Postprint of the Study on Mineral Requirements of 35~50 kg Dorset × Small-tailed Han Crossbred Male Lambs

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Abstract

This study aimed to investigate the maintenance requirements and net growth requirements of calcium, phosphorus, potassium, sodium, and magnesium for Dorset × Small-tailed Han crossbred male lambs weighing 35–50 kg. Twenty-five 6-month-old Dorset × Small-tailed Han crossbred male lambs with a body weight of (34.54$±$0.40) kg were selected and divided into 5 groups: initial group, intermediate group, final 100% group, final 60% group, and final 40% group (with feeding levels of 100%, 60%, and 40%, respectively). The initial, intermediate, and final groups were slaughtered when the lambs reached body weights of 35, 43, and 50 kg, respectively. The contents of calcium, phosphorus, potassium, sodium, and magnesium in animal body tissues were determined, and mathematical models were established to predict the maintenance and net growth requirements of minerals. The results showed that for Dao-Han crossbred male lambs at the 35–50 kg body weight stage, the maintenance requirements for calcium, phosphorus, potassium, sodium, and magnesium were 0.73, 0.72, 0.32, 0.32, and 0.13 g/d, respectively, and the net growth requirements based on empty body weight (EBW) were 13.47-14.00 g/kg EBW, 7.18-7.41 g/kg EBW, 0.13-0.17 g/kg EBW, 1.20-1.73 g/kg EBW, and 0.45-0.58 g/kg EBW, respectively. This study developed models for mineral maintenance and net growth requirements for Dorset × Small-tailed Han crossbred male lambs weighing 35–50 kg.

Full Text

Mineral Requirements for Dorset×Thin-Tailed Han Crossbred Male Lambs at 35 to 50 kg

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Abstract

This study was conducted to estimate the maintenance requirements and net growth requirements of calcium (Ca), phosphorus (P), potassium (K), sodium (Na), and magnesium (Mg) for Dorset×Thin-Tailed Han crossbred male lambs during the 35 to 50 kg body weight stage. Twenty-five healthy 6-month-old Dorset×Thin-Tailed Han crossbred male lambs with an average body weight of (34.54$±0.40)*kgwererandomlydividedintofivegroups* : *baselinegroup*, *intermediategroup*, *andthreefinalgroups*(100×$Thin-Tailed Han crossbred male lambs at 35 to 50 kg body weight.

Keywords: lamb; mineral; requirement

Chinese Classification Number: S826

Although minerals constitute only a small proportion of animal body mass, they play crucial roles in various tissue metabolic processes, such as maintaining osmotic pressure, acid-base balance, and cell permeability, and serve as essential components of hormones, enzymes, and tissues including bone. The importance of minerals has been increasingly recognized, and numerous related studies have been conducted. NRC (2007) published mineral nutrition requirements for small ruminants. Bellof et al. investigated mineral requirements for 18–55 kg German Merino lambs. Araújo et al. and Gomes et al. studied mineral requirements for 25 kg and 20 kg Saanen dairy goats, respectively. Ji Shoukun examined mineral requirements for 20–35 kg Dorper×Thin-Tailed Han crossbred lambs. While these studies have explored mineral requirements for meat sheep, the mineral requirements for male lambs during the 35–50 kg stage have not been reported. This study used 35–50 kg body weight Dorset×Thin-Tailed Han crossbred male lambs as experimental animals, employing comparative slaughter techniques to measure mineral contents in body tissues and establish mathematical models for predicting maintenance requirements and net growth requirements (NRG). The objective was to obtain mineral recommendations for this breed and provide fundamental data for improving China' s meat sheep feeding standard system.

1 Materials and Methods

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1.1 Experimental Time and Location

This experiment was conducted from May 23, 2014, to July 24, 2014, at Hengshui Shunyao Breeding Co., Ltd. (National Meat Sheep Industry Technology System Comprehensive Experimental Station).

