Postprint: Energy Metabolism Patterns and Requirements in Growing Qinchuan Cattle

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Abstract

This study aimed to investigate the energy metabolism patterns and requirements of growing Qinchuan cattle. Thirty growing Qinchuan bulls with good body condition and similar body weight [(336.33±18.28) kg] were randomly divided into 5 groups with 6 cattle per group, and fed five experimental diets formulated to provide 85.0% (Group), 92.5% (Group), 100.0% (Group), 107.5% (Group), and 115.0% (Group) of the net energy required for an expected average daily gain of 900 g/d according to China' s 'Feeding Standard of Beef Cattle' (NY/T 815-2004). A feeding trial and a digestion-metabolism trial were conducted to determine the growth performance and energy metabolism indices of Qinchuan cattle, and to establish prediction models for digestible energy and metabolizable energy requirements. The preliminary period lasted 10 d, and the formal experimental period lasted 42 d. The results showed that the average daily gain of Qinchuan cattle in Group was 880.15 g/d, which was slightly lower than the expected value; Group achieved the maximum average daily gain (1,160.10 g/d) with the highest energy utilization efficiency; the mean values of gross energy digestibility, gross energy metabolizability, and digestible energy metabolizability were (76.44±3.23)%, (66.75±3.16)%, and (87.31±0.54)%, respectively; the regression equations for digestible energy and metabolizable energy requirements of Qinchuan cattle were: DER=0.778W0.75+37.05ADG; MER=0.668W0.75+33.49ADG [DER is digestible energy requirement (MJ/d), MER is metabolizable energy requirement (MJ/d), W0.75 is metabolic body weight (kg), ADG is average daily gain (kg/d)]. In conclusion, the maintenance digestible energy and metabolizable energy requirements of growing Qinchuan cattle were 0.778 and 0.668 MJ/(kg W0.75), respectively, and the digestible energy and metabolizable energy requirements per kilogram of gain were 37.05 and 33.49 MJ, respectively.

Full Text

Energy Metabolism and Requirement of Growing Qinchuan Cattle

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Abstract: This experiment aimed to investigate the energy metabolism patterns and requirements of growing Qinchuan cattle. Thirty healthy growing Qinchuan bulls with similar body weight [(336.33±18.28) kg] were selected and randomly allocated into five groups (n=6 per group). The cattle were fed five experimental diets formulated to provide 85.0% (Group I), 92.5% (Group II), 100.0% (Group III), 107.5% (Group IV), and 115.0% (Group V) of the net energy required for an expected average daily gain of 900 g/d, according to China' s *Feeding Standard of Beef Cattle* (NY/T 815-2004). Feeding trials and digestion-metabolism trials were conducted to measure growth performance and energy metabolism indices, and to establish prediction models for digestive energy and metabolizable energy requirements. The preliminary period lasted 10 days, followed by a 42-day experimental period.

The results showed that the average daily gain of Group III was 880.15 g/d, slightly lower than expected, while Group IV achieved the maximum average daily gain (1,160.10 g/d) with the highest energy utilization efficiency. The mean values for gross energy digestibility, gross energy metabolic rate, and digestive energy metabolic rate were (76.44±3.23)%, (66.75±3.16)%, and (87.31±0.54)%, respectively. The regression equations for digestive energy requirement (DER) and metabolizable energy requirement (MER) of Qinchuan cattle were established as:

$$DER = 0.778W^{0.75} + 37.05ADG$$
$$MER = 0.668W^{0.75} + 33.49ADG$$

where DER is digestive energy requirement (MJ/d), MER is metabolizable energy requirement (MJ/d), $W^{0.75}$ is metabolic body weight (kg), and ADG is average daily gain (kg/d). In summary, the maintenance requirements for digestive energy and metabolizable energy in growing Qinchuan cattle are 0.778 and 0.668 MJ/(kg $W^{0.75}$), respectively, while the digestive and metabolizable energy required per kilogram of weight gain are 37.05 and 33.49 MJ.

Keywords: Qinchuan cattle; digestive energy; metabolizable energy; requirement
Classification: S823

Qinchuan cattle, originating from the Guanzhong Plain region of the Wei River basin in Shaanxi Province, represent one of China' s renowned local breeds and have become a nationally protected genetic resource. This dual-purpose breed (draft and beef) is characterized by medium-to-large body size, tender meat, and prominent marbling. Previous research reported that 27–28-month-old Qinchuan steers achieved average dressing and meat percentages of 64.32% and 54.54%, respectively, with a meat-to-bone ratio of 6.74, demonstrating excellent economic value.

