# Energy Requirements of Laoshan Dairy Goats During the Growth Period: Postprint

**Authors:** Song Xiaowen, Zhang Guangfeng, Wang Huimin, Cheng Ming, Dai Zhenghao, Lin Yingting

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## Abstract

This experiment aimed to investigate the effects of dietary energy level on energy utilization efficiency in growing Laoshan dairy goats. Thirty growing Laoshan dairy goat does with a body weight of (18.43$±$0.76) kg were selected and randomly divided into 3 groups using a single-factor randomized design, with 10 replicates per group and 1 goat per replicate. They were fed three total mixed rations with basically consistent levels of crude protein, calcium, and phosphorus, but with digestible energy levels of 10.40, 11.47, and 12.51 MJ/kg, respectively. The pre-trial period was 10 days, and the formal trial period was 90 days. The results showed that 1) In the later stage of the experiment, the gross energy digestibility of the three groups of test goats increased sequentially with the increase in dietary energy level; the gross energy digestibility, gross energy metabolizability, and digestible energy metabolizability of goats in the 12.51 MJ/kg group were significantly higher than those in the 10.40 MJ/kg group ($P<0.05$); gross energy, fecal energy, and urinary energy among the three groups of test goats showed significant differences ($P<0.05$), with the order being 10.40 MJ/kg group < 11.47 MJ/kg group < 12.51 MJ/kg group; the methane energy of goats in the 10.40 MJ/kg group was significantly lower than that in the 11.47 and 12.51 MJ/kg groups ($P<0.05$). 2) The final body weight and average daily gain of goats in the 10.40 MJ/kg group were significantly lower than those in the 11.47 and 12.51 MJ/kg groups ($P<0.05$), but there was no significant difference between the 11.47 and 12.51 MJ/kg groups ($P>0.05$). 3) The regression equations for the relationship between digestible energy and metabolizable energy requirements and metabolic body weight and average daily gain in growing Laoshan dairy goats were: DE=0.675W0.75+0.110ADG (P=0.006, R2=0.982); ME=0.526W0.75+0.076ADG (P=0.027, R2=0.873) [where DE is digestible energy (MJ/d), ME is metabolizable energy (MJ/d), W0.75 is metabolic body weight (kg), and ADG is average daily gain (g)]. In conclusion, a dietary digestible energy level of 11.47-12.51 MJ/kg (dry matter basis) is appropriate for

growing Laoshan dairy goat does.

## Full Text

# Energy Requirement of Laoshan Dairy Goats During the Growing Period

**SONG Xiaowen[1], ZHANG Guangfeng[1], WANG Huimin[1], CHENG Ming[2], DAI Zhenghao[2], LIN Yingting[1]***

[1]College of Animal Science and Technology, Qingdao Agricultural University, Qingdao 266109, China
[2]Institute of Animal Husbandry and Veterinary Medicine, Qingdao City, Qingdao 266109, China

### Abstract

This experiment investigated the effects of dietary energy level on energy utilization in growing Laoshan dairy goats. Thirty growing female Laoshan dairy goats with an average body weight of (18.43$±0.76)kgwererandomlyallocatedtothreegroupsusingasingle−factordesign, with10replicatespergroupandonegoatperreplicate.Theanimalswerefedthreetotalmixedrations daypreliminaryperiodfollowedbya90 − dayformaltrial.Theresultsshowed : (1)Duringthelaterstage, grossenergydigestibilityincreasedsequentiallywithdietaryenergylevel.The12.51MJ/ 0.05).Significantdifferencesamongthethreegroupswereobservedforgrossenergy, fecalenergy, andurinaryen 0.05), followingthepattern : 10.40MJ/kg < 11.47MJ/kg < 12.51MJ/kg.Methaneenergyinthe10.40MJ/kggr 0.05).(2)Finalbodyweightandaveragedailygain(ADG)inthe10.40MJ/kggroupweresignificantlylowerthantho 0.05), withnosignificantdifferencebetweenthelattertwogroups(P > 0.05).(3)Regressionequationsrelatingen DE = 0.675W^{0}·{75}$ + 0.110ADG (P=0.006, $R^2$=0.982) and ME = 0.526$W^{0·75}$ + 0.076ADG (P=0.027, $R^2$=0.873), where DE is digestible energy (MJ/d), ME is metabolizable energy (MJ/d), $W^{0·75}$ is metabolic body weight (kg), and ADG is average daily gain (g). In conclusion, a dietary DE level of 11.47-12.51 MJ/kg (dry matter basis) is appropriate for growing female Laoshan dairy goats.

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

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## 1. Materials and Methods

### 1.1 Experimental Animals and Design

Thirty healthy growing female Laoshan dairy goats approximately 170 days old, with a body weight of (18.43$±$0.76) kg, were selected and randomly divided into three groups (A, B, and C) using a single-factor randomized design with weight balancing. Each group comprised 10 replicates with one goat per replicate. The trial was conducted at Qingdao Aote Dairy Goat Farm and lasted 100 days, including a 10-day preliminary period and a 90-day formal experimental period.