1.2 Experimental Design

Twenty-five healthy, hornless Dorset×Thin-Tailed Han crossbred male lambs (second-generation intercrossed offspring) aged 6 months with good body condition and an average body weight of (34.54$±$0.40) kg were randomly selected. Five lambs were randomly selected and slaughtered at the beginning of the experiment to determine initial body composition (baseline group, B). When the lambs reached 43 kg body weight, another five were randomly selected for slaughter (intermediate group, I). The remaining 15 lambs were equally divided into three feeding level groups: 100% (L100%), 60% (L60%), and 40% (L40%), and were slaughtered when the L100% group reached 50 kg body weight.

1.3 Basal Diet and Experimental Management

The basal diet formulation was prepared according to NRC (2007) nutrient requirements for late-maturing sheep (40 kg body weight, 300 g/d daily gain) and processed into complete pelleted feed (pellet diameter 5 mm, length 8–10 mm). The concentrate-to-forage ratio (excluding mineral and vitamin additives) was 6:4. The composition and nutrient levels of the basal diet are shown in Table 1 .

Before the experiment, ear tags were applied, vaccines were administered, and anthelmintic treatment was provided. Lambs were housed individually in indoor pens and fed once daily at 08:00 with free access to water. A 7-day pre-experimental period allowed adaptation to individual housing and pelleted feed. Initial body weight was recorded at the start of the formal experiment. Daily feed intake was calculated by recording individual feed offered and refusals. The feed allowance for L60% and L40% groups for each week was determined based on the average daily intake of the L100% group in the previous week, with the objective of maintaining the L40% group at maintenance level and the L60% group at an intermediate growth rate between L100% and L40% groups. Lambs were weighed weekly.

Table 1 Composition and nutrient levels of the basal diet (air-dry basis) %

Items	Content
Ingredients	
Leymus chinensis	

Items	Content
Corn	
Soybean meal	
$CaHPO_4$	
Limestone	
NaCl	
Premix[1])	
Total	
Nutrient levels[2])	
DM	
CP	
NDF	
ADF	
GE/(MJ/kg)	
ME/(MJ/kg)	
Ca	
Na	
Mg	

[1]) Premix provides the following per kg of diet: VA 10,260 IU, VE 301 IU, VD 2,200 IU, Fe 57.86 mg, Zn 42.73 mg, Mn 33.65 mg, Cu 9.34 mg, Se 0.19 mg, I 0.76 mg, Co 0.23 mg.

[2]) Nutrient levels are measured values.

1.4 Sample Collection and Measurement Indicators

During the experimental period, daily dry matter intake (DMI) and feed refusal were recorded for each lamb, and samples were collected and stored frozen at -20°C.

Lambs that reached slaughter weight were weighed at 17:00 the day before slaughter, fasted for 16 hours without water, and weighed again at 09:00 the next day before being slaughtered by exsanguination via jugular vein. The viscera were removed, and the digestive tract (esophagus, rumen, reticulum, omasum, abomasum, small intestine, large intestine) was separated and cleaned. The head and carcass were split longitudinally along the midline and weighed separately. The right side of the carcass was separated into bone, muscle, and fat. The skin and wool were separated. Samples of approximately 500 g each were taken from bone, muscle, and fat after grinding, from blood and viscera after mixing and grinding, from skin after cutting into pieces, and from wool by uniform sampling. All samples were stored frozen at -20°C.

Feed samples were dried at 105°C for 8 hours to determine dry matter (DM) content. Carcass samples were freeze-dried for 48 hours to determine DM content, then ground to measure gross energy, crude protein, ether extract, and other conventional nutrients. Phosphorus content was determined by ultraviolet spectrophotometry, and Ca, K, Na, and Mg contents were determined by flame atomic absorption spectrometry.

1.5 Calculation of Maintenance Requirements

Regression equation was established between empty body weight (EBW) and mineral content in the body for the baseline group, and regression equation was established between EBW and shrunk body weight (SBW). Using equations and , the initial mineral contents for each group were predicted based on their starting body weights.

Where: y is mineral content in the body after removing digestive tract contents (g); EBW is in kg; a is intercept; b is regression coefficient. The same applies below.

Mineral retention (MR) during the experimental period was calculated as the difference between final and initial mineral contents in the body. The maintenance requirement was calculated using the linear regression relationship between MR (g) and DMI (kg/d). The negative intercept when DMI was extrapolated to 0 was considered endogenous metabolic mineral loss, i.e., net mineral requirement under maintenance conditions.