Nutritional requirements form the foundation for improving the efficiency of large-scale beef cattle production. With advances in scientific technology and nutritional research methodologies, studies on nutrient metabolism patterns and requirements in ruminants have progressed considerably. Animal nutrition experts worldwide have continuously investigated beef cattle feeding standards and nutritional requirements, developing standards tailored to national conditions, such as those from the U.S. National Research Council (NRC) and the UK Agricultural Research Council (ARC). China formulated its first *Draft Feeding Standard of Beef Cattle* in 1985, revised it in 2000, and officially issued the agricultural industry standard *Feeding Standard of Beef Cattle* (NY/T 815-2004) in 2004, which has guided beef cattle production nationwide.

However, China encompasses vast territories with diverse local and improved cattle breeds, and significant variations in climate and feeding environments across regions result in substantial differences in nutritional requirements. Consequently, investigating the nutritional needs of different breeds under various climatic and management conditions is essential. Energy constitutes a critical feed component that determines animal feed intake, and all other nutrient intakes are influenced by energy supply. Therefore, establishing energy requirements is particularly crucial. While energy metabolism patterns and requirements have been studied in Limousin × Luxi crossbred cattle, Jinjiang cattle, and Xiangzhong Black cattle, research on Qinchuan cattle nutritional requirements remains scarce. Thus, investigating the energy metabolism patterns and requirements of Qinchuan cattle holds significant importance for the industry. This study aims to determine targeted and precise energy requirement data for growing Qinchuan cattle, providing references for optimizing diet formulation and maximizing production performance.

1.1 Experimental Animals

The experiment was conducted at the beef cattle farm of Chongqing Hengdu Agriculture Group Co., Ltd. Thirty healthy 10-month-old growing Qinchuan bulls with good body condition and similar body weight [(336.33±18.28) kg] were selected.

1.2 Experimental Design and Diets

A completely randomized design was employed, with the 30 bulls randomly divided into five groups (six replicates per group, one bull per replicate). Diets were formulated based on the nutritional requirements for 300-kg beef cattle according to China’ s *Feeding Standard of Beef Cattle* (NY/T 815-2004). The five groups received diets providing 85.0% (Group I), 92.5% (Group II), 100.0% (Group III), 107.5% (Group IV), and 115.0% (Group V) of the net energy required for an expected average daily gain of 900 g/d. Diet composition and nutrient levels are presented in Table 1 . Diets consisted of concentrate and forage at a 40:60 ratio. The preliminary period lasted 10 days, followed by a 42-day experimental period, with the final 4 days designated for digestion-metabolism trials.

1.3 Feeding Trial

During the experimental period, the average ambient temperature was 18.5°C with 64.3% relative humidity. All cattle were housed individually in tie-stall barns and fed twice daily (07:00 and 16:00) with ad libitum access to feed and water. Feed offered and refusals were recorded accurately for each animal to calculate actual feed intake. Other management practices followed the farm’ s standard procedures. Initial body weight was determined as the average of two consecutive fasting weights at 07:00 before the trial; final body weight was similarly measured at the trial’ s conclusion. Average daily gain was calculated from these measurements and the number of feeding days.

1.4 Digestion-Metabolism Trial

Following the feeding trial, four cattle from each group with body weights closest to the group mean were selected for digestion-metabolism trials under identical conditions, with total fecal and urinary collection conducted for four consecutive days.

Feces were collected continuously over 24 hours for each animal, weighed daily, and recorded. Each day’ s fecal output per animal was thoroughly mixed and divided into two subsamples: one dried at 65°C for routine nutrient analysis, and another treated with 10% sulfuric acid for nitrogen fixation (20 mL acid per 100 g fresh feces) before drying at 65°C to create air-dried samples, which were then ground to pass a 40-mesh sieve for nitrogen analysis.

Urine was collected continuously over 24 hours and measured accurately with a graduated cylinder. After filtration through 6–8 layers of gauze, 10% of each animal’ s daily urine volume was transferred to clean plastic bottles, acidified with 10% sulfuric acid (10 mL acid per 100 mL urine), sealed (with plastic film under the cap), and stored at -20°C for analysis.

1.5 Measurement Indicators and Methods

Dry matter, crude protein, neutral detergent fiber, acid detergent fiber, calcium, and phosphorus contents were determined according to *Feed Analysis and Feed Quality Detection Technology*. Energy in diets, feces, and urine was measured using a Parr 1281 bomb calorimeter.