### 1.2 Experimental Diets and Nutrient Levels

Based on the DE levels recommended by the NRC (2007) for goats and the principle of maintaining consistent dietary calcium, phosphorus, and protein levels, three total mixed rations (TMR) with DE levels of 10.40, 11.47, and 12.51 MJ/kg were formulated. The composition and nutrient levels of the experimental diets are presented in Table 1 .

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

*Note: 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 separate pens and fed at 06:30, 12:00, and 18:00 daily. They were allowed access to exercise areas during fixed time periods and provided with unlimited clean drinking water. The experimental facilities were kept clean, and deworming and vaccination procedures followed the standard farm protocol. Feeding and management conditions were identical across all groups.

### 1.4 Digestion and Metabolism Trial

On days 10 (early stage) and 90 (late stage) of the feeding trial, three goats from each group with body weights close to the group average were selected and housed in specialized metabolism cages for a 10-day digestion and metabolism study, comprising a 7-day preliminary period and a 3-day formal collection period. The experimental diets and feeding methods were identical to those used in the feeding trial. Feed intake and refusals were recorded, with refusals collected and dried at 65°C to constant weight to prepare air-dried samples.

During each collection period, total feces and urine were collected continuously for three days. Fecal samples (10% of daily fecal weight) were mixed with 10% hydrochloric acid solution at one-quarter of the fecal weight, then dried at 65°C to constant weight to prepare air-dried samples, which were labeled and stored. Daily urine output was filtered through eight layers of gauze, preserved with 10% $H_2SO_4$ (10 mL per 100 mL urine), and mixed thoroughly. Three-day urine samples were combined, and 5% was retained and stored at -20°C for subsequent analysis.

## 1.5 Measurements

**1.5.1 Average Daily Gain** Body weight was measured at 08:00 on day 1 and day 91 after overnight fasting. Average daily gain was calculated based on these measurements.

**1.5.2 Routine Components in Diets, Feces, and Urine** Dietary routine components were determined using standard methods, while dry matter content and energy in feces and urine were measured according to methods described by He Jianhua [?].

**1.5.3 Calculation of Energy Metabolism Indices** Based on energy measurements in the three diets and their corresponding feces and urine, combined with estimated methane energy, energy metabolism indices were calculated using the following formulas:

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

Methane energy was estimated using the method of Blaxter [?]:

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

Where: D = apparent digestibility of gross energy intake. The estimated average methane energy for the three groups in this trial was 7.15% of gross energy intake.

**1.5.4 Digestible and Metabolizable Energy Intake** Digestible and metabolizable energy intake were calculated based on experimental records and laboratory analysis results:

DEI (MJ/d) = Σ(F × C × D )
MEI (MJ/d) = Σ(F × C × M )

Where: DEI and MEI represent digestible energy and metabolizable energy intake for group i; F is the actual daily feed intake of diet j by group i; C is the gross energy of diet j; and D and M are the gross energy digestibility and gross energy metabolic rate for group i, respectively.

## 1.6 Statistical Analysis

Experimental data were organized using Excel and analyzed using SPSS 20.0.0 software. One-way ANOVA was performed, and differences among groups were tested using the LSD method. Data are expressed as "mean ± standard error."

## 2. Results

### 2.1 Effects of Dietary Energy Level on Energy Digestion and Metabolism

As shown in Table 2 , during the early stage, gross energy and fecal energy in group A were significantly lower than those in groups B and C (P<0.05), with no significant difference between groups B and C (P>0.05). No significant differences were observed among groups for urinary energy, gross energy digestibility, gross energy metabolic rate, or digestible energy metabolic rate (P>0.05).

During the late stage, gross energy digestibility ranged from 59.30% to 63.13% and increased sequentially with dietary energy level. Group C exhibited significantly higher gross energy digestibility, gross energy metabolic rate, and digestible energy metabolic rate compared to group A (P<0.05), but these parameters did not differ significantly from group B (P>0.05). Significant differences among the three groups were observed for gross energy, fecal energy, and urinary energy (P<0.05), following the pattern: group A < group B < group C. Methane energy in group A was significantly lower than in groups B and C (P<0.05), with no significant difference between the latter two groups (P>0.05).

**Table 2** Effects of dietary energy level on energy digestion and metabolism in Laoshan dairy goats

*Note: In the same row, values with no letter or the same letter superscripts indicate no significant difference (P>0.05), while different lowercase letters indicate significant difference (P<0.05), and different uppercase letters indicate highly significant difference (P<0.01). The same applies below.*

### 2.2 Effects of Dietary Energy Level on Body Weight

As shown in Table 3 , initial body weight did not differ significantly among the three groups (P>0.05). Due to sequentially increasing gross energy, digestible energy, and metabolizable energy intake in groups A, B, and C, final body weight also increased accordingly. Final body weight and average daily gain in group A were significantly lower than those in groups B and C (P<0.05), with no significant difference between groups B and C (P>0.05). These results indicate that under conditions of consistent crude protein intake that meets normal growth requirements, average daily gain increases with energy intake, but further energy increases beyond a certain threshold have no significant effect.