Body mineral content can be derived using an allometric growth model with its logarithmic relationship to EBW. Equation was obtained by transforming equation to predict mineral content per unit EBW:

Where: y is mineral requirement per kg EBW increase (g/kg); a and b were obtained from equation . To predict y under live conditions, BW can be used to convert to EBW.

Data were processed using Excel 2010 and analyzed statistically using SAS 9.0 software. The GLM procedure was used for variance analysis according to a randomized experimental design, and multiple comparisons among different groups were performed using LSD method, with $P<0.05$ as the significance threshold. The PROC REG procedure was used for regression analysis.

2 Results

2.1 Growth Performance of Lambs

As shown in Table 2 , under the same feeding level (comparison among B, I, and L100% groups), DMI in the L100% group was higher than in the I group, but the difference was not significant ($P>0.05$), indicating that DMI increased with body weight. However, average daily gain (ADG) in the L100% group was significantly lower than in the I group ($P<0.05$), indicating slower growth rate. Empty body weight increased significantly with slaughter weight ($P<0.05$) among B, I, and L100% groups. Under different feeding levels (comparison among L100%, L60%, and L40% groups), ADG in the L100% group was significantly higher than in L60% and L40% groups (P<0.05).

Table 2 Growth performance of lambs in different growing periods

Groups	DMI (kg/d)	Initial BW (kg)	Slaughter BW (kg)	EBW (kg)	ADG (g)
B	1.66$±0.04c|35.87±1.20b|35.87±1.20a|28.37±1.52a|317.78±31.15d||I|1.71±0.00c|36.00±3.10b|41.83±				

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

2.2 Mineral Contents in Lamb Body

As shown in Table 3 , under the same feeding level, potassium content increased with slaughter weight, with no significant difference between I and L100% groups (P>0.05) but both significantly higher than the B group (P<0.05). Calcium, sodium, and magnesium contents were highest in the L100% group, all significantly higher than in the B group (P<0.05). Under different feeding levels, the contents of Ca, P, K, Na, and Mg all decreased with decreasing feeding level.

Table 3 Mineral contents in body of lambs (g)

Groups	Ca	P	K	Na	Mg
B	362.31$±69.63a|250.11±33.82b|2.81±0.31a|19.85±3.74a|8.76±1.67ab||I|458.06±65.85b|3				

2.3.1 Prediction of Initial Mineral Content in Lambs

Table 4 shows the relationships established between mineral content and EBW, which were used to predict initial Ca, P, K, Na, and Mg contents for each group.

Table 4 The relationship between mineral contents (g) and EBW (kg)

Items	Allometric equation	R^2
EBW	EBW = -10.945 + 1.096 × BW	
Ca	lgCa = 6.4512 - 2.6773 × lgEBW	
P	lgP = 6.1612 - 2.5604 × lgEBW	
K	lgK = 3.0658 - 1.8238 × lgEBW	
Na	lgNa = 5.4112 - 2.8362 × lgEBW	
Mg	lgMg = 5.1072 - 2.8720 × lgEBW	

2.3.2 Mineral Retention (MR) in Lambs

Table 5 shows the mineral retention in the I, L100%, L60%, and L40% groups during the experimental period.

Table 5 Mineral retention in lambs (g)

<table>
<tr><th>Groups</th><th>Ca</th><th>P</th><th>K</th><th>Na</th><th>Mg</th></tr>
<tr><td>I</td><td colspan="5">3.51$±0.43|2.29±0.14|1.99±0.11|0.61±0.05|0.36±0.04||L100±0.16|1.01±0.16|2.30±0.43|0
0.03±$0.01</td></tr>
</table>

2.3.3 Relationship Between MR and DMI and Prediction of Mineral Maintenance Requirements

Table 6 shows the linear regression relationships established between MR and DMI, demonstrating high linear correlations (R^2 = 0.8539–0.9838). The predicted mineral maintenance requirements calculated from Table 6 formulas are shown in Table 7 , indicating maintenance requirements of 0.73, 0.72, 0.32, 0.32, and 0.13 g/d for Ca, P, K, Na, and Mg, respectively.

