups B and C (P>0.05). Milk yield, 4% FCM yield, and net energy for lactation (NEL) in group A were significantly lower than in groups B and C (P<0.05). No significant differences were found in gross energy intake or dry matter intake among the three groups (P>0.05). These results indicate that under conditions where dietary crude protein levels are adequate and consistent, milk yield increases with energy intake, but further elevation beyond a certain threshold does not significantly enhance milk production.

**Table 3** Effects of dietary energy level on production performance of lactating Laoshan dairy goats

**Regression Analysis of Energy Intake with Body Weight, ADG, and Milk Yield** According to nutritional principles, the digestible or metabolizable energy requirement of lactating Laoshan dairy goats equals the sum of requirements for maintenance, weight gain, and milk production, expressed as:

$$NR = a_1 \times W^{0 \cdot 75} + a_2 \times ADG + a_3 \times M$$

Where: NR = digestible or metabolizable energy requirement (MJ/d); $a_1$ = constant for growth requirement; $a_2$ = constant for maintenance requirement; $a_3$ = constant for lactation requirement; $W^{0 \cdot 75}$ = metabolic body weight (kg); ADG = average daily gain (g); M = milk yield (kg).

Through regression analysis of relevant data, the following equations were established to represent the relationship between digestible/metabolizable energy requirements and metabolic body weight, ADG, and milk yield:

$$DE\ (MJ/d) = 0.487W^{0 \cdot 75} + 0.354ADG + 6.120M\ (P=0.028,\ R^2=0.870)$$
$$ME\ (MJ/d) = 0.394W^{0 \cdot 75} + 0.312ADG + 5.281M\ (P=0.031,\ R^2=0.873)$$

## Discussion

**Effects of Dietary Energy Level on Energy Utilization Efficiency** Energy is fundamental for all metabolic and productive activities in animals. Ruminants lose 20-50% of ingested feed energy as fecal energy and 4-5% as urinary energy [8]. Numerous domestic studies have investigated energy utilization efficiency in various sheep breeds [9]. Both fecal and urinary energy increase to varying degrees with dietary energy level, though how to further improve energy utilization efficiency in Laoshan dairy goats requires additional research. Sutter et al. [10] reported that increasing dietary energy level does not significantly increase urinary energy excretion, consistent with our findings. Normally, fecal and urinary energy excretion increase correspondingly with dietary energy level. Under our experimental conditions, gross energy digestibility and gross energy metabolic rate of lactating Laoshan dairy goats ranged from 56% to 61% and 46% to 51%, respectively. The digestible energy metabolic rate of goats fed low-energy diets was significantly lower than those fed medium- and high-energy diets, consistent with results from Hu Xiuzhi et al. [11] studying energy requirements of lactating Shaanbei cashmere goats. Zhang Zhenwei et al. [12] reported that increasing dietary energy level significantly improved gross energy digestibility and metabolic rate in Zhongwei goat wethers. Zhao Minmeng et al. [13] fed Qing goats diets with DE levels of 8.91, 9.79, and 10.62

MJ/kg, finding that the 9.79 MJ/kg energy level resulted in higher digestible and metabolizable energy intake, representing a more appropriate energy level.

**Effects of Dietary Energy Level on Production Performance** Milk production performance is a crucial economic trait in dairy goats, and dietary energy level is a key factor determining animal production performance, significantly affecting milk yield and composition [14]. Within a certain nutritional range, ruminants fed high-nutrient diets can achieve higher milk yields. For instance, Wang Jianhua et al. [15] found that high-energy diets (net energy 5.3 MJ/kg) improved milk yield in Laoshan dairy goats compared to low-energy diets (net energy 4.9 MJ/kg). Zhao Jinshan et al. [16] reported that concentrate energy levels of 13.30 and 13.00 MJ/kg resulted in significantly higher milk yields than levels of 12.75 and 12.68 MJ/kg in Laoshan dairy goats. Our results demonstrate that under conditions of adequate and consistent dietary crude protein intake, milk yield and ADG of does increased with digestible energy intake, though no significant effects were observed when energy levels exceeded a certain threshold.

**Energy Requirements of Lactating Laoshan Dairy Goats** Dietary energy level determines feed consumption and the supply of protein and other nutrients, thereby affecting animal production performance, nutrient absorption and utilization, and ultimately growth, development, and health. Therefore, determining energy requirements for Laoshan dairy goats is of great significance. Generally, breed characteristics and environmental conditions are important factors influencing energy requirements. Our results indicate that under normal production conditions, a dietary DE level of 10.80-11.60 MJ/kg (DM basis) is appropriate for lactating Laoshan dairy goat does. Wang Hui [17] reported DE requirements of 9.17-10.14 MJ/kg for Shaanbei cashmere goats, while Cao Suying [18] found that a DE supply of 12.92 MJ/kg maintained high milk yield in Boer goats. Our results are generally consistent with previous studies and align with NRC (2007) recommendations for dairy goats. Currently, metabolizable energy maintenance requirements are primarily estimated through feeding and calorimetry trials, with reported variations likely attributable to differences in experimental methodology and breed factors. Our study determined that a DE level of 10.80-11.60 MJ/kg is suitable for lactating Laoshan dairy goats, which is slightly lower than results from Xinong Saanen goats, possibly due to breed differences and experimental conditions.

## Conclusion

1. Under our experimental conditions, gross energy digestibility and gross energy metabolic rate of lactating Laoshan dairy goats ranged from 56% to 61% and 46% to 51%, respectively. A dietary DE level of 10.80-11.60 MJ/kg (DM basis) is appropriate for lactating Laoshan dairy goat does.

2. The digestible energy and metabolizable energy requirements of lactating

Laoshan dairy goats are:
DE (MJ/d) = $0.487W^{0.75} + 0.354ADG + 6.120M$ (P=0.028, $R^2$=0.870)
ME (MJ/d) = $0.394W^{0.75} + 0.312ADG + 5.281M$ (P=0.031, $R^2$=0.873)
(where DE is digestible energy, $W^{0.75}$ is metabolic body weight, ADG is average daily gain, M is milk yield, and ME is metabolizable energy).

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