1.6 Calculation Formulas and Model Development

Key calculations were performed as follows:

- Average daily gain (g/d) = (final body weight - initial body weight) / experimental days
- Dry matter intake (kg/d) = diet dry matter content × average daily feed intake
- Digestive energy intake (MJ/d) = gross energy intake - fecal energy excretion
- Metabolizable energy intake (MJ/d) = gross energy intake - fecal energy excretion - urinary energy excretion - methane energy excretion
- Gross energy digestibility (%) = 100 × (gross energy intake - fecal energy excretion) / gross energy intake
- Gross energy metabolic rate (%) = 100 × (gross energy intake - fecal energy excretion - urinary energy excretion - methane energy excretion) / gross energy intake
- Digestive energy metabolic rate (%) = 100 × metabolizable energy intake / (gross energy intake - fecal energy excretion)
- $K_m = 0.1875\times$ (digestive energy intake / gross energy intake) + 0.4579
- Net energy for maintenance (MJ/d) = digestive energy intake × K_m
- $K_f = 0.523\times$ (digestive energy intake / gross energy intake) + 0.00589
- Net energy for gain (MJ/d) = digestive energy intake × K_f
- $K_{mf} = K_m \times K_f \times 1.5/(K_f + 0.5 \times K_m)$
- Net energy for production (MJ/d) = digestive energy intake × K_{mf}

Methane energy was calculated using Blaxter et al.'s formula: methane energy as percentage of gross energy = 6.05 + 0.02 × energy digestibility. K_m represents the efficiency of converting digestive energy to net energy for maintenance, K_f for gain, and K_{mf} for production.

Based on factorial analysis principles, energy requirements were partitioned into maintenance and gain components, with regression models developed as:

$$ER = a \times W^{0.75} + b \times ADG$$

where ER represents digestive or metabolizable energy requirement (MJ/d), $W^{0.75}$ is metabolic body weight (kg), a and b are regression coefficients, and ADG is average daily gain.

1.7 Statistical Analysis

Data were initially processed using Excel 2010 and analyzed with SPSS 17.0 software. Significance testing employed one-way ANOVA and Duncan's multiple comparison tests. Results are expressed as means ± standard deviation, with $P < 0.05$ considered significant. Multiple regression analysis was used for model development.

2.1 Effects of Dietary Energy Level on Growth Performance

As shown in Table 2 , average daily gain increased with dietary energy level. Group III achieved 880.15 g/d, slightly lower than the expected 900 g/d, while Group IV reached the maximum average daily gain (1,160.10 g/d). The feed-to-gain ratio of Groups IV and V was significantly lower than other groups ($P < 0.05$), though not significantly different between these two groups ($P > 0.05$).

2.2 Effects of Dietary Energy Level on Energy Digestibility and Metabolic Rate

Table 3 reveals that energy intake (gross, digestive, and metabolizable) increased with dietary energy level, with Groups III, IV, and V showing no significant differences among themselves ($P > 0.05$) but significantly higher values than Groups I and II ($P < 0.05$), and Group II significantly higher than Group I ($P < 0.05$). Methane energy excretion, net energy for maintenance, net energy for gain, and net energy for production followed similar trends. Digestive energy metabolic rate increased with energy level, with Group V significantly higher than all other groups ($P < 0.05$). Gross energy digestibility and metabolic rate initially increased then decreased, peaking in Group IV, though without significant differences among Groups III, IV, and V ($P > 0.05$), or between Groups I and II ($P > 0.05$).

2.3 Model Development for Digestive and Metabolizable Energy Requirements

Based on feeding and digestion-metabolism trial results, regression analysis between energy intake and metabolic body weight plus average daily gain yielded the following equations:

$$DER(MJ/d) = 0.778W^{0.75} + 37.05ADG \quad (R^2 = 0.928, P < 0.05)$$
$$MER(MJ/d) = 0.668W^{0.75} + 33.49ADG \quad (R^2 = 0.925, P < 0.05)$$

These equations indicate highly positive correlations between energy requirements and average daily gain, with correlation coefficients of 0.928 and 0.925 for digestive and metabolizable energy, respectively. Maintenance requirements were 0.778 and 0.668 MJ/(kg $W^{0.75} \cdot$ d), with conversion efficiencies from digestive to metabolizable energy of 0.85 for maintenance. Energy required per kilogram of gain was 37.05 MJ digestive energy and 33.49 MJ metabolizable energy, with a conversion efficiency of 0.90.