Table 6 The relationship between MR (g) and DMI (kg/d)

Items	Prediction equations	R^2
Ca	MRCa = -0.7314 + 2.6745 × DMI	
P	MRP = -0.7188 + 1.6956 × DMI	
K	MRK = -0.3161 + 0.5784 × DMI	
Na	MRNa = -0.3179 + 0.4633 × DMI	
Mg	MRMg = -0.1343 + 0.1511 × DMI	

Table 7 Mineral requirements for maintenance of lambs (g/d)

Items	Requirement
Ca	0.73
P	0.72
K	0.32
Na	0.32
Mg	0.13

2.4.1 Allometric Relationship Between Mineral Content and EBW

As shown in Table 8 , the regression relationship between EBW and BW was EBW = -4.2550 + 0.9139 × BW (R^2 = 0.9306), indicating a linear correlation and confirming that using BW to predict EBW is feasible. Additionally, mineral contents showed high correlations with EBW (R^2 = 0.7109–0.9219).

Table 8 Allometric relationship between mineral contents (g) and EBW (kg)

Items	Regression equation	R^2
EBW	EBW = -4.2550 + 0.9139 × BW	0.9306
Ca	lgCa = 0.9501 + 1.0965 × lgEBW	
P	lgP = 0.6952 + 1.0598 × lgEBW	
K	lgK = -1.9460 + 1.6031 × lgEBW	
Na	lgNa = -1.5345 + 1.9212 × lgEBW	
Mg	lgMg = -1.4608 + 1.6274 × lgEBW	

2.4.2 Prediction Model for Mineral Net Requirement for Growth (NRG)

Based on the allometric relationships in Table 8, prediction models for Ca, P, K, Na, and Mg NRG during the 35–50 kg stage were developed. Table 9 shows these models and the corresponding NRG values at 35, 40, 45, and 50 kg body weight.

Table 9 Mineral NRG for growth of Dorset×Thin-Tailed Han crossbred male lambs at 35 to 50 kg

Items	Equation	35 kg	40 kg	45 kg	50 kg
EBW (kg)	EBW = -4.2550 + 0.9139 × BW				
Ca (g/kg EBW)	NRGCa = 9.7748 × EBW^0.0965				
P (g/kg EBW)	NRGP = 9.6091 × EBW^-0.0781				
K (g/kg EBW)	NRGK = 0.0182 × EBW^0.6031				
Na (g/kg EBW)	NRGNa = 0.0561 × EBW^0.9212				
Mg (g/kg EBW)	NRGMg = 0.0563 × EBW^0.6274				

3 Discussion

3.1 Changes in Mineral Content in Lambs at Different Slaughter Weights

Araújo et al. found that in 15–25 kg Moxotó goats, Ca, P, K, Na, and Mg contents all increased with body weight. Gomes et al. reported that in 5–20 kg Saanen kids, Ca and P contents increased with body weight, while Na, K, and Mg contents decreased. Ji Shoukun observed that in 20–35 kg Dorper×Thin-Tailed Han crossbred lambs, Ca and Na contents per unit body weight decreased with increasing body weight, while K and Mg contents per unit body weight increased to some extent. Our results showed that Ca, P, K, Na, and Mg contents all increased with body weight, which differs from previous findings. These discrepancies suggest that breed differences and measurement stages significantly affect mineral content in lambs.

3.2 Maintenance Requirements of Ca, P, K, Na, and Mg for Lambs

Mineral requirements for different animal species are typically determined using the factorial method, which yields a dynamic model that estimates maintenance requirements at different body weights and growth requirements at different growth rates. Currently, NRC (2007), NRC (2001), NRC (2000), and Suttle have adopted the factorial model, which divides mineral requirements into two components: maintenance and production, expressed as: GR = (P + M)/A (where GR is total requirement, P is NRG, M is maintenance requirement, and A is nutrient absorption and utilization rate). Therefore, accurate determination of NRG and maintenance requirements is crucial for establishing mineral requirement models.

ARC (1980) determined calcium maintenance requirements for sheep as 16 mg/(kg BW · d) based on the relationship between fecal calcium excretion and DMI, corresponding to 0.56-0.80 g/d for the 35-50 kg stage. This was later adopted by AFRC (1991). NRC (2007) proposed calcium maintenance requirement as 0.623 × DMI + 0.228. With DMI of 0.718-1.709 kg in this study, the corresponding calcium maintenance requirement would be 0.68-1.29 g/d. These previous studies show some variation, and our measured calcium maintenance requirement of 0.73 g/d is similar to their recommended values.