**Table 3** Effects of dietary energy level on body weight of Laoshan dairy goats

### 2.3 Regression Analysis of Energy Requirements with Metabolic Body Weight and Average Daily Gain

According to nutritional principles, the energy requirement of growing Laoshan dairy goats can be expressed as:

$NR = a_1 \times W^{0.75} + a_2 \times ADG$

Where: NR = digestible or metabolizable energy requirement (MJ/d); $a_1$ = maintenance requirement constant; $a_2$ = growth requirement constant; $W^{0.75}$ = metabolic body weight (kg); ADG = average daily gain (g).

When ADG = 0, NR = $a_1 \times W^{0.75}$, representing the maintenance metabolizable energy requirement (MEm). Based on the experimental animals' body weight, this can be expressed on a per-unit metabolic body weight basis: MEm = $a_1 \times W^{0.75}$. From this relationship, the metabolizable energy required per gram of live weight gain (MEg) can be calculated as MEg = $a_2$ MJ/g. Based on these principles, regression analysis of the relevant data yielded the following equations describing the relationship between energy requirements and metabolic body weight and ADG for growing Laoshan dairy goats:

$DE = 0.675W^{0.75} + 0.110ADG$ (P=0.006, $R^2$=0.982)
$ME = 0.526W^{0.75} + 0.076ADG$ (P=0.027, $R^2$=0.873)

Where: DE = digestible energy (MJ/d); ME = metabolizable energy (MJ/d); $W^{0.75}$ = metabolic body weight (kg); ADG = average daily gain (g).

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## 3. Discussion

### 3.1 Energy Utilization Efficiency in Growing Laoshan Dairy Goats

Energy is fundamental to all metabolic and productive activities in animals. Ruminants lose 20-50% of dietary energy through feces and 4-5% through urine. Recent domestic research has extensively investigated energy utilization efficiency in various sheep breeds [?, ?]. Sun et al. [?] reported that when feeding a diet with 13% crude protein, Qingshan goats exhibited gross energy digestibility and gross energy metabolic rates of 63.5% and 52.3%, respectively. Jin et al. [?] found that Saanen dairy goats had gross energy digestibility and metabolic rates of 66.8% and 54.4%, respectively. Sutter et al. [?] and Moorby et al. [?] reported that increasing dietary energy level did not significantly increase urinary energy excretion, which contradicts the present findings and warrants further investigation. Under the conditions of this trial, growing Laoshan dairy goats exhibited gross energy digestibility and metabolic rates of 59.30-63.13% and 49.33-53.24%, respectively. The low energy level group showed significantly lower gross energy digestibility, gross energy metabolic rate, and digestible energy metabolic rate compared to the medium and high energy level groups, consistent with results from Wang Hui [?] in a study on energy requirements of non-pregnant Northern

Shaanxi cashmere goats. As dietary energy level increased, both fecal and urinary energy increased to varying degrees. Further research is needed to improve energy utilization efficiency in Laoshan dairy goats.

### 3.2 Comparison of Energy Requirements with Other Sheep Breeds

Breed characteristics and environmental conditions are primary factors affecting energy requirements in growing ewes. Adequate energy supply is essential for full utilization of other nutrients, making the determination of energy requirements critical for production. The present results indicate that the maintenance metabolizable energy requirement for growing Laoshan dairy goats is 0.526 MJ/kg $W^{0\cdot75}$, with 0.076 MJ required per gram of daily weight gain. This maintenance requirement is generally consistent with findings for growing Saanen goats (0.4061 MJ/kg $W^{0\cdot75}$) and Guanzhong dairy goats aged 60–90 days (0.487 MJ/kg $W^{0\cdot7}$) [?, ?], though slightly higher, possibly due to breed differences and environmental factors.

### 3.3 Determination of Appropriate Dietary Energy Level

Dietary energy level determines feed intake and the supply of protein and other nutrients, thereby influencing animal performance, nutrient absorption and utilization, growth, and health. Therefore, determining energy requirements for Laoshan dairy goats is of significant importance. Generally, breed characteristics and environmental conditions are key factors affecting energy requirements. Based on the relevant parameters obtained in this study, combined with energy requirement research findings and NRC standards, it is estimated that under normal production conditions, a dietary DE level of 11.47–12.51 MJ/kg (dry matter basis) is appropriate for growing female Laoshan dairy goats.

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## Conclusion

1. Under the conditions of this experiment, growing Laoshan dairy goats exhibited gross energy digestibility and metabolic rates of 61.5% and 51.5%, respectively. A dietary DE level of 11.47–12.51 MJ/kg (dry matter basis) is appropriate for growing female Laoshan dairy goats.
2. The regression equations relating digestible energy and metabolizable energy requirements to metabolic body weight and average daily gain for growing Laoshan dairy goats are:

$DE = 0.675W^{0\cdot75} + 0.110ADG$ ($P=0.006$, $R^2=0.982$)
$ME = 0.526W^{0\cdot75} + 0.076ADG$ ($P=0.027$, $R^2=0.873$)

Where: DE = digestible energy (MJ/d); ME = metabolizable energy (MJ/d); $W^{0\cdot75}$ = metabolic body weight (kg); ADG = average daily gain (g).

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