3.1 Effects on Growth Performance and Energy Utilization

This study demonstrated that increasing digestive and metabolizable energy intake progressively improved average daily gain while significantly reducing feed-to-gain ratio, consistent with findings in Xiangzhong Black cattle. Excessive energy supply did not further enhance growth performance significantly. Growing Qinchuan cattle exhibited mean gross energy digestibility of (76.44±3.23)%, gross energy metabolic rate of (66.75±3.16)%, and digestive energy metabolic rate of (87.31±0.54)%. While numerous domestic studies have investigated energy utilization in beef cattle, efficiency varies with breed, age, and physiological stage. Reported values include 67.51%, 58.05%, and 85.92% for 12-13-month-old Xiangzhong Black cattle; 67.11%, 57.48%, and 85.66% for Chinese Holstein cows; 66.60%, 56.95%, and 85.51% for 4-6-month-old Limousin × Luxi crossbreds; 64.12%, 54.20%, and 84.53% for 7-10-month-old Limousin × Luxi crossbreds; 71.37%, 59.23%, and 82.98% for growing female buffaloes; 67.11% and 55.07% for 14-15-month-old female buffaloes; and 74.83% and 63.73% for Holstein cows. The gross energy digestibility in growing Qinchuan cattle was slightly lower than the 77.2% reported by Chizzotti et al. for Hereford steers using energy balance trials, possibly due to dietary composition differences. The observed increase in dry matter and energy intake with dietary energy level, accompanied by improved energy digestibility and metabolic rates, aligns with previous research.

3.2 Model Development for Energy Requirements

This study determined maintenance requirements of 0.778 and 0.668 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) for digestive and metabolizable energy, respectively, with corresponding requirements of 37.05 and 33.49 MJ per kilogram of gain. Comparative literature reports include: 0.514 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) metabolizable energy for maintenance and 21.12 MJ/kg gain in 5-month-old Holstein heifers; 1.278 and 0.627 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) digestive and metabolizable energy for maintenance with 35.535 and 33.194 MJ/kg gain in 6-7-month-old Jinjiang cattle; 0.648 and 0.506 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) with 33.12 and 32.15 MJ/kg gain in 12-13-month-old Xiangzhong Black cattle; 0.517 and 0.402 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) with 40.17 and 36.02 MJ/kg gain in 11-12-month-old Xianan cattle; 0.659 and 0.514 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) with 24.079 and 18.711 MJ/kg gain in 90-120-kg Holstein heifers, and 0.665 and 0.588 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) with 36.051 and 32.042 MJ/kg gain in 140-200-kg Holstein heifers; and 0.675 and 0.570 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) with 25.7 and 22.4 MJ/kg gain in 4-6-month-old Limousin × Luxi crossbreds, and 0.616 and 0.521 MJ/(kg $W^{0.75} \cdot \mathrm{d}$) with 33.81 and 28.58 MJ/kg gain in 7-10-month-old crossbreds. These discrepancies likely reflect differences in breed, growth stage, management, and environmental conditions.

Based on this study' s results, a 300-kg Qinchuan cattle requires 93.13 MJ digestive energy and 81.64 MJ metabolizable energy per kilogram of gain—values higher than the Soviet livestock feeding standard reference (69 MJ/d) and the *Japanese Feeding Standard for Beef Cattle* (71.36 and 72.33 MJ/d for fattening steers and bulls, respectively). While China' s current feeding standards are valuable, regional adaptation is essential. Application should consider local feed resources and conduct further research on breed-specific and condition-specific nutritional requirements rather than rigidly following recommended values.

In conclusion, increasing dietary energy level significantly reduced feed-to-gain ratio in growing Qinchuan cattle, with maximum average daily gain achieved at 107.5% of the *Feeding Standard of Beef Cattle* (NY/T 815-2004) energy level. Gross energy digestibility and metabolic rate initially increased then decreased, and excessive energy supply did not further improve growth performance significantly. The derived equations for energy requirements are:

$$DER(MJ/d) = 0.778W^{0.75} + 37.05ADG$$
$$MER(MJ/d) = 0.668W^{0.75} + 33.49ADG$$

with maintenance requirements of 0.778 and 0.668 MJ/(kg $W^{0.75}\cdot$d), and energy requirements per kilogram of gain of 37.05 MJ digestive energy and 33.49 MJ metabolizable energy.

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