ARC (1980) determined phosphorus maintenance requirement for sheep as 14 mg/kg BW based on endogenous excretion, corresponding to 0.49-0.70 g/d for the 35-50 kg stage. NRC (1985) recommended 20 mg/kg BW for pre-pregnant and growing sheep, corresponding to 0.70-1.00 g/d for this stage. AFRC (1991) established the relationship: phosphorus maintenance requirement = 0.693 × DMI - 0.06, yielding 0.44-1.12 g/d for our DMI range. Our measured phosphorus maintenance requirement of 0.72 g/d is slightly higher than ARC (1980) but similar to NRC (1985) and AFRC (1991).

NRC (2007) recommended potassium maintenance requirement = 2.6 × DMI + 0.038 × BW, yielding 3.20-6.34 g/d under our conditions. Our measured potassium maintenance requirement of 0.32 g/d is substantially lower than NRC (2007) recommendations.

ARC (1980) estimated endogenous sodium loss in sheep as 5.8 mg/kg BW through feces and 20.0 mg through urine, totaling 25.8 mg/kg BW/d, corresponding to 0.90-1.30 g/d for the 35-50 kg stage. NRC (2007) recommended 10.8 mg/kg BW/d, corresponding to 0.38-0.54 g/d. Our measured sodium maintenance requirement of 0.32 g/d is higher than ARC (1980) but slightly lower than NRC (2007).

ARC (1980) recommended magnesium maintenance requirement as 3 mg/kg BW, corresponding to 0.11-0.15 g/d for the 35-50 kg stage, which was later adopted by NRC (2007) and Suttle. Our measured magnesium maintenance requirement of 0.13 g/d is similar to these previous recommendations.

3.3 Net Requirement for Growth (NRG) of Ca, P, K, Na, and Mg in Lambs

Our results indicate that NRG for Ca, P, K, Na, and Mg in 35-50 kg Dorset×Thin-Tailed Han crossbred male lambs were 13.47-14.00 g/kg EBW, 7.18-7.41 g/kg EBW, 0.13-0.17 g/kg EBW, 1.20-1.73 g/kg EBW, and 0.45-0.58 g/kg EBW, respectively. When expressed per kg body weight, these correspond to 10.69-11.57 g/kg BW, 5.88-5.93 g/kg BW, 0.10-0.14 g/kg BW, 0.95-1.43 g/kg BW, and 0.36-0.48 g/kg BW, respectively. INRA (1989) recommended values of 9.5, 5.5, 1.8, 0.9, and 0.4 g/kg BW for Ca, P, K, Na, and Mg, respectively. Compared with these recommendations, our NRG values for Ca, P, Na, and Mg are higher, while K is lower. NRC (2007) recommended NRG values of 11.0, 6.0, 1.8, 1.1, and 0.41 g/kg EBW, respectively. Our Ca and P NRG values are higher, while K, Na, and Mg are lower than NRC recommendations. Bellof et al. reported NRG values of 14.0, 7.5, 1.7, 0.9, and 0.4 g/kg EBW for 30-55 kg German Merino lambs. Our Ca, P, and Mg values are similar, K is lower, and Na is higher than their recommendations. These differences highlight the specificity of mineral requirements for domestic crossbred lambs.

The variations between our results and previous studies may be attributed to differences in experimental animal breeds, growth stages, and feeding environments, further emphasizing the necessity of conducting nutrient requirement studies specific to Chinese meat sheep breeds.

4 Conclusion

The maintenance requirements for Ca, P, K, Na, and Mg in 35-50 kg Dorset×Thin-Tailed Han crossbred male lambs were 0.73, 0.72, 0.32, 0.32, and 0.13 g/d, respectively. The net growth requirements were 13.47-14.00 g/kg EBW, 7.18-7.41 g/kg EBW, 0.13-0.17 g/kg EBW, 1.20-1.73 g/kg EBW, and 0.45-0.58 g/kg EBW, respectively